Unmanned Maritime Systems Defense & Security UUV & USV Markets, Technologies and Opportunities Outlook 2012 – 2020

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1. Introduction

This is the most comprehensive Unmanned Maritime System (UMS) report in the market to date – spanning current and future markets, technologies and applications in this rapidly evolving sector.

1.1. Scope of This Report

The report covers UMS and their applications in the Defense and Security market segments. It covers markets (globally and regionally), technologies, and applications (surface, sub-surface, hybrid). Additionally, the report provides:

- detailed analysis of specific scenarios and hardware (case focus),
- new business opportunities, and
- a catalogue of about 100 Unmanned Underwater Vehicles (UUV) and 100 Unmanned Surface Vehicles (USV).

This research can serve as a reference report on UMS. It provides the uninitiated with a thorough understanding of Unmanned Maritime Vehicle (UMV) markets, and the veteran with insight and a wealth of business opportunities. The report discusses the *dynamics* of the UMV Defense and Security markets, providing actual understanding of *why* and *how* UMS solve current and future problems.

Note: The report does *not* include classified information.

1.2. Basic Terms of Reference

1.2.1. Unmanned Maritime Vehicle – UMV

UMV includes any type of maritime robots on the surface of below surface of fresh or salt water.

1.2.2. Unmanned Surface Vehicle – USV

USV refers to a boat without operator/pilot. Hybrid vehicles that are partly on and partly below the surface are also categorized as USV if there is a floating hull that is always on the surface.

1.2.3. Unmanned Underwater Vehicle – UUV

UUV includes AUVs (Autonomous Underwater Vehicles), and ROVs (Remotely Operated Vehicles). ROVs are remotely operated through a tether and have very few autonomous functions.

Important Notes:

- This report covers AUVs rather than ROVs, most of which are used for oil and gas off-shore operations. Mine Disposal Vehicles, which are often remotely operated with a tether, are covered in this report.
- Static systems, such as a sonobuoy or a diver's detection system, are not included in the UUV category since it is not a vehicle. UUV sometimes also stands for Unmanned Undersea Vehicle – but that use seems to limit UUV operations to salt (sea) water, while they can be used in estuaries, lakes, and rivers, and other non-salt bodies of water. Others use the term "Untethered Unmanned Vehicle", but it does not refer to the maritime domain, so we will not use it.
- The term UUV has become more prevalent over the last decade. AUV is still being used, but only in maritime technology circles. Expect the terms to evolve much like unmanned aircraft systems have gone from UAV to UAS to RPA, and have different names for different communities.
- The "V "of Vehicle can usually be substituted for the "S" of System, since the vehicle is only a part of an unmanned system that includes a monitoring / control station plus a command and control base. As UMVs become more connected to information networks, the vehicle itself becomes a part of a much larger system. This report addresses UMS (Unmanned Maritime Systems), but only as long as the system includes an unmanned maritime vehicle.

1.3. Language Disclaimer and Further Information

This report was written in American English, for English as a second language readers, etc. as appropriate. Footnotes and the Glossary provide explanations of significant or unusual information.

Note: Copyrights are acknowledged for all trademarks and images, where appropriate.

1.4. Methodology

The Market Intel Group LLC team that researched analyzed and wrote this report brings together a blend of skills and talents in relevant areas, including: homeland security technology, economics, politics and policy-making, business and general intelligence, counter-terrorism, industry/market research and analysis.

Every forecast requires a mix of explicit or implicit methods, assumptions, and data, almost none of which can be perfect. The play and power of the forecast uncertainties both expand as the forecast period extends.

There are seven steps to the forecasts in this outlook, built on our analysts' years of experience in forecasting the Homeland Security and Defense technology markets:

- Describe and clearly categorize the areas covered by this report as they are today.

- Estimate the baseline segments.
- Draw on the experience and judgment of expert observers. We interviewed centrally-positioned professionals regarding key elements of this report and analysis, and used their input to test and inform the thinking of our researchers and analysts.
- Review and distill information in the literature, the trade press, conference notes, and many informal interviews within the related communities. Specify relevant facts and assumptions.
- Review and distil our own experience with technology market forecasts for relevant clues and examples.
- Define major potential scenarios rooted in the dynamics of the relevant market. The principal difference between the scenarios is the occurrence of a major terrorist event.
- Pull the information together and populate the forecast algorithms for market evolution over the forecast period.

Despite the risk of being inaccurate, forecasts are worth doing and using. Business decisions must be made on incomplete and imperfect information; forecasts help distill critical information and reduce the chaos.

Important Notes:

- The reader is invited to read our analysis and conclusions with an open mind and a healthy dose of skepticism. Forecasts, even the best-reasoned ones, are still exactly that - forecasts. Only the future will judge their accuracy.
- This report assumes no prior familiarity on the part of the reader with the material discussed. The report also assumes that readers may not read the material sequentially, but will concentrate on their relevant sections. It is critical, however, that all readers start with the first two sections so as to understand the context for all that follows.
- Where appropriate, the report presents data in tabulated and/or graph format. The tables, graphs and drawings are original, purpose-built for this report, and based on authors' research and analysis. When data and tables of other sources are used, the source is indicated

1.5. Basic Scenario Assumptions

The authors postulate two potential scenarios to serve as context for analysis of future trends and evolution in relevant sectors. The scenarios are:

Scenario I – Constant Threat: According to this scenario, maritime threats remain constant, with continuing piracy, sporadic show of controlled power by North Korea, and continuing failed or mitigated terrorist attacks again military ships or against maritime targets along Eurasian hot spots. Budget constraints decrease the number of manned vessels in each country's fleet. There is a sustained cultural resistance to fully using USV. This is today's reality.

Scenario II – Gradually Increasing Conflict: This scenario postulates a conflict gradually escalating with Iran. Small attack boats swarm off-shore oil rigs in Kuwait and Saudi Arabia. The Strait of Hormuz is mined, blocking all foreign navies at the Gulf of Oman. Midget submarines navigate the shallow waters of the Persian Gulf, while regular submarines cannot operate safely. Iranian military assets are spread along the coasts, hidden by small islands and coves. Expeditionary forces are not powerful enough to win the conflict. Drifting mines are seen along the coast of Qatar. Oil prices reach $150 a barrel. Consequently, piracy increases in the Arabian Sea. Shipping costs increase by at least 15% due to a rise in oil prices and insurances premiums.

Other possible scenarios:

- ❑ Terrorist attack on a Liquid Natural Gas facility in Australia, using a small fast boat loaded with explosives.
- ❑ Piracy extends beyond the Eastern coast of Africa south to the Cape of Good Hope, presenting a threat to the alternate route taken to avoid the Gulf of Aden. Military presence does not increase due to lack of funding and competing naval presence needs in the Mediterranean Sea. Commercial vessels are less protected, leading to increased piracy.
- ❑ North Korea sporadically attacks South Korea including mining South Korean littorals. A weakened Japan and a silent China contribute to heightened tension in the East China and Philippine Seas.
- ❑ A Disney Cruise ship is attacked and held by pirates. Special Operations forces take the pirates down. The cruise industry is badly damaged. Insurers of maritime shipping companies create a private anti-piracy task force, backed by various governments.
- ❑ Terrorists attack offshore oil platforms in the Gulf of Guinea and refineries in Nigeria. International oil & gas companies increase the protection of their properties off the West African coast.
- ❑ A bomb attached to the hull of a tanker explodes just before the tanker enters the Suez Canal. The canal is blocked for a short period.

Important Notes:

- ❑ The analysis in this report assumes **Scenario I** as the basic environment.

- In some cases, we provide insight into **Scenario II** options. Where this is done, we clearly indicate that the presentation relates to **Scenario II**.

1.6. Who is This Report For?

1.6.1. Organizations

This report provides valuable information to:

- **For-profit Companies** that are in or considering the UMS market
- **Non-profit Groups** such as research and development labs, associations, and universities to give them valuable insight in market forecasts or technological priorities
- **Government Administrations** in search of a comprehensive overview of the technology and global activities in UMS

1.6.2. Professionals

This report contains information essential to:

- Leaders & Strategists
- Business development
- Sales
- Marketing
- Market research
- Business analysis
- Business consultants
- Program managers
- Project managers
- Officials in policy development and strategy
- Officials in acquisition programs
- Researchers

1.7. How will this report benefit you?

This report contains information that will provide you with in-depth insight regarding:

- Current markets
- Future markets (by UMV type, by region, by application)
- Potential applications
- Technological hurdles to overcome
- Current technological status and uses

- Expected technological advances
- Current vendors and vehicles
- Business opportunities
- Competitive assessment
- Market entry/new product/new service opportunities
- Business opportunities for equipment, sub-systems, sensors, and services providers
- Growth opportunities
- Reaction to market changes

Note: This report focuses on defense and security applications. It does not cover non-security applications such oil & gas exploration or environmental research.

1.8. Value Beyond Forecasts

Many market research companies publish forecasts using inexperienced analysts in sweat shop environments with little or no industry experience or global perspective. Real insight is only achieved via the perspective of time and immersive experience. We know that because those analysts apply to work at MiG after burning out in anonymity at another firm. Typically though, they have no technical experience or understanding and so do not fit into our business model of finding analysts who truly understand their technology and markets.

But at half the price, copycat reports will sell to unsuspecting buyers who mistakenly believe forecasts are all the same. In August of 2009, as the moderator for AUVSI's first-ever panel discussion on UAS market forecasts, a MiG lead analyst had the opportunity to question an audience of over two hundred attendees on the value of market research industry reports.

Their dissatisfaction with ignorance of the product was evidenced by an overwhelming show of hands. The audience was generally dissatisfied with most of their purchases. It is MiG's intent to change that reality by using insightful and experienced analysts who can defend their arguments and support readers. Integrity then, is the value of MiG's reports and the value of knowing the lead analyst.

1.9. About the Lead Analyst

Antoine Martin combines his extensive background in systems engineering and business development to help companies take the necessary steps to successfully enter the unmanned systems market.

Antoine's engineering background includes designing an obstacle avoidance module for an autonomous underwater vehicle and testing design-to-manufacturing processes of embedded chips for high-speed telecommunications. He has two Master's degrees under his belt, one in Electronics and another in Ocean Engineering. Examples of his work include research sponsored by a grant from the American Office of Naval Research and product development for Intel Corporation. Antoine also leverages his experience in mapping, remote sensing, and Lidar from maritime and aerial platforms to unmanned systems.

With his international background, engineering experience and business acumen, Antoine offers a unique skill-set. He earned his MBA in Entrepreneurship through an exhaustive mentoring program taught by serial entrepreneurs. He wasted no time applying these tools to resolve the complex problems entrepreneurs and executives face every day. Currently, he consults for small and mid-sized companies, assisting executives and founders facing growth challenges by crafting go-to-market strategies through business development and other targeted initiatives.

Maritime and aerial unmanned systems are Antoine's area of expertise. He has forged ongoing relationships throughout the industry's value chain, ensuring a holistic understanding of how value is created to satisfy users' needs. Antoine has been passionate about robotics since his childhood, back to the days when he built tethered helicopters with Lego wings or attached a VHS camcorder onto his toy, remote-controlled car. He strongly believes that the potential in unmanned applications is largely untapped.

Antoine brings not only the invaluable ability to understand complex technological problems and create solutions, but an ability to integrate them into the unmanned systems industry through a successful market offering.

For this report on unmanned maritime systems, you are getting a business developer and ocean engineer as well as an experienced analyst.

2. Executive Summary

2.1. Systems, Not Vehicles

Although the unmanned vehicle itself holds the sensors and is the part of the system that ventures into high-risk areas, it is important to think in terms of a system. That is: one or a number of vehicles, their control elements, their data distribution and analysis components, their support logistics, the persons "in the loop", and the larger operating picture of which the vehicle is but a piece.

Thinking in terms of system:

- Makes us understand better the big picture and how the parts relate to one another
- Exposes us to opportunities often overlooked and promotes an out-of-the-box perspective
- Makes us understand that unmanning a system does not remove a person from the operation, but moves the person elsewhere within the system
- Makes us realize that the greatest untapped potential is in the system, not in any of the parts alone
- Helps us realize that no end-user is looking for a stand-alone fix, but rather for a repeatable and lasting operational solution. The solution will come from the system, not the vehicle

This report mostly addresses the vehicles, since they are the critical element of the system and themselves include many sub-systems. This report also describes in detail the dynamics between the users, the threats, the technology, and the contextual environment. Understanding how the parts relate is critical to understanding UMS in general.

2.2. Why a Surge of Interest in Unmanned Maritime Systems?

Many factors are leading the surge of interest in UMS, USV in particular.

- **Maritime Security on the Increase and Changing:** The terrorists' attack on the USS Cole in 2000, maritime piracy increasing despite attempts to curb it, the rising threat of Iran in the Middle East, territorial disputes in Eastern Asia, asymmetric warfare on the rise - all contribute to a nation's need to better secure littorals, ports, estuaries, channels, and bodies of water. UMS offer an improved response capability to the new maritime security threats - better than traditional equipment that has not changed significantly since the sixties.
- **Evolving Technologies**: The transition from large and expensive vessels to multi-mission frigates results in the introduction of a number of new vessels, some already in operation and others just conceptual. These new designs are meant to undertake a number of missions, from mine countermeasure to

surface warfare. These ships, less capable than multiple dedicated ships, rely on UMS to perform dedicated missions. UMS offer to increase both power and capabilities.

- **Military Budget Pressures:** Taking 10 or 15 years to build ships and submarines, at exorbitant costs, is not an option anymore. With manpower being the single most costly expense, there is a need to both reduce the number of people on ships and to decrease the risks each to each person. This pressure drives a move to simpler ships with fewer people. UMV offer a long-term solution to reduced budgets while increasing capabilities.
- **New USV Designs**: USVs have matured to the point where they are interesting to both operators and the politicians who pay for them.
- **Unmanned Aircraft Systems:** These relatively newcomers have shown the value and limits of remotely piloted aircraft in real conflict scenarios. Unmanned Ground Vehicles have saved many lives in Improved Explosive Devices mitigation roles. A number of countries have used unmanned systems so their operations, procurement, and use is better known. Therefore, government offices are now developing unmanned systems plans as part of larger operations.
- Unmanned Underwater Vehicles demonstrated their worth over and over again in mine countermeasures operations and are ready to transition to other uses.

This report addresses every one of these points in detail, and enables a deeper understanding of today's and tomorrow's dynamics, trends, uses, operations, and markets.

2.3. From Big Problems to Big Opportunities

The unmanned maritime market is still emerging. The number of stakeholders is very small compared to unmanned aerial vehicle markets. Challenges abound, and with each challenge comes opportunities for those who know which to pick up and execute. Unmanned Maritime Systems are today where Unmanned Aircraft Systems were in the mid-nineties, just before the Kosovo war. The maritime domain offers almost unlimited possibilities, and is not monitored significantly or even well understood.

Fifty business opportunities are listed at the end of the report. The report itself includes at least one hundred others for those who understand that each need and technical issue holds the key to unexploited opportunities.

2.4. Major Findings/Conclusions

2.4.1. Important Tables and Graphs

Table 1 - Global UMS Market Forecast by Market Segments by [$Millions] – 2012-2020

	2012	2013	2014	2015	2016	2017	2018	2019	2020	∑12-20	CAGR 12-20
Procurement											
Operations & Maintenance											
R&D											
Total											

Figure 1 - Global UMS Market Forecast by Market Segments by [$Millions] – 2012-2020

Notes:

Table 2 - Global UMS Market Forecast by Market Sectors by [$Millions] – 2012-2020

	2012	2013	2014	2015	2016	2017	2018	2019	2020	∑12-20	CAGR 12-20
Defense											
Security											
Total											

Important Note: This table **does not include a Research and Development Market** which does not belong to any specific market sector at the R&D stage.

Figure 2 - Global UMS Market Forecast by Market Sectors by [$Millions] – 2012-2020

Notes:

Table 3 - Global UMS Market Forecast by System Type by [$Millions] – 2012-2020

	2012	2013	2014	2015	2016	2017	2018	2019	2020	∑12-20	CAGR 12-20
USV											
UUV											
Total											

Figure 3 - Global UMS Market Forecast by System Type by [$Millions] – 2012-2020

Notes:

3. Drivers and Inhibitors

This chapter presents a detailed analysis of the drivers and inhibitors that will impact UMV industry evolution during the forecast period.

3.1. Market Drivers

3.1.1. UUVs and USVs Defense Sector Drivers

Note: This section spans 10 pages.

3.2. Market Inhibitors

Note: This section spans 5 pages.

4. Unmanned Maritime Systems – Current Uses

This Chapter explores in detail current defense and security uses of all types of Unmanned Maritime Systems.

At present, UMVs are mostly used as Unmanned Underwater Vehicles - that is: Autonomous Underwater Vehicles and Remotely Operated Vehicles.

These vehicles perform the following functions:

- **Defense:** Mine field clearing, anti-submarine warfare preparation
- **Commercial:** Oil and gas, telecommunication, underwater infrastructure management
- **Research:** Water quality, oceans' dynamics for climate change understanding, environmental disaster assessment

Unmanned Surface Vehicles have been used almost exclusively by military forces for security functions, including:

- Monitoring
- Deterrence at ports, harbors, and near-shore zones

There is a niche market of small USV for commercial and research uses, mostly for bathymetry and oceanography.

4.1. Current Defense Uses

4.1.1. Definition

The UMV defense market includes military use of UUVs and USVs.

4.1.2. Categorizing UUVs

The US Navy classified AUVs (they use the term UUV often instead of AUV) as follows:

Table 4 - UUV Classes by US Navy

Class	Diameter (inches)	Displacement (lbs.)	Endurance High Hotel Load (hours)	Endurance Low Hotel Load (hours)	Payload (ft^3)
Main-Portable	3-9	<100	< 10	10-20	< 0.25
LWV	12.75	~500	10-20	20-40	1-3
HWV	21	< 3,000	20-50	40-80	4-6
Large	>36	~20,000	100-300	>>400	15 – 30 + External Stores

Class Definitions:

The Man-Portable class, which includes vehicles from about 25 to 100 pounds displacement, with an endurance of 10 - 20 hours. There is no specific hull shape for this class.

The Light Weight Vehicle (LWV) class are nominally 12.75 inches in diameter and displace about 500 pounds. Payload increases six- to 12-fold over the man-portable class and endurance is doubled.

The Heavy Weight Vehicle (HWV) class is 21 inches in diameter, displaces about 3000 pounds, and provides another factor of two improvement in capability. This class includes submarine compatible vehicles.

The Large Vehicle class will displace approximately 10 long-tons and will be compatible with both surface ship and submarine use.

Source: UUV Master Plan 2004

4.1.3. Categorizing USVs

The US Navy classifies USVs as follows:

- **Fleet Class I -** Used as a mission module launched from a naval ship, for MCM and ASM mission - 36-foot hull
- **Semi-Submersible Snorkeling Vessel** - Used for towing SONAR for MCM
- **Harbor Class -** Used for maritime security, intelligence, surveillance and reconnaissance (ISR) missions located around ports and closer to shore - 23-foot hull
- **Small Class** - Used for various naval missions

Source: PEO LMW

4.1.4. Main UUV differentiators

UUV's main differentiators are:

- Launch capabilities from a surface vessel, dock, or by personnel
- Small size
- Concealable - small size, low noise, small footprint
- Ability to operate in dangerous environments, considered too risky for a manned platform
- Persistence
- Ability to free up human assets for re-deployment elsewhere

- ❑ Inexpensive, compared with current platforms (e.g., MCM: frigates, submarines, maritime patrol aircraft and helicopters)
- ❑ Can often be outfitted for multiple uses

For comparison with USV, see Figure 33 - UMV Characteristics Comparison Chart.

4.1.5. UMVs Value to Navies

UMVs offer sought-after values to any navy, including:

- ❑ Potential 24/7 persistent capability
- ❑ Expanded area of operations to include inaccessible and hazardous areas
- ❑ Complement current forces
- ❑ Augment human personnel at a low cost
- ❑ Reduce human personnel requirement
- ❑ Enable adaptive operations and improved information sharing

4.1.6. USV - History

Radio-controlled USVs have been developed since World War II. Early USV systems were primarily used as gunnery and missiles targets. In the 1970s, USVs started fulfilling mine sweeping missions due to their ability to reduce the risk associated with such operations, as well as the possibility to control several USV missions simultaneously. Although appreciated for their ability to perform dangerous tasks, sparing human lives and expensive vessels, lack of sufficiently sophisticated electronics and software, as well as lack of proper command and control, hampered their wide-spread use.

In the meantime, reliability and functionality in the maritime battlespace has improved considerably. A recurring important issue in any modern navy is the search to reduce equipment procurement and running costs while maintaining and increasing capability levels. Modern-day navies need flexible systems, which can operate in multi-role missions with good performance in each mission type.

USV operations are ready for growth; the technology has matured. Unmanned systems have been deployed in a variety of uses: UAVs for Intelligence, Surveillance and Reconnaissance roles plus combat, UGVs for IED disposal, AUVs for MCM and surveys. The laggards are USVs. A study in 2003 predicted that USVs were poised for growth, with 300 units in operations in the US alone [Moiré Incorporated, The Growing US Market for USV]. Though arriving significantly later than predicted, it appears the USV's time is indeed coming. For example: littoral combat ships (LCSs) *will* include USVs for operations.

4.1.7. Mine Counter Measures (MCM)

Mines and mine counter-measures have evolved into a unique naval weapons discipline, designed to deal with threats that are difficult if not impossible to detect, and mitigate such threats by helping detect, avoid and neutralize increasingly more sophisticated mines. This section will outline the threat of marine mines, and introduce some of the thinking involved in mitigating this threat.

4.1.7.1. Mines: Current Status

Underwater and surface mines still pose an enormous threat to maritime operations. They are a cheap naval weapon, which can cause devastating damage to submarines and ships. Commercial ships and cruise ships are not too much in danger because they travel routes that are largely mine-free.

Mines can be deployed by submarines, surface ships, small crafts, commercial vessels, pleasure boats, aircrafts, helicopters, swimmers, trucks and other means. Their weight ranges from a few pounds to several tons.

Naval mines are one of the easiest weapons to deploy, particularly where traffic is heavy. This extremely asymmetric threat, when unchecked, allows adversaries to effectively deny control of vital areas such as ports, anchorages, offshore structures or strategic coastal zones to a superior militarily force. Because maritime mines are very effective, cheap to manufacture and/or buy, and easy to deploy, it has become the weapon of choice for many less well-off nations who are seeking to confront ‘classic’ naval power.

Defensively, mines are positioned by military forces in order to prevent submarines and war ships from accessing a protected and strategic area.

Offensively, mines can be positioned to paralyze a fleet, for example, preventing it from leaving a harbor.

The most time-consuming activity associated with mine counter-measures today is the activity related to efforts to clear or neutralize mines in ’historical’ mine fields. Those are mines from World War II and the Cold War era. The North Sea, Baltic Sea and English Channels alone have an estimated 80,000 maritime mines. Clearing mines is a very slow, expensive and resource-intensive process.

Because of their low cost, ease of manufacture, and ease of acquisition, more than 50 nations are using maritime mines at this time. Most countries keep mine locations and numbers a secret, and many mines from World War II and the Cold War are still active (unexploded) and extremely dangerous. By now, their rough location is known and mapped. Although few nations lay mines today, many nations have mine-laying capabilities and an arsenal of mines ready to be deployed.

Many developed nations do not have an offensive maritime mine warfare program, although little is known with absolute certainty in this area. For instance, the United States used offensive mine operations in 1972 in North Vietnam, to close the port of Hai Phong, and in 1991 against Iraq.

The US has a small but well establish current active mine inventory, such as Quickstrike. Laid by submarine or aircraft, the mines are laid at the seafloor of shallow waters and detonate based on magnetic, seismic, or pressure detection.

Mines are becoming much more difficult to detect and deal with. Sweden, Russia, China and Italy continue to manufacture and export sophisticated mines built with stealth technology, irregular shapes, anechoic coatings and nonmagnetic materials. Advanced microprocessor-controlled target detection devices, ship counters, remote control features and delayed arming mechanisms make detection very difficult.

Another MCM task is to prepare for modern mine warfare. The United States and Russia have gotten rid of nuclear mines and torpedoes; North Korea is suspected of developing nuclear underwater weapons. Nuclear mines and torpedoes represent a real and considerable threat today.

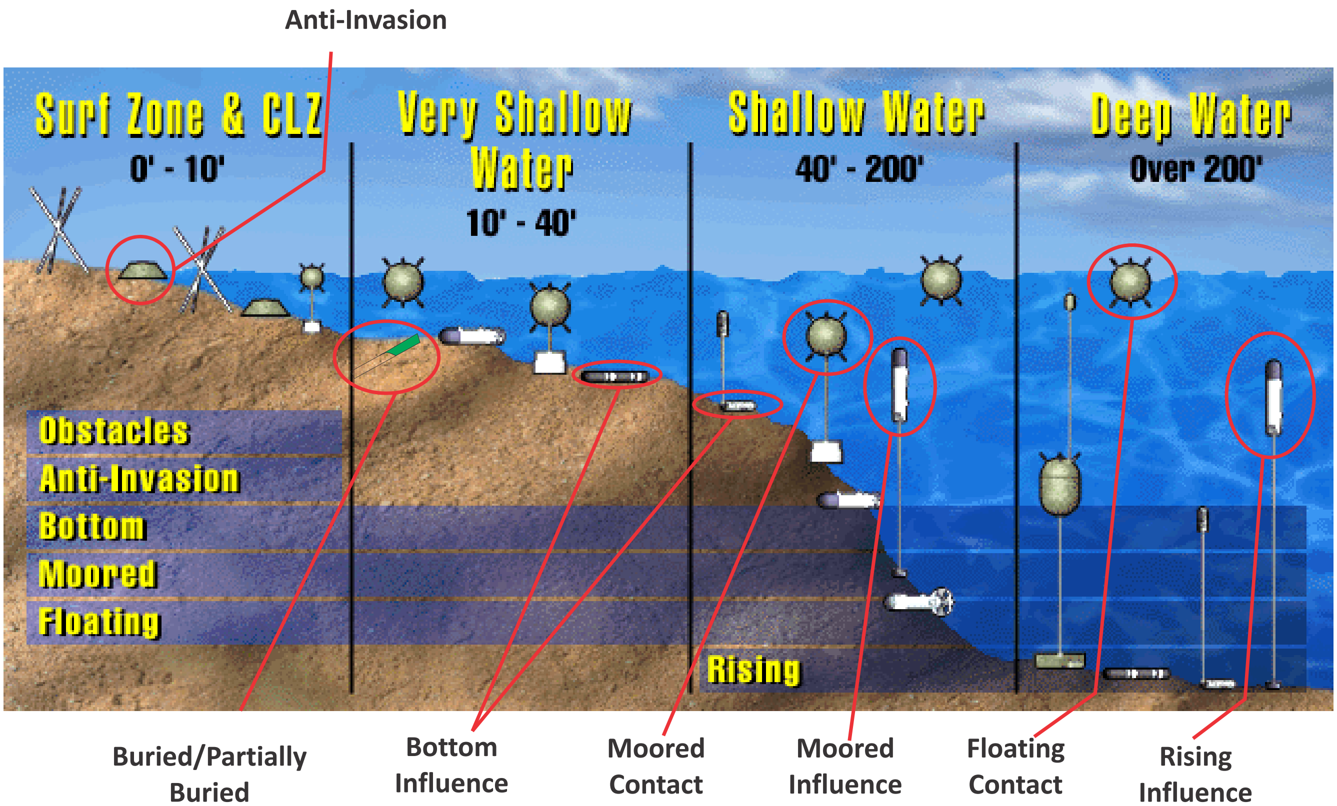
4.1.7.2. Mine Types

There are over 300 types of maritime mines. They come in many shapes and sizes, such as:

- **Bottom mines -** These mines have negative buoyancy; they remain on the seabed. They are triggered by a target's magnetic field, noise or pressure effect. Being in their vicinity is sufficient for them to explode and damage the target. They come with various level of sophistication.
- **Moored mine -** These mines have positive buoyancy; they are moored to the bottom of the sea and are designed to float on or below the water's surface. They detonate by influence (magnetic, noise or pressure change) or are triggered by contact.
- **Drifting mines -** These mines have positive or neutral buoyancy and drift freely. Because sea currents and streams can carry them to unknown locations, they are prohibited under the Hague Convention. Nevertheless they are deployed during certain conflicts.
- **Moving mine -** This is a collective term, covering mines that can move without control of its course or use powered propulsion. The drifting mine is a type of moving mine. Areas of coverage are large and their location is planned in advance, to maximize their threat, deterrence value and impact. The moving mine is a much more expensive compared to other maritime mine types.

Modern mines are very difficult to detect. Today, a number of countries, including developed countries, have an arsenal of modern mines.

Figure 4 - Mines Types by Depth



Source: US Navy, Mine Warfare Branch

4.1.7.3. Mine Damage

During World War II, mines sank at least 150 military vessels and a number of merchant ships.

Since the end of World War II, hostile mines have damaged or destroyed three times the number of U.S. Navy ships damaged or destroyed by *all* other threats *combined* (that includes: torpedoes, air strikes on vessels, ship-to-ship guided missiles, and ground-based missiles striking littoral ships).

In August 1984, Libyan naval personnel used the ferry Ghat to roll off 99,501 mines in the Red Sea and Gulf of Suez. More than 19 ships reported damage from underwater explosions (that's a 0.02% rate of number of mines divided by the number of vessels damaged). An intense multinational MCM effort followed. Enormous resources were allocated to respond to this one threat event. From this single event, one can understand the perception (and reality) of the damage and potential consequences associated with maritime mines.

Because mines are cheap to develop, manufacture and deploy, and because ships are expensive and submarines are *very* expensive, the potential damage per mine to a vessel (ship or submarine) is extremely high. Maritime mine experts suggest that the "damages return per investment" ratio is more than 2,000:1. That does not include collateral damage from disabling the ships. As an example, in the first Gulf War, a $1,500 mine caused $96,000,000 worth of damage to the USS Samuel Roberts.

As we can see, mines are the ultimate "asymmetric" maritime weapon.

4.1.7.4. The Psychological Threats of Mines

Aside from their ability to cause damage, we should also consider the psychological threat associated with mines. Such a threat impedes access to maritime locations. “If you make an announcement that there are mines in the water, you’ve succeeded in 75 percent of your mission”, says former Rear Admiral Stephen Baker of the US Navy.

4.1.7.5. Countering Mines

The threat of mines resulted in the development of a mine counter-measures field, to enable proper naval operations. First, the mine hunter needs detect the mine; then it will be possible to avoid or disable the mine (including detonating it without incurring damage). As mine’s sophistication increases, so does the sophistication of mine countermeasures. Mine developers, in turn, increase the sophistication of the mines to counter the countermeasures, and so forth. The result is an endless mine/anti-mine cycle. Today, mines have evolved into a threat that is very hard to detect. Much like the F-117A jet fighter’s design aimed at defeating radar detection, so do new mine designs aim at making the mines “transparent” to SONARs and other detection means.

This vicious circle has turned both mines and mine countermeasures into a distinct discipline. Mines and mine-countermeasures are a major part of naval operations and present an area where unmanned maritime systems offer another tool designed to help achieve superiority in this domain. The types of mines and their uses dictate the needs and characteristics for UUV and USV.[1]

Of course, preventing the deployment of mines is the most successful mine counter-measure.

4.1.7.6. Counter-Mines Vessels

In order to reduce their magnetic field (which would detonate an influence mine), mine hunting vessels (“minehunters”) are built from special materials and use special procedures designed to make them less detectable by mines; hence their high cost. Their hull is usually made of fiberglass (it used to be wood) and their structure is made to withstand a nearby underwater explosion. The vessels are capable of reconnaissance, classification, and neutralization of various mine types. They are equipped with a number of complementary SONARs and usually also with wire-guided remotely-operated vehicles (ROVs). In recent years, AUVs are becoming more common on such vessels, although many navies still use ROVs exclusively.

When deploying ROVs, minehunters must be able to work close to danger zones (i.e. suspected mine fields) because of the tethering mechanism. Also, the navigation of the ROV must be carefully managed to avoid damage to the cable. Therefore, navigating an ROV takes longer than using an AUV for detecting mines.

Neutralizing mines is a lengthy and costly effort. Laying a mine can cost as little as 0.5% of the cost of removing it; that explains why mines from WWII are still deployed to this day.

[1] http://www.defencetalk.com/usvs-and-uuvs-as-minehunters-22711/

Figure 5 - Kingfisher Minehunter (MCH-56, US Navy)

Source: NavSource Online: Mine Warfare Ship Photo Archive[2]

[2] http://www.navsource.org/archives/11/0456.htm

4.1.7.7. Diver EOD

Mine-hunting vessels are large, making them useless at handling shallow water mines. Mitigating such a threat requires divers, which is a very risky endeavor. Expert EOD Divers (part of a Diver Explosive Ordinance Disposal team) are sometimes sent to detect and classify mines, assisting the effort to neutralize such threats.

Figure 6 - Diver EOD Disabling a Mine

Source: US Navy

4.1.7.8. Mammals Deployed as Mine Counter-Measures

Ever since the 1960s, various navies have been using trained sea lions, dolphins, and even beluga whales to detect mines. But it is not always easy to ship such mammals to another region, and sometimes the water is not suitable for dolphins (dolphins have become sluggish and less effectives in the warm waters of the Persian Gulf). Also, sea lions tend to be very noisy in their cages, giving away the presence of demining teams. Still, mammals have proven effective not only at finding mines, but also at preventing diver-led underwater attacks by pursuing the attackers.

Figure 7 - A Sea Lion Disabling a Mine

Source: The Telegraph[3]

UMVs help keep people out of harm's way, and are much more resilient than either human beings or other mammals.

Figure 8 - Dolphins and AUVs are Used for Mine Detection

Source: Seebyte

[3] http://www.telegraph.co.uk/news/worldnews/northamerica/usa/6653439/US-use-sea-lions-in-terrorism-fight.html

4.1.7.9. Airborne MCM

An airborne MCM system consists of a helicopter carrying a mine-hunting SONAR, which is "dipped" below the surface of the water.

Detected mines can subsequently be detonated – also from the air.

A helicopter tows a surface "sled" (a hydrofoil catamaran) across long distances, where mines are neutralized (detonated) as the sled passes.

This is a successful method but it is limited in effect due to the following shortfalls:

- It seldom detects low-signature and buried mines
- It requires a vessel with a large deck for the helicopter
- Endurance is limited by the helicopter's fuel capacity
- Helicopters can perform this mission only under acceptable weather conditions
- Deployment takes time

Figure 9 - Airborne Mine Sweeping Operation

Source: US Navy[4]

[4] http://www.navy.mil/view_single.asp?id=40648

Airplanes (fixed wing) equipped with water-penetrating Light Detection and Ranging (LiDAR) can also be used to detect shallow water mines.

A USV can provide wide area clearance and a long endurance sweep.

A AUV equipped with low frequency, broadband SONAR can detect buried mines better than a towed SONAR.

4.1.7.10. Current Shortfalls of Traditional MCM

Current (manned) MCM methods are expensive and labor intensive. Their shortfalls are:

- Low transit speed, meaning slow reaction time to a threat
- Slow operational speed
- MCM vessels and divers are exposed to mine detonation
- Risky for personnel and assets in general
- Heavy equipment needs to be on site
- MCM boats are usually limited to greater than 10 meters water depth
- Long training of divers and mine-hunters personnel
- Mammals need care and results are not consistent
- Buried mines are very hard to detect
- Drifting mines are very hard to neutralize
- Smart mines sometimes defeat the counter-mines devices
- Slow classification of mines

4.1.7.11. The UUV Advantage in MCM

AUVs are very useful when there is a need to cover a large area and rapidly survey it. Although minefield locations are known, determining the actual mine locations and types requires a close-in inspection. AUVs have been used for 8-9 years in such operations. They also provide important information about the detected mines' surrounding environment. Before a mine is neutralized, it is important to know that no pipeline, fiber optics, and any other infrastructure exist in the vicinity, to prevent damage on detonation. AUVs can give us that precious information before the mines are swept. AUVs do not always enable classification. ROVs are still used a lot for mine classification.

ROVs are used to neutralize mines. The tethering cable enables the monitoring of real time imagery of the mine, which is observed under different angles through precise maneuvering of the ROV by skilled operators. Some ROVs then detonate the mine by attaching to it, at a specific place so as to minimize the explosion, and after positioning the mine-hunter in a safe location.

UUVs are also used to detonate mines.

4.1.7.12. AUVs - MCM Missions Capabilities

The following list summarizes the capabilities of AUVs in MCM:

- Quicker than ROVs in mine field survey operations
- Mine location detection capabilities
- Basic mine classification capabilities
- Large minefield survey capabilities due to AUV persistence
- Ability to deploy and operate multiple AUVs simultaneously (manufacturer dependent)
- Mine warfare risk assessment capabilities (can determine the absence or presence of mines, compute probability of safe passage for high value assets)
- Localize targets for prosecution using mine detonation
- Inspect surrounding infrastructure and assets presents in mine field
- Find alternate routes
- Record all objects in mine warfare database, enabling future surveillance operations

4.1.7.13. Current UUV's MCM Uses

In March 2003, as part of Operation 'Iraqi Freedom', the US Navy deployed the Hydroid REMUS 100 system into the shallow waters of the Northern Arabian Gulf and used its side-scan SONAR to systematically map the approaches into the port of Umm Qasr.

In the intervening period, a handful of other navies introduce AUVs into their frontline MCM order-of-battle. Many others have acquired limited numbers of AUVs for trials and experimentation purposes, with most identifying MCM reconnaissance and route survey as their initial interest.

Today, many navies are buying a small number of AUVs for the first time. Navies familiar with operating AUVs are buying more units and developing their own vehicles and systems.

4.1.7.14. Case Focus: iRobot Ranger, Man-Portable AUV

The Ranger, a UUV developed by iRobot Maritime, is man-portable at about 20 Kg and measures 1meter (3 feet) long. It is intended to be used for MCM but also ISR. It is possible to quickly launch this UUV from a small inflatable boat, from the shore or in very shallow waters. This enables quick deployment and a rapid threat assessment capability of the surveyed area. The Ranger is not yet in full production.[5]

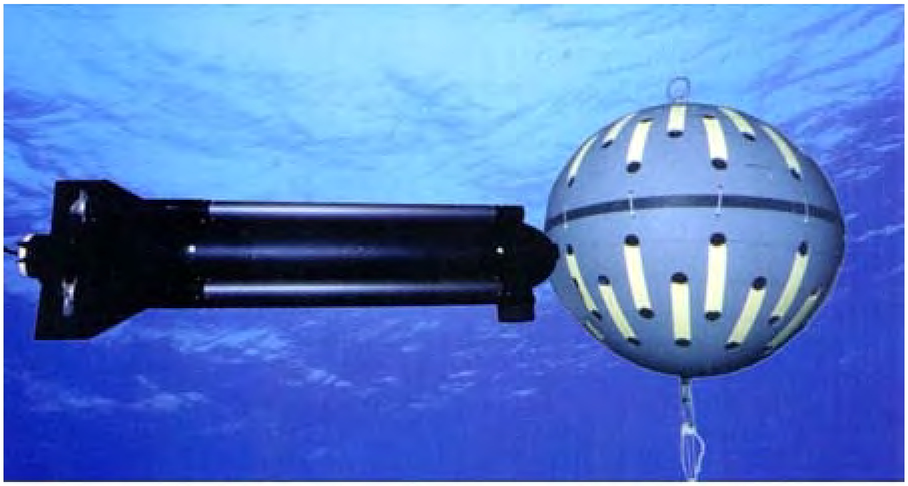
4.1.7.15. Case Focus: ROVs as Mine Disablers Used by the German Navy

[5] http://www.naval-technology.com/features/feature98410/, Nov 2010

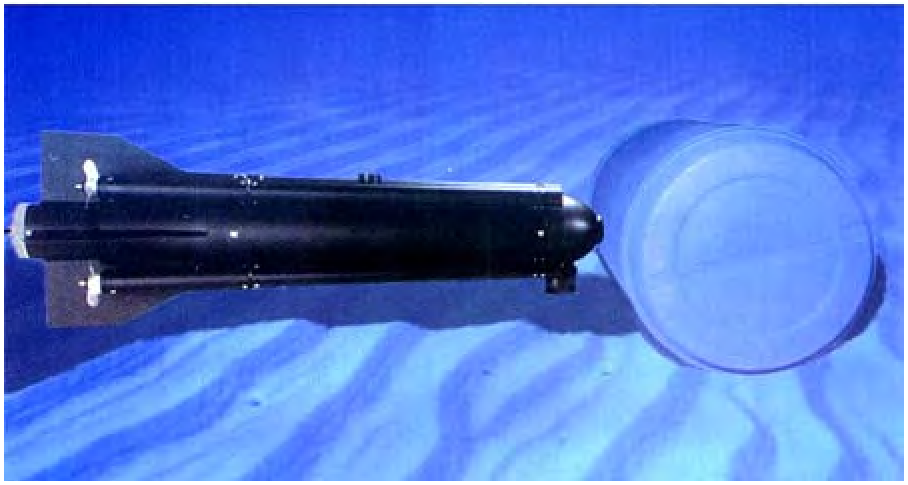
The German navy equipped a mine hunting vessel with one-way Seawolf and Seafox mine disposal vehicles from the Naval Division of Atlas Elektronik. Seafox and Seawolf are single-shot mine disposal vehicles, Seawolf is the larger and heavier version. Seawolf is armed with a larger explosive charge than Seafox to detonate large, buried mines. Seafox and Seawolf are non-recovery, lightweight, self-propelled munitions, equipped with SONAR for automatic homing and also a fiber optic link for operation from the ship. A live television camera and halogen headlights allow positive identification of the target prior to detonation.[6]

Figure 10 – Seafox in Attack Position

Moored mine



Ground Mine



Source: Naval Technology[7]

Although unmanned, an ROV is tethered and, therefore, can operate only at a limited distance from the mine-hunter. AUVs and USVs offer a safe alternative and a much greater range.

[6] http://www.naval-technology.com/projects/hameln/, Nov 29 2010
[7] http://www.naval-technology.com/projects/hameln/hameln2.html

4.1.7.16. Case Focus: Stated Needs from the US Navy for MCM Operations

The US Navy's mine warfare branch, N852, has stated the following needs to conduct MCM (and mine-laying) operations with the help of UMV:

- Need to be able to do mine clearance in cluttered, very shallow water environments
- Need to avoidance obstacles while conducting MCM missions
- Need to develop single-pass, detect-to-engagement of mines
- Need to develop a smart yet common design for UUV/USV [interoperability]
- Need to reduce manpower
- Need for innovative ideas on offensive maritime mining

Note that Homeland Security customer needs differ a bit from the military's. Cooperation amongst the security agencies needs to improve. On the UMV side, they are looking for surveillance and threat assessment as well so as to prevent mining.

4.1.8. Anti-Submarine Warfare (ASW).

As of 2007, there were about 450 submarines in service worldwide:

- 135 nuclear (from: US, China, UK, France, Russia, India)
- 315 air-dependent propulsion (from 48 nations)

Out of about 450 submarines today, almost half are operated by non-allied nations. Diesel subs are relatively inexpensive (compared with nuclear subs), yet still provide a great platform for a host of weapons: torpedoes, anti-ship cruise missiles, anti ship mines, and even nuclear weapons. Quiet diesel-electric subs are difficult to detect and neutralize.

Russia and China have publicly declared that the submarine is the single most potent vessel in their fleet. Other countries have been buying submarines from Russia, France, Sweden and other countries to increase their maritime dominance. The seas have hence become more crowded with an increased number of nations deploying and utilizing submarines to project power far and wide (e.g., Israel, Iran, Turkey).

There are today fewer submarines than 20 years ago, but each submarine is much more efficient (in capabilities and performance). The average lifespan of a submarine is 30 years.

Submarines commonly operate in the Persian Gulf, around the Korean peninsula and in the Taiwan straits.

Submarines operate mostly covertly. Because they rarely surface, they are very hard to detect. Not knowing where a weaponized threat is present poses a risk and a threat to potential adversaries. Radio-frequency transmission signals do not penetrate water so submerged submarines are immune to radars. Sonar send acoustic signals that travel through water but, because of the properties of salt water and those of acoustic underwater signals propagation, SONARs have limited ranges. Detecting submarines is, therefore, a tricky endeavor.

What does this mean to the current UMV market? UMVs represent both a tool to augment a submarine fleet and a tool to counter an enemy submarine. As submarines are increasingly expensive to develop, UMV represent a good option for anti-submarine warfare capabilities.

ASW USV concepts are mostly (and importantly) aimed at towing SONARs over long distances. Multi-mission frigates will be equipped with ASW USV capabilities as those have already been developed. Still, the market is nascent. New USV designs will track submarines over very long distances but no UUV is replacing primary submarine functions. However, there has been a lot of work done to deploy and recover UUV from submarine torpedo tubes.

It is important to understand the relationship between submarines and UMV. Submarine warfare being very secretive, it is difficult to truly understand existing programs.

Anti Submarine Warfare is a platform-intensive team game, requiring a broad use of airborne, surface and subsurface assets to detect, track, localize and sometimes disable the submarine. In all, unmanned maritime systems are the choice platform to cut costs, decrease the risks and increase the effectiveness of anti-submarine warfare.

4.1.8.1. Challenges to ASW

The challenges of ASW, not related to UMVs, are:

- Underwater intelligence gathered by submarines cannot be integrated with vessels and air defense assets because of a lack of relay buoys that would act as “tactical decision aids”
- Current environmental models of the seabed, the water and its acoustics properties are limited, and yield sub-optimal results to underwater communication and navigation
- Communication: range, bandwidth

4.1.8.2. Torpedoes and Torpedoes Countermeasures

Torpedoes targeted at submarines or ships are sometimes too fast for the targeted vessel to escape in time, once the threat is detected. Decoys can be launched from torpedo tubes or from the deck of a vessel and serve to deviate the torpedo away from the vessel. They send acoustic signals that fool the incoming torpedoes which then chase the decoy or lose their original (real) target.

Other counter-torpedo systems emit loud “noise” so the attacked submarine or vessel becomes lost in the noise – and the incoming torpedo does not know where the target is. As torpedoes get more sophisticated, it becomes more difficult to fool them. In turn, counter torpedoes measures attempt to outsmart them. Of course, most navies designing torpedoes also design their counter-measure components. A new technology and its implementation can give a few years of lead against others. Technological advances in materials (less detectable), SONARs (to detect) and autonomous systems (to react in real time to the situation) can indeed save lives and enable maritime dominance. It, therefore, makes sense for new systems to be kept secret.

Torpedoes today are full of electronics and software. A good warhead is important to damage the target but the most difficult task consists of being able to locate, track and hit the target. Because the target is always on the lookout for incoming torpedoes, working to perceive them at great distances, torpedoes have to make their own decisions to reach the target. Remote controlling a torpedo is tough because underwater communication is a much more difficult task than aerial communication. The high speed and range of torpedoes does not allow for them to be remotely controlled. Many torpedoes today are tethered to the host submarine. In a way, torpedoes are UUVs: they are unmanned, control themselves, have sensors and a mission to accomplish. And so do counter-torpedoes.

4.1.8.3. UUV use for ASW: Gliders

ROVs have nothing to do with ASW. Current technology limits AUVs to trailing submarines, because of persistence and power limitations. AUVs are not yet used as torpedoes and have not publicly been used for countering torpedo attacks.

There is, however, one area where UUVs are being used for ASW. It is not for detecting, trailing or damaging a submarine. Instead, it is to better understand the underwater environment so as to enhance communication and ISR.

Gliders are just starting to be used in real-time data gathering for ASW. So far, simultaneous use of gliders has been demonstrated, as well as their covering certain areas at various depths, data collection capabilities, and launch and recovery capabilities from military vessels. Long glider “rides” have been performed, but it has mostly been as general remote sensing missions rather than as specific ASW missions – although the military is certainly using the data as input for their models.

Please see the “Future Uses” section for further information on the use of UUVs in ASW.

4.1.8.4. USV use for ASW

USVs are not used in ASW operations. But development and testing of USVs for ASW missions is taking place at a pace similar to that of the development of USVs use for MCM.

Please see the “Future Uses” section for further information on the use of USVs in ASW.

4.1.8.5. Case Focus: AUV for Access Route Monitoring

Using UUVs for MCM does not necessarily mean mine removal. As French Navy Commander Denis Camelin explains: “Our MCM concept in peacetime is to maintain very accurate knowledge of the seabed so as to be able to detect any new contact during regular surveys of the major channels. This is very much a strategic mission, as we must assure access to our ballistic missile submarines in Brest and the strike carrier Charles de Gaulle in Toulon”.

Therefore, regular monitoring of access routes is a necessary step for readiness.[8]

[8] UV Online Magazine Oct/Nov 2010

4.1.9. Environmental Monitoring

Glider UUVs have recently migrated from a traditional research/scientific remote sensing role to military remote sensing, especially in terms of ocean properties data collection missions aimed at enhancing tactics and equipment functionality.

In addition, navies sometimes lead tasks such as environmental monitoring; they perform these tasks in cooperation with “civilian” administrations, regularly responsible for environmental supervision. This is a demonstration of the cross-domain position of UUVs, as they are being used for scientific research and defense purposes simultaneously.

4.1.10. Intelligence, Surveillance, Reconnaissance

There is evidence of a small but growing use of UUVs for ISR, especially in tasks associated with preventing deployment of underwater IEDs and mines in ports and harbors. This task is described in the security section of this report.

USVs are also being tested in ISR defense missions, such as to provide early warning and attack mitigation services for naval and government/commercial assets.

4.1.11. Case Focus: Large USV Requirements for Defense Uses

Large USVs, meant to be launched from a host vessel and operate on the high seas, have different requirements than smaller USVs that are meant to operate in ports, estuaries and close to shore.

Pounding, impact resistance and the need for stability drive requirements for littoral and deep-sea USVs. High speed, maneuverability and the ability to tow or carry men means that engines need to be powerful, which results in the design of a vessel that is large and heavy. High fuel capacity, necessary to enable the endurance of the USV, adds space and weight. High seas mean intense stress on the hull and all the equipment on-board, in addition to corrosion and humidity. In conjunction with need for a rugged boat, the electronic components need to be able to handle the environmental impact as well.

4.1.12. Defense Customers AUV Attributes

Defense customers want to use AUVs more autonomously and at distances greater than the data link range (4Km at present on most AUVs). When processing the SONAR data while the AUV is back in range, they want immediate interpretation of the data so action can be taken right away.

Defense customers also want endurance and often choose a more expensive battery type to get it.

The military market for AUVs increasingly values autonomy/intelligence, little need for communications during a mission and smart data processing done quickly.

4.2. Current Security Uses

4.2.1. Introduction to Maritime Security

Maritime security, whether protecting port facilities or maintaining the security of shipping lanes through international straits, is essential to both the global economy and peace.

Maritime security's role covers ports, harbors, estuaries, rivers, lakes, onshore plants such as nuclear and chemical, offshore oil and gas extraction facilities, cargo ships, cruise ships, fishing vessels, illegal immigration, drugs and all sorts of illicit trafficking, biological and chemical threats, beach vacationers protection, container loading and unloading on docks, pipelines, electricity, and communications infrastructure, luxury boats, as well as military ports and bases.

In any given country, no two ports are alike. They vary by geography, channels, navigation markers, bathymetry, winds, tides, currents and many other factors, which makes it hard to develop a unique and standard security solution.

Australia has more than 25,000 Km of coast line. The United States has 15 to 20 ports of strategic military and economic value. Asia has the largest ports. Densely used maritime routes pass through some of the most geopolitically sensitive regions in the world.

The maritime transportation system is very vulnerable to terrorist attacks. Currently, about 70% to 90% of the world's trade (90% by volume, 70% by value) is conducted by sea and involves over 180,000 ships larger than 100 gross register tons. Nearly 50 million barrels per day, or some 50% of the world's oil production is carried by approximately 4,000 tankers. Over 20 million containers make over 350 million transits annually, carrying nearly 1000 million tons of cargo. Between 12 and 15 million containers are thought to be at sea at any time.

Table 5 - World Ports Ranking by Cargo Volume by [Tons x 1000] - 2008

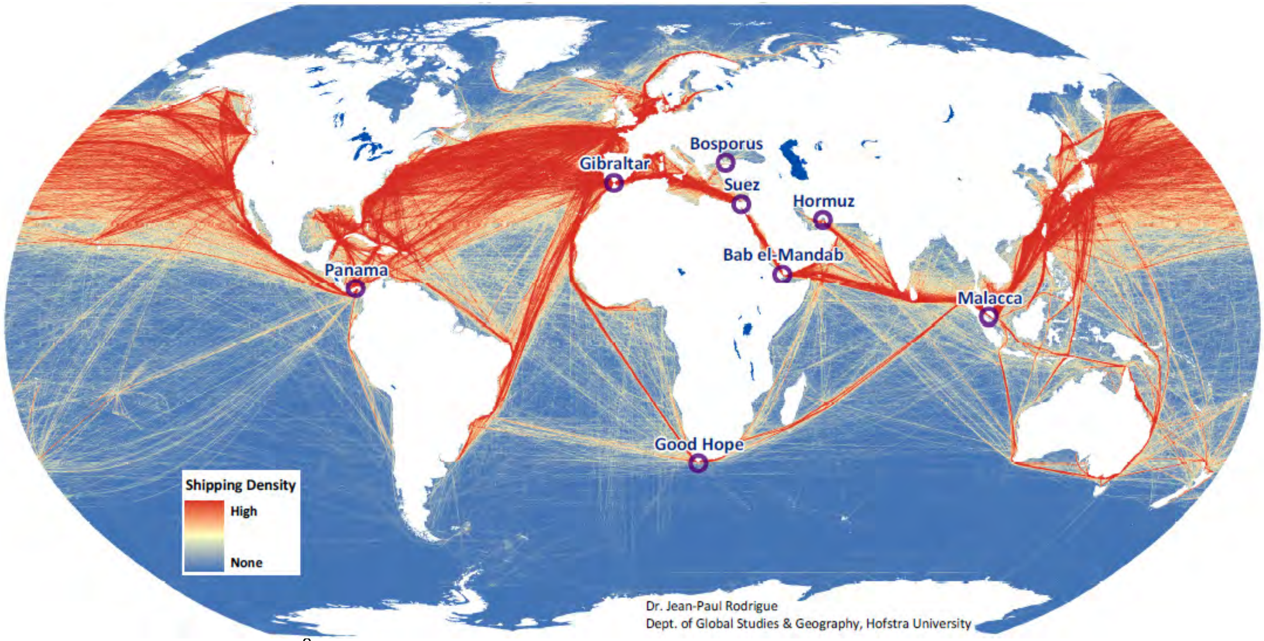
Rank	Port	Country	Measure	Tons
1.	Singapore	Singapore	freight	515,415
2.	Shanghai	China	metric	508,000
3.	Rotterdam	Netherlands	metric	421,136
4.	Tianjin	China	metric	365,163
5.	Ningbo	China	metric	361,850
6.	Guangzhou	China	metric	347,000
7.	Qingdao	China	metric	278,271
8.	Hong Kong	China	metric	259,402
9.	Qinhuangdao	China	metric	252,000
10.	Dalian	China	metric	246,000

Table 6 - World Ports Ranking by Container Traffic - 2008

Rank	Port	Country	TEUS
1.	Singapore	Singapore	29,918,200
2.	Shanghai	China	28,006,400
3.	Hong Kong	China	24,494,229
4.	Shenzhen	China	21,416,400
5.	Busan	South Korea	13,445,693
6.	Dubai	UAE	11,827,299
7.	Ningbo	China	11,226,000
8.	Guangzhou	China	11,001,400
9.	Rotterdam	Netherlands	10,783,825
10.	Qingdao	China	10,024,400

* - TEUs - Twenty-Foot Equivalent Units

Figure 11 - Maritime Shipping Routes and Strategic Locations



Source: Hofstra University [9]

[9] http://www.people.hofstra.edu/geotrans/eng/ch5en/conc5en/img/Map_Strategic_Passages.pdf

The importance of maritime security is understated by the fact that we, humans, only see the surface of the water and above. While we comprehend that maritime threats are likely to be concealed under the surface, the invisibility of the threat enables us to concentrate on what we can better see and understand. At-sea threats are also best understood by seafarers and people working in the industry.

A report on countering proliferation and nuclear, biological and chemical terrorism listed the need to improve maritime interdiction capabilities (to include ports and harbors) as its #1 recommendation.[10]

Since there is essentially no fixed structure to hide under or behind in the ocean, the only remaining option for concealment is to hide underwater. Boats are easily detectable by radar in the open seas. Detection becomes much harder in high traffic areas. Therefore, the maritime threat increases as the threats mix with peaceful traffic. High seas strategic assets like cruise ships and oil tankers are evident targets that pirates have successfully attacked. As with most threat reduction initiatives, the ultimate threat elimination is to prevent the threat from being deployed. Once deployed, it is a chess game, where each party needs to play its assets to prevent incursion into one’s camp. This is where the effectiveness of maritime security assets can make a difference.

We know threats are unavoidable – and mitigating against *all* of them would require resources we do not possess. It is then a matter of reducing the risks of casualties and damage by using the resources to the most effective manner.

4.2.1.1. Maritime Traffic

The maritime transport industry is one of the most globalized in terms of ownership. Maritime shipping companies, and the majority of the largest port terminals, are either privately owned or operated. Such large assets must be efficiently managed, which requires extensive capital requirements. The trend in recent years has been a convergence between the maritime segments of global trade with inland freight distribution. Global port operators, such as APM (Denmark), DPW (Dubai), HPH (Hong Kong) and PSA (Singapore), have been actively acquiring a portfolio of terminal assets in almost all the major ports of the world. Some, like APM, are a direct subsidiary of a maritime shipping company: Maersk, the world’s largest in this case.

Thus, a growing convergence between maritime shipping, ports and inland operations enables large private conglomerates to achieve a level of control over global supply chains. This is particularly important as global trade is more than a matter of capacity. It is also concerned about the timeliness and reliability of the distribution.[11]

For relevant business opportunities, see Section: **Error! Reference source not found.**

[10] Counter proliferation Program Review Committee
[11] Ports and Maritime Trade by Dr. Jean-Paul Rodrigue

Table 7 - Ranking of the 10 Largest Container Shipment Operators

Rank	Operator	TEU	Share
1.	APM-Maersk	2,069,267	15.2%
2.	Mediterranean Shg, Co.	1,491,578	11.0%
3.	CMA CGM Group	1,014,789	7.5%
4.	Evergreen Line	562,986	4.1%
5.	APL	550,384	4.0%
6.	Hapag-Lloyd	470,744	3.5%
7.	CSCL	453,792	3.3%
8.	Cosco Container L.	452,442	3.3%
9.	Hanjin Shipping	426,186	310.0%
10.	NYK	410,727	3.0%

Source: UK Ports and Logistics[12]

4.2.1.2. Commercial Maritime and Strategic Choke Points

Some 75% of the world's maritime trade, and half of the oil trade, passes through a handful of international straits and canals. The closing of a major international strait for any length of time would result in substantial damage to the international oil trade. The use of alternate routes by land or by the sea would greatly increase delivery time and cost of transport.

The significant maritime logistic choke points are:

- The Strait of Hormuz
- The Strait of Malacca
- The Suez Canal
- The Bosphorus

Many important maritime trade choke points are quite narrow and often shallow. Commercial vessels, and especially large tankers transiting a strait or narrows, are extremely vulnerable to attacks by maritime terrorists or pirates. Oil tankers are usually very large, relatively slow and cumbersome in avoiding attacks by small and fast boats laden with explosives.

Yet, despite the obvious vulnerabilities, there is little funding for choke point security.

Aviation security improved drastically in response to the Sept 11 2001 attacks. Will it take an attack on a major maritime asset to ramp up maritime security?

Delivering reasonable maritime security will cost a lot, and will necessitate a coordinated and comprehensive effort by government and private industry alike. A broad engagement from various local and national governments, and industries, will be necessary and each stakeholder will have to commit substantial resources. And because there are no physical boundaries in the sea – a wall cannot be constructed - the challenges and constraints posed by nature and political and economic realities are significant.

12 http://www.ukportsandlogistics.com/worldcontainerstatistics.html

4.2.2. Maritime Laws Varies Land Distance

The Third UN Convention on the Law of the Sea (UNCLOS), also known as the Law of the Sea Convention, was signed in December 1982.It extended the jurisdiction of coastal nations to include a 200 nautical mile exclusive economic zone (EEZ). This set a trend, with Navies concentrating on warfighting missions while Coast Guards focusing on protecting national sovereignty in home waters. Coastal states now must maintain safety and security in their waters, protect the marine environment, prevent marine pollution, prevent illegal fishing, and prevent criminal activities such as piracy and smuggling.

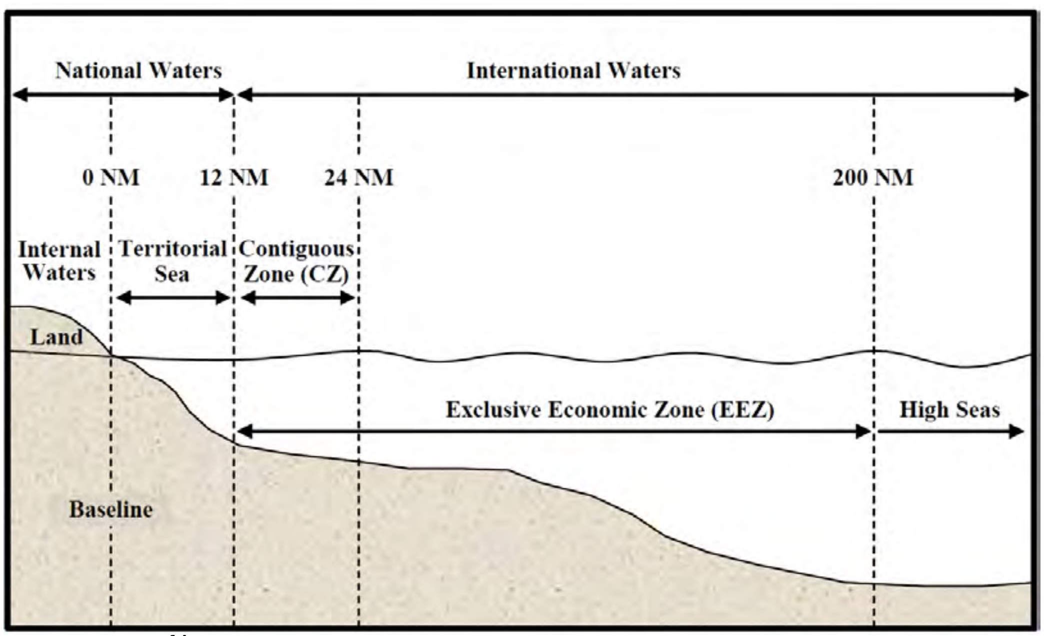
In general, there are three defined maritime security zones:

1. **Domestic Zone -** includes ports and their facilities and installations
2. **Border/coastal Zone -** includes the territorial sea (usually 12 nautical miles wide) plus the 200 nautical miles wide EEZ
3. **International Zone -** includes the sea and ocean beyond the EEZ boundary and also includes foreign ports where cargo for domestic ports has originated

A country's jurisdiction extends to all vessels, facilities and port security in the domestic and border/coastal zones.

Surveillance, tracking and interdiction can be conducted on the high seas, but boarding and interdiction are usually carried out in territorial waters. In addition, inspections can be carried out in inshore waters, ports and their approaches.[13]

Figure 12 - Maritime Boundaries



Source: DTIC[14]

4.2.3. Maritime Security Threats

[13] Coastal Surveillance, DefenseIQ
[14] http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA463720&Location=U2&doc=GetTRDoc.pdf

Maritime security threats include:

- Piracy
- Harbor attacks
- Port attacks
- Drug trafficking
- Illegal immigration
- Littoral surveillance
- Terrorism
- Arms trafficking
- Beach attack
- Attacks on chemical, petro-chemical plants (on-shore, near-shore and off-shore)
- Attacks on Nuclear plants
- Attacks on desalinization plants
- Attacks on vessels and ships

Today, maritime security is handled by defense agencies with maritime capabilities and by coast guards, police, homeland security, drugs enforcement, border patrol and special operations.

4.2.4. Port and Harbor Security

Port and harbor security includes:

- In-harbor protection
- Enforcing interdiction operations
- Surveillance and response
- Vulnerability assessment
- Domain awareness
- Infrastructure protection
- Under-hull surveys
- Floating object inspection and disabling
- Diver detection
- Vessel inspection
- Escort of vessel into and out of harbor
- Persistent patrol, night and day
- Underwater structure inspection (walls, piers, docks)
- Seafloor survey and change detection analysis

- Passage blockage
- Hostage rescue
- Bomb detection and disablement
- Boat registration and license identification
- Activity monitoring
- Communications

Small ROVs are currently the tool of choice of many law enforcement and police agencies for ports, harbors, lake, rivers, and canals.

4.2.5. Harbor Underwater Surveys

Although AUVs are the right tool to for surveying a harbor's bottom without disrupting daily operations, AUVs surveying and operations present several challenges:

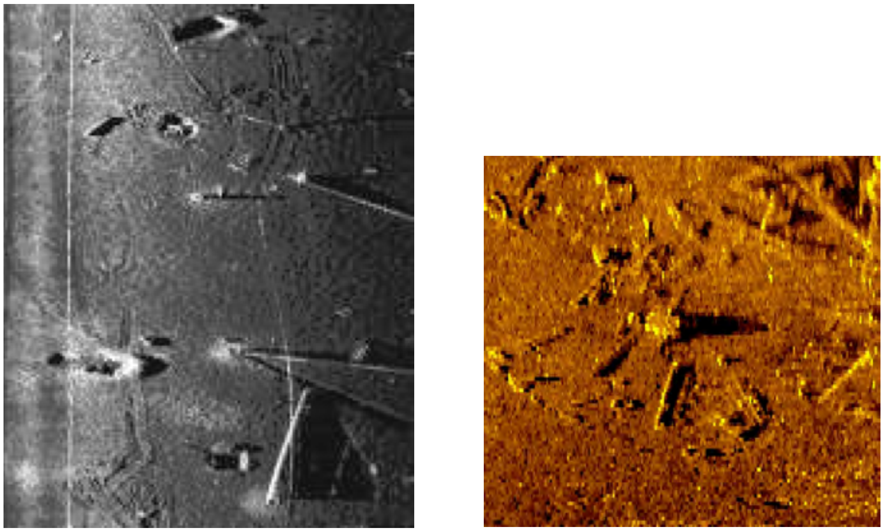
- Navigation in constricted areas is not possible unless there is sufficient environmental knowledge
- It is difficult to identify small objects because of high clutter
- Change detection in this enormous mass of data is very difficult
- The efficiency of the search can be a challenge

Many of those hurdles would, undoubtedly, also be present if the survey was done by a SONAR attached to a boat.

AUVs provide these benefits:

- Using SONAR as an active sensor enables operations day or night, without worrying about sources and impact of illumination
- Sonar data quality is excellent; especially as the UUVs can operate a lot closer to the survey subject (they don't have to remain on the surface)
- UUVs operate underwater, where there is very little activity compared to the surface
- Today's AUV technology has proven itself in the field

Figure 13 - Harbor Clutter



As with any remote sensing capability, data must be processed correctly and quickly. Sonars, as well as any imaging sensor, require not only intense computing but also complex algorithms in signal processing. To truly exploit the data, the algorithms need be customized to the task at hand, to take into consideration the type of object to be detected, properties of the water at the location of operation, mission preparation, etc. Such costs add to the purchase or lease price of the AUV and its command and control station.

4.2.6. Other Water Bodies Requiring Securing

Waterways, rivers, estuaries, deltas, channels and lakes need to be secure as well. Due to the expanse of those water bodies, the task can be challenging. An underwater explosive on the Panama or Suez Canals would be consequential. Traffic of commercial vessels can be extremely dense, such as in the Black Sea. Any disruption would create significant consequences. The mere potential for a threat can cause a disruption.

4.2.7. Countering Terrorism

4.2.7.1. Maritime Terrorism Activities

Maritime terrorism can take place at sea, on inland waterways, or in ports and coastal infrastructure. The scope of the terrorist threat increased greatly after 9/11.. Terrorist are likely to attack either assets of symbolic importance, such as a military vessel, or assets of high visibility and high "reward" for damage, such as cruise liners, oil tankers, liquefied gas carriers, and other vessels transporting strategic cargo.

Potential targets include commercial ships transiting a strait, sailing close to the coast and in waterways and as it approaches to a port, at a pier or anchored, at ports with their facilities/installations, critical installations ashore, and oil / gas rigs located in a country's EEZ.[15]

Other strategic targets include desalination plants, fish farms and recreation facilities.

The consequences of a terrorist attack on a port could be extensive. In a 2006 report, the U.S. Congressional Budget Office estimated that the closure of the ports of Los Angeles and Long Beach would reduce the U.S. Gross Domestic Product by up to $150 million per day.

Al Qaeda has been successful at attacking maritime targets in the past. The USS Cole was attacked in 2000, killing 18 and resulting in a $250M repair of a $1billion ship. An Israeli cruise ship in the Turkish Mediterranean port of Antalya was targeted with bombs aboard, ready to be detonated by a diver – but the operation failed. A bomb hidden aboard the cruise ship SuperFerry14 killed 118. In 2002, a boat was rammed into MV Limburg, a crude oil carrier. Ninety thousand barrels of oil were spilled and one man aboard the Limburg was killed. A suicide boat loaded with explosive was launched from a beach to target the USS Sullivans in 2000 – but the suicide boat sank immediately due to weight and balance problems. Beyond those successful and almost-successful attacks, many more attacks were prevented.

Other terror attacks came from the sea, such as the Mumbai attacks of 2008. Ten attackers arrived by sea from Pakistan to attack multiple targets in Mumbai. In February 2011, two barrels packed with explosives landed on the Israeli shore, just North of the Gaza strip.

In a maritime terrorist attack, the time the terrorists spend out at sea is short. Unless the method, the place and the exact time of the attack are known, it is extremely hard to interdict such an attack. Maritime police units and navies have a very limited opportunity to successfully respond to maritime terrorism.

Several, and increasingly more, terrorist groups have demonstrated interest in developing and expanding their range of maritime capabilities. Over time, most threat groups with access to water move from conducting support operations to guiding surface and underwater attack capabilities. Maritime terrorist technologies have usually originated in the Middle East but now they can be seen increasingly in Asia.

In the coming years, Asian threat groups are likely to create technologies and tactics that Middle Eastern groups will copy.

While maritime assets are vulnerable to terrorist attacks, the threat to naval ships and commercial shipping is medium to low when compared to aviation. There are two reasons:

- Very few terrorist groups have the capabilities to attack maritime targets

[15] Coastal Surveillance, DefenseIQ

- Very few attractive maritime targets could be attacked without expending significant resources

If the number of maritime attacks increase, governments and the private sector will invest excessively in securing the maritime domain.[16]

4.2.7.2. Cruise Ships

Seventeen million people took cruises in 2010 on about 358 cruise ships.. They navigate most regions in the world, with the Caribbean and the Mediterranean being most popular. Besides piracy attacks, terrorist attacks are a major concern for cruise ships. A successful attack would surely hurt an industry dependent on new customers (40% of total passengers have been realized in the past 5 years alone).

As a 2008 market study from the Cruise Lines International Association shows, safety is a major item of concern and a decision factor when it comes to deciding whether to go on a cruise. Cruise companies take safety seriously and have well-developed, internal organizations that continuously assess and address risk, using a combination of people, processes, and technology. Still, the environment of the seas is constantly changing and cruises routinely harbor in unprotected ports.

Table 8 - Percent Distribution of Capacity on Cruise Regions, 2008

Cruise regions	Jan- April	May- Sept.	Oct.- Dec.
Alaska	0	13	0
Caribbean	48	19	38
Europe, North	2	16	2
Far East	4	3	5
Indian ocean/Red Sea	2	0	1
St Lawrence/Bermuda/USEC	0	5	3
Med/Black Sea	11	35	29
Pacific	8	4	8
South Am/Antarctic	7	0	3
Mexican Riviera/Panama Canal	9	0	8
Other	8	4	3

Source: ShipPax

Cruise ships are natural targets, since they carry many people and an attack on them would surely command extensive media coverage – and/or bring a high ransom. Cruise ships are the single largest passenger conveyances in the world, with one ship currently in service that can carry more than 8,500 passengers and crew. The U.S. Coast Guard considers cruise ships to be highly attractive targets to terrorists. Moreover, terrorists have either targeted cruise ships or been able to board cruise ships in the past. The hijacking of the cruise ship Achille Lauro, with the killing of passenger Leon Klinghoffer by terrorists in 1985, was a watershed event for the cruise industry, leading to major changes in security procedures. More recently, a 2005 plot to

[16] Rohan Gunaratna: The Threat to the Maritime Domain

attack Israeli cruise ships off of the Turkish Mediterranean coast was discovered after the premature explosion of a bomb that was intended for the attack. Reduced demand for cruise travel following an attack could also have substantial economic effects as direct spending for goods and services by the cruise lines and their passengers - in the United States alone - was about $19.1 billion in 2008.[17]

Figure 14 - Cruise Ship Escorted by Military Vessel

Cruise ships are routinely escorted by military vessels, to and from port, and sometimes on the high seas in high threat areas. USVs could be use to augment or replace that force.

4.2.7.3. UMV uses for Counter-Terrorism

Although port and harbor security is using advanced naval technology, there has been no real use of UMVs for counter-terrorism activity. However, there have been real life demonstrations to navies, mostly by USV manufacturers.

The US Navy has tested the Protector, an armed USV designed to patrol harbors and defend vessels.

In 2010, Meggitt Training Systems of Canada performed a large-scale demonstration. Conducted at Canadian Forces Base Esquimalt in British Columbia, the demonstration involved simultaneous operation over seven hours of 16 USV controlled on a single radio frequency. The USV simulated small and armed assault vessels attacking a naval ship. This was an exercise of naval counter-swarm procedures.

UUVs have also been involved in exploring methods to counter potential terrorist attacks, particularly underwater threats.

[17] Excerpt from Varied Actions Taken to Enhance Cruise Ship Security, June 2010, from maritimesecurity.com

In particular, terrorist divers pose a real threat. The RILS system (Reacquire, Identify and Localize Swimmers), is being developed to defend against hostile swimmers intent on attacking ships in port. To counter a possible incursion, the man-portable UUV will travel to the vulnerable location, deploy a gateway buoy and then activate its on-board imaging SONAR. RILS can follow a threat that swims out of detection system range and sends GPS updates until help arrives. The system is developed by iRobot Maritime.

USVs can also help protect harbors against other threats, including terrorist attacks and illegal trafficking, by providing permanent surveillance of the zone at risk. To date, it is not clear who uses USVs for security enforcement. Certainly, the Israeli Navy and the Singapore Navy use USVs. Accounts of USV use by other nations indicate mostly testing and operational experimentation.

UMVs offer crucial protection against threats because of their capacity to maintain a permanent presence and to immediately inform the authority of new vessels or objects in a harbor.

4.2.7.4. Case Focus: Littoral Security

Early adopters of USVs for littoral patrols are mostly found in the Middle East, where the terrorism threat is high, along with tensions amongst states. Private interests are also very high due to the high value and production of oil and gas facilities.

Figure 15 - The Interceptor by 5G Marine, Patrolling the Coast of Oman

Source: 5G Marine

4.2.8. Anti-Piracy

4.2.8.1. Definition

Piracy is commonly defined as boarding (or attempting to board) any vessel with intent to commit theft or any other crime, and with an intent or capacity to use force to carry out such aims. Pirates are not commissioned by any sovereign nation. Piracy can also include the plundering of land resources from the sea as well as taking control of a plane. Acts of piracy include robbery, detention, criminal violence and war-like acts.

Most acts of piracy occur in South-east Asia, South Asia and off the east and west coast of Africa. All attacks off Somalia's coast were launched against ships at sea, while the majority of attacks elsewhere have occurred against ships that were berthed or anchored.[18]

Note: In this report, piracy means maritime piracy and includes any type of illegal attack from a ship onto another ship.

4.2.8.2. Pirate Attacks Statistics and Locations

Piracy started when men started to explore and conquer by sea, and has never stopped since. But such attacks have increased recently and caused enough trouble to raise piracy to a global concern. Over the last five years, maritime piracy has been on the rise:

Table 9 - Maritime Piracy Statistics - 2006-2010

Year	Number of Ships Attacked	Annual Increase
2006	239	-13%
2007	263	10%
2008	293	11%
2009	406	38%
2010	445	10%

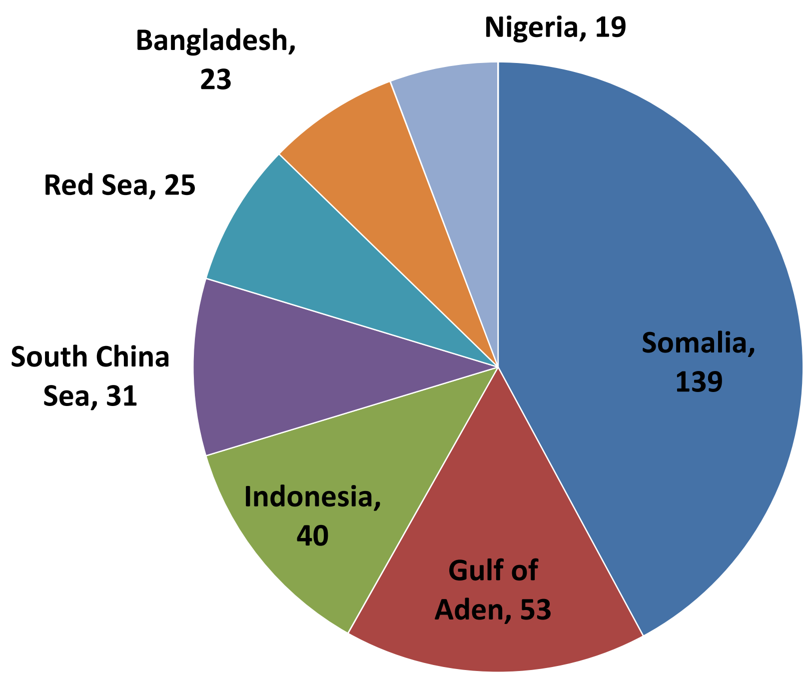
[18] Coastal Surveillance, DefenseIQ

Figure 16 - Piracy Attacks Statistic - by Region - 2010

Source: Piracy and Armed Robbery Against Ships, Annual Report 2010, by ICC International Maritime Bureau

As we can see, piracy is considerably more prevalent in Africa.

Figure 17 - Piracy Attacks Statistic - by Neighboring Country - 2010



Source: Piracy and Armed Robbery Against Ships, Annual Report 2010, by ICC International Maritime Bureau

Note: 75% of total reported incidents happen in the waters neighboring the above countries.

4.2.9. Piracy - Current Situation

In March 2011, five Somali men were sentenced for engaging in piracy. A jury in Virginia, United States, convicted the pirates in the first piracy trial in the United States since 1820. Is it the beginning of a new era?[19]

As of 13 June 2011, 439 seafarers of various nationalities are being held for ransom on board 23 ships under various flags at various locations off the extensive Somali coastline – reflecting a situation which has progressively worsened over the last years. Ships are being boarded and seized, and seafarers' lives put at risk for prolonged periods of time, in an area that has extended beyond the waters off the coast of Somalia to the Gulf of Aden and the wider Indian Ocean.

Piracy attacks are becoming more violent and the tactics used by pirates include using hijacked ships as bases ("mother ships") for carrying out further attacks, with their crews remaining on board as "human shields".

Furthermore, recent attacks on ships sailing far away from the Somali coast and in areas north and east of the Horn of Africa, which, until now, were considered relatively safe, have made an already complicated issue even more difficult. These developments make military intervention even more arduous and highlight the urgent need for ships to take every possible measure to avoid being taken in the first place.

Of the 445 vessels attacked in 2010, 196 were boarded, 53 hijacked, 107 fired upon, and 1181 hostages were taken. Pirates are not afraid to use their weapons to press their demands. Hostages are held longer. In March 2011, 26 hostages from the MV Rak Afrikana (Tanzanian, Indian, and Pakistani) were released after 332 days in captivity.

Pirates attack all types of ships: oil tankers, commercial ships with containers, cruise ships, and even military ships. And much smaller ships too. Some will hijack ships simply for the cargo while others will attack a boat to kidnap the crew in the hopes of a hefty ransom. Boats represent "easy pickings," especially off the coast of lawless countries like Somalia or in places where maritime security is weak.

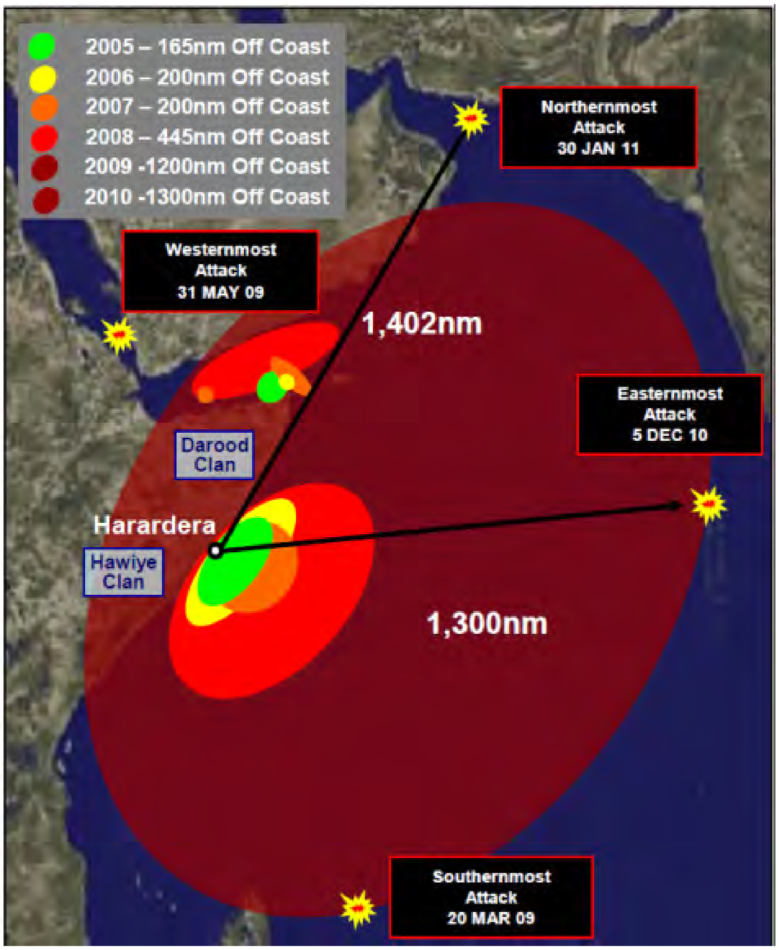
Pirates seek to take on-board equipment such as radios and electronics, and often hold a ship and its personnel for cash – a ransom. In 2008, ransoms ranged from $0.5M to $2M. 2009 has seen higher ransoms: in February 2009 a $3.2M was paid for a Ukrainian cargo ship. To date, the highest ransom paid was $9.5M to release a South Korean oil tanker. The average ransom in 2010 is now $5.4M, up from $150,000 in 2005. The One Earth Future Foundation, which conducted a study on the global impact of maritime piracy, estimated the economic cost to be at least $7B.

Rocket Propelled Grenades (RPG) are especially dangerous when aimed at tankers, because their explosion could ignite the stored oil. In March 2011 a grenade landed on the deck of a tanker and fell down into the accommodation structure. Fortunately, it failed to explode.

As pirates become more desperate and determined to attack ships, violence has increased: Somali pirates routinely fire their RPG and automatic weapons indiscriminately to intimidate the Master to stop the vessel. Recent attacks have happened more than 1000 nautical miles from Mogadishu. Somali pirates are now attacking vessels off Kenya, Tanzania, Seychelles, Madagascar and in the Indian Ocean.

[19] http://www.marinelink.com/news/convicted-nicholas336318.aspx, accessed Dec 5 2010

Figure 18 - Pirates' Reach Increasing



Source: Maritime Security Operations, INEGMA Brief by Rear Admiral Charles Gouette, Deputy Commander, Naval Forces Central Command, United States presented in February 2011

Another great concern is that Somali pirates are using more hijacked ocean fishing and merchant vessels to conduct piracy operations. This allows them to attack unsuspecting passing vessels. Their fuel capacity and speed limits have also increased.

Eastern Somalia is an obvious problem while other hot spots around the world include the Gulf of Aden, the Malacca Straits (between Malaysia and the Indonesian island of Sumatra), Nigeria, Bangladesh, Iraq and the northeastern coast of South America. Attacks in the Gulf of Aden have dropped by 50% due to the international naval patrols and positive action by seafarers. However, Somalia attacks in other areas have gone up substantially.

4.2.9.1. Insurance Premiums and Delays

In 2009, insurance premium for commercial ships (tankers and containers) increased 10 times, adding about $400M to insurance costs. Commercial shipping companies are very concerned. The Italian association of ship owners, Confitarma, wonders if the Cape of Good Hope will return as the route of choice for transporting goods from Italy to Asia. Going through the Cape of Good Hope increases the distance by 62% and adds 10 days to the trip, compared to passing through the Suez Canal.

The major problem is not the fuel cost but the fact that ship owners need to buy more vessels in order to maintain the same frequency of delivery. For Italian shippers with their 600 vessels, the added costs of morevessels alone – if all ships were going to Good Hope – would be $16B. This fact explains the ongoing discussion between commercial shipping companies, insurers and various navies. There is tremendous pressure on the navies to provide increased counter-piracy services – diverting the costs of counter-piracy operations away from the shippers and insurers onto the military, which is already strained by budget cuts.

Maersk estimates the cost of piracy (to Maersk alone) to have been $100M in 2010 while others have estimated the cost of piracy in the Indian Ocean to be between $7B and $12B in 2010. Shippers publicize the attacks to pressure governments to act.

4.2.9.2. How do Pirates Operate?

Pirates are usually desperate to get a hold of anything of value within reach and they understand the high risks. With high risks must come high rewards, so the pirates are not afraid to attack much bigger and stronger vessels than theirs. Dire poverty and hunger drive men to take on piracy as an option to have a chance to improve their lives.

To better counter piracy, it is essential to understand how pirates operate.

The initial goal of today's pirates is to simply get within threatening range with their rocket-propelled grenades and/or machine guns. The last thing ships transporting volatile cargo like oil want is a rocket propelled grenade launched into the side of their vessel which would most likely result in an explosion and fire. Large and slow tankers are easy targets as they cannot possibly escape the pirates once targeted. Loaded cargo boats have low deck levels due to the heavy load they transport.

Pirates often operate very far from shore, outside the territorial waters of any state or nation.

Since pirates often act in bands, a simple counter-piracy vessel can be baited by one pirate's boat while the other pirates assault the target vessel. Pirates often use a mother ship from which to launch their attack. Sometimes the hostage ship itself becomes a mother ship and is used to launch other attacks.

Figure 19 - Pirate Small Boat

Source: The Status and Challenges of Privacy Today[20]

With a few exceptions, most ships actually captured by Somali pirates are smaller, slower vessels not owned by major shipping companies.

Throughout Asia, most piracy incidents involved vessels at anchor or in port, which is very different from incidents involving Somali pirates. In Asia, patrols are effective as the number of attacks decline with an increase in patrols. But they slowly creep up again once patrols are reduced. “The pirates usually attack during the hours of darkness and they target the ship’s safe, property and personal belongings,” said Noel Choong, head of the International Maritime Bureau’s piracy monitoring centre.

“Unlike Somali pirates, Asian pirates abort their attempts when they are spotted so we advise all vessels to ensure they are vigilant to prevent such boarding,” Mr. Choong added.

A persistent port and littoral patrol presence 24/7 would be effective at reducing such piracy.

Another common tactic of modern-day pirates is to put out a distress call, then ambush any ship that responds. As current USVs have about 10 miles of RF communication distance with the host vessel, sending a USV with EO capabilities would at least enable a ship to respond to a distress call without falling victim to a piracy trap.

From the Somali pirates to the Indonesian pirates, we learn that different methods and tools are required to counter maritime piracy.

4.2.9.3. Legal Considerations

Although a pirate vessel has a flag state, universal jurisdiction means action can be taken against pirates without objection from their home. However, complex jurisdictional issues concerning a vessel’s flag, port of departure, nationalities of the persons aboard, location of attack, international maritime and national maritime laws, and other legal issues last beyond the act of piracy itself.

[20] http://www.navy.forces.gc.ca/navy_images/public_media/pottengal_mukundan.pdf

There are two major impediments to employing lethal force in defense of ships at sea. The first is obvious risk associated with employing weapons from the deck of large vessels carrying volatile cargo, fire and explosion. Second, there are political issues regarding (foreign) cargo vessels entering ports carrying lethal weapons. Some nations simply will not permit civilians with weapons to enter their ports. There are also inherent issues associated with rules of engagement and legal jurisdictions when lethal force is employed by civilian security forces. All of these issues add complexity to the question of using lethal force in defense of vessels.[21]

Furthermore, there are rules of engagement when defending a vessel. Most boats do not carry any guns for various reasons: maritime laws, port of departure laws, port of arrival laws, religious reasons of the personnel, not to mention the risk of having a weapons fired on a boat that may be carrying inflammable materials.

Therefore, it is best to avoid the pirates before they climb onboard the target ship.

4.2.9.4. Counter-Piracy Operations

Training a vessel's crew in anti-piracy procedures, and making them responsible to conduct an anti-piracy operation, is not always feasible. Often, the captain and master of the boat are the only personnel qualified to professionally resist pirates. Of course, the best recourse is to call for help as soon as the piracy threat materializes. Various navies have been busy conducting such counter-piracy operations. In 2010, there were 23 nations involved in counter-piracy operations.

Figure 20 - Combined Task Force 151

Anti-piracy operations are extremely costly because they rely on precious and expensive military forces. Military interventions have been very effective but have tied up significant resources. Currently, there are about 10,000 oil tankers sailing the oceans without protection because they are prohibited from carrying weapons. Protecting all those tankers is impossible, and protecting just a fraction is tying up many resources at a prohibitive cost. Besides, is a fully equipped destroyer an appropriate counter-measure to fight two pirate boats of 7 men each?

[21] Journal of Energy Security, Chris Brewer, 2009

The first picture below depicts an attacking pirate skiff. The second picture shows the USS Farragut, a guided missile destroyer, near a skiff it destroyed after pirates tried to attack a Sierra Leone-flagged tanker.[22]

Figure 21 - Pirate Attack and Rare Consequences to Them

Augmenting the counter-piracy force by adding staffed vessels is not a financially-feasible solution, even in the short term.

The minimum requirements for preventing piracy with military forces are:[23]

- **Establishment of a naval presence in remote locations** - basing naval forces in close proximity to the areas where they may be needed. This improves maritime security and enables the forces to gain superior intelligence about the enemy.
- **Establishing a protected area -** prioritize naval activity to protect the most important areas.
- **Short response time -** naval forces must be prepared to engage pirates before they can fire on or board protected vessels.
- **Appropriate forces -** manned and unmanned systems must be designed for their mission.

There are a number of steps a vessel can take to independently deter and repel an attack. A commonly used approach today is to hire a team of trained and armed counter-piracy professionals. However, at $4,000 or so per day, most commercial ships cannot afford the increased cost. Fuel costs to run the vessel and slim profits make most independent anti-piracy schemes cost prohibitive.

[22] http://news.blogs.cnn.com/2010/04/02/photos-show-navy-warship-destroying-pirate-mother-ship/
[23] Augmenting Naval Capabilities in Remote Locations, Naval Post graduate School, December 2009

Using anti-boarding nets and deploying slippery substances to prevent pirates from climbing requires costly modifications or added equipment. Such policies contribute to delaying or sometimes preventing boarding. But the increased use of weapons by frustrated pirates can worsen the situation.

USVs could be an option, but they are too costly at present for private shipping companies to deploy.

The best prevention is simply to avoid the pirates. In 2010, commercial shipping companies have altered their routes to avoid the Gulf of Aden, preferring to add 2,500 miles going through Cape of Good Hope at the Southern tip of the African continent. However, avoiding the pirates might just shift the problem elsewhere: it slows the transit of goods and increase costs of fuel and crew. It also requires shipping firms to operate more vessels to maintain the same delivery schedule. Companies choosing the alternate route become less competitive and less profitable. Besides, pirates are reaching out more towards South Africa and India. As more ships chose the Good Hope route, more pirates will probably take their "business" there.

4.2.10. USV uses in Security

In early 2009, two different USVs were bought by the Israeli Navy and put into action for the first time during Operation Cast Lead in the Gaza Strip. Their role was to enforce the sea blockade aimed at stopping weapons shipments. Although the systems were not declared operational, we can assume that by now the Israeli Navy is using USVs for defense and security purposes. They will not comment on USVs. But considering the security threats along the Eastern Mediterranean coast, and the fact that two USV technology leaders are Israeli, one can only assume that the Israeli Navy has been using USVs in military and security operations for a while.

When it comes to inspecting a naval threat such as an identified boat or a floating object, sending a manned boat puts a crew directly at risk: a bomb can be remotely detonated, or the enemy might use weapons against the inspecting vessel. As an Israeli Navy spokesman commented in 2009: "There are areas that the Navy prefers to first enter in an unmanned capacity before a manned capacity."

Unmanned surface vehicles have been operated militarily since World War II but are now emerging into the mainstream of naval assets.[24]

[24] Unmanned Surface Vehicles: An Operational Commander's Tool for Maritime security by Matthew Graham, Oct 2008 http://www.stormingmedia.us/56/5614/A561494.html

4.2.11. Case Focus: UMV Use against Self-Propelled Semi-Submersibles

Self-propelled semi-submersibles (SPSS), quasi submarines used to transport drugs, can be detected using some of the same technology used for ASW. In late 2010, the US Southern Command and the US Office of the Secretary of Defense allocated $6M for development, testing and demonstration of autonomous surface vehicles designed to detect, monitor and support SPSS interdiction.

4.3. Adoption of UUVs and USVs Today

Although their technology is proven for military and security operations, USVs have been used sparingly in this capacity. Most of the USVs existing today have been functioning as technology development platforms, and are only used sporadically in real settings. AUVs have been used more often in the “real world”, but still minimally compared to unmanned aerial vehicles and unmanned ground vehicles. Many militaries have yet to use AUVs at all.

The U.S. Coast Guard is about to use unmanned systems for the first time in order to bring those capabilities to non-defense roles. Few ports are routinely surveyed by UUVs. Although the technology is not new; its employment is relatively new. The military has a variety of needs for UMV. Security operators will take longer to adopt and integrate UMVs, since they typically wait for the military to integrate new technologies.

In addition, unmanned systems disrupt the routine operations of defense and security organizations. Unmanned systems both add capabilities that were non-existent beforehand, and replace existing technology – along with some humans too. As with any change, it will be resisted. Processes and bureaucracies are by nature slow to accept and adapt to change.

One reason why UUVs have been developed earlier is their triple uses: defense (MCM), civil (oceanographic research), and commercial (oil & gas, telecommunications).

USVs will stay prohibitively expensive if the military alone uses them. Even if militaries purchase them in large quantities, the cost problem will not be solved for commercial operators.

There are today about 7,000 UAVs used by the US military alone. Yet the cost of the most basic models is still too expensive for commercial customers. USVs’ high cost is one obvious reason why they have not sold more. Two Israeli companies have “ready-to-go” USVs, proven in the field, equipped with the right sensors for the job, yet the security market has not used them.

It is not entirely clear who is responsible for securing ports, harbors, and waterways: is it the national Navy? Is it the Coast Guard? Is it the police, or fire departments? Is it the Bomb Squad? Federal, regional, local and something tribal authorities - all have a certain areas of responsibility. Depending on the threat or the type of asset threatened, it is often not clear who should act first. Until responsibilities are defined, there is little that can be done to operate UMVs when they are needed the most, which is why it will probably take a very serious event for UMVs to be fully accepted.

4.4. Case Focus: AUV Priorities and Classes for the US Navy

In 2004, the US Navy developed a UUV Master Plan. AUV classification and prioritized use is depicted below:

Table 10 - AUV Classification by the US Navy

Priority	Sub Pillar Capability	Man Portable	LWV	HWV	Large
1.	Intelligence, Surveillance, Reconnaissance	Special Purpose	Harbor	Tactical	Persistent
5.	Oceanography		Special Purpose	Littoral Access	Long Range
6.	Communication / Navigation Network Nodes	VSW / SOF	Mobile CN3		
2	Mine Countermeasures	VSW / SW SCM / RI Neutralizers	OPAREA Clearance	Clandestine Recon.	
3.	Anti-Submarine Warfare				Hold-at-risk
4.	Inspection / ID	HLD/A TFP			
7.	Payload Delivery				SOF ASW MCM TCS
8.	Information Operations		Network Attack	Submarine Decoy	
9.	Time Critical Strike				(see Payload Delivery)

Source: UUV Master Plan of 2004

4.5. Case Focus: USV Mission Priorities by the US Navy

In 2007, the US Navy developed a USV Master plan. USV classification and their prioritized use is depicted below:

Table 11 - US Navy USV Priorities per Class

USV MP Priority	Joint Capability Area	Seapower Pillar	Joint Capability Area Missions	X-Class (small)	Harbor Class (7M)	Snorkeler Class (7M SS)	Fleet Class (11M)
1.	Battle Space Awareness (BSA)/Access/ Littoral Control	Sea Shield	Mine Countermeasures (MCM)		MCM Delivery, Search / Neutralization	MCM Search, Towed, Delivery, Neutralization	MCM Sweep, Delivery, Neutralization
2.	BSA/Access/ Littoral Control	Sea Shield	Anti-Submarine Warfare (ASW)			Maritime Shield	Protected Passage and Maritime Shield
3.	BSA, HLD, Non-Traditional Ops, 7 Others	FORCE net	Maritime Security		ISR / Gun Payloads		7M Payloads
4.	BSA/Access/ Littoral Control	Sea Shield	Surface Warfare (SUW)		SUW, Gun	SUW (Torpedo), Option	SUW, Gun & Torpedo
5.	BSA/Access/ Littoral Control/ Non-Traditional Ops	Sea Strike	Special Operation Forces (SOF) Support	SOF Support	SOF Support		Other Delivery Missions (SOF)
6.	BSA, C&C, Net Ops, IO, Non-Traditional Ops, Access, Littoral Control	Sea Strike	Electronic Warfare		Other IO	High Power EW	High Power EW
7.	BSA, Stability, Non-Traditional Ops, Littoral Control	Sea Shield	Maritime Interdiction Operations (MIO) Support	MIO USV for 11M L&R	ISR / Gun Payloads		
				Secondary Missions of each class that are possible			

Source: Unmanned Systems Overview, US Navy, presented to The Maritime Alliance Conference in November 2010

4.6. Case Focus: Operational USV Limits

Although USVs hold great potential, real operational effectiveness has not been fully demonstrated.

High sea conditions and heavy rain severely limit on-board sensors, in addition to making launch and recovery more perilous. Communications is not always reliable; the placement of antennas has proven to be critical as it is sensitive to host ship signal cutouts.

5. Current Technologies

This Chapter provides a detailed review of the technologies currently used in UMVs.

5.1. USVs and USSs

5.1.1. Unmanned Surface Systems – Description

Unmanned Surface Systems are composed of:

- One or more vehicles, entirely or partially operated autonomously
- A manually-operated mission planning and control station
- One or more mission-specific payloads on-board the USVs, with a corresponding control station operated manually

Where the USV denotes the actual vehicle, the USS denotes the entire system. Systems usually include at least two vehicles. The control station can command a number of USVs, and a station can sometimes command a number of types and models of unmanned vehicles.

5.1.1.1. Unmanned Surface Sub-Systems Elements

The major sub-systems of a USV are:

- Hull
- Auxiliary structural elements
- Propulsion system
- Energy storage
- Internal command and control:
  - Navigation, guidance, vehicle control, adaptive behavior
  - Sensors data logging and processing
  - Internal communication between modules, sensors and components
  - Engine management
  - Payload control and management
  - Mission execution and adaptation
  - Data communication to the host control station
- External communication system:
  - Radio-frequency
  - Optional satellite communication
- Host control station:
  - Command and control of the vehicle(s)
  - Command and control of the payloads and sensors
  - Data processing
  - Data analysis

  - Data recording
  - Autonomous or remotely piloted mode and in-between levels of autonomy
  - Optional command and control of UAV, UGV
  - Communication and networking
- Launch and Recovery gear

5.1.1.2. Critical Sub-Systems Elements

The critical sub-system elements are:

- Hull design: must be able to withstand high sea conditions
- Intelligent monitoring systems and improved durability and reliability: the surface of the seas is a rough environment where electronics and mechanics are subject to intense pressures and stress. That includes detecting the waves and anticipating them for navigation.
- Command and control, and a common control architecture
  - Navigation elements
  - Redundant hardware
  - Sense and avoid
- Launch and Recovery
  - USV itself
  - Equipment on-board the USV

In particular, the architecture can enable mission flexibility through hardware and payload modularity, and conformance to standards. Standardization increases safety and reliability through test and evaluation, and enables the integration of existing components for faster and cheaper development of new functionality.

5.1.1.3. Important Sub-Systems Elements

The important sub-system elements are:

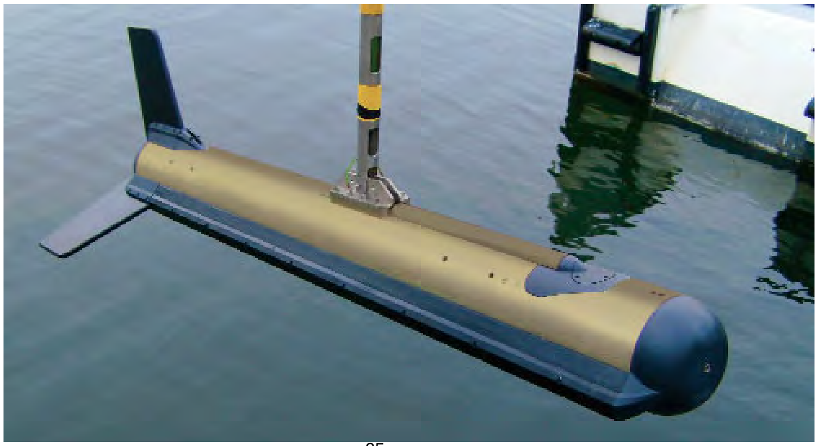
- Propulsion system: high speed capability would enable more applications, especially in drug trafficking monitoring and interception
- Energy storage
- Sensors data processing
- Interoperability and operational availability
- Command and control – allowing cooperative UxV behavior
- Mission specific components

5.1.1.4. Mission Specific Components

Depending on the mission(s), a USV can be equipped with a number of payload configurations, consisting of active or passive equipment, sensors, actuators and technological hardware that adds to required USV sub-systems, such as:

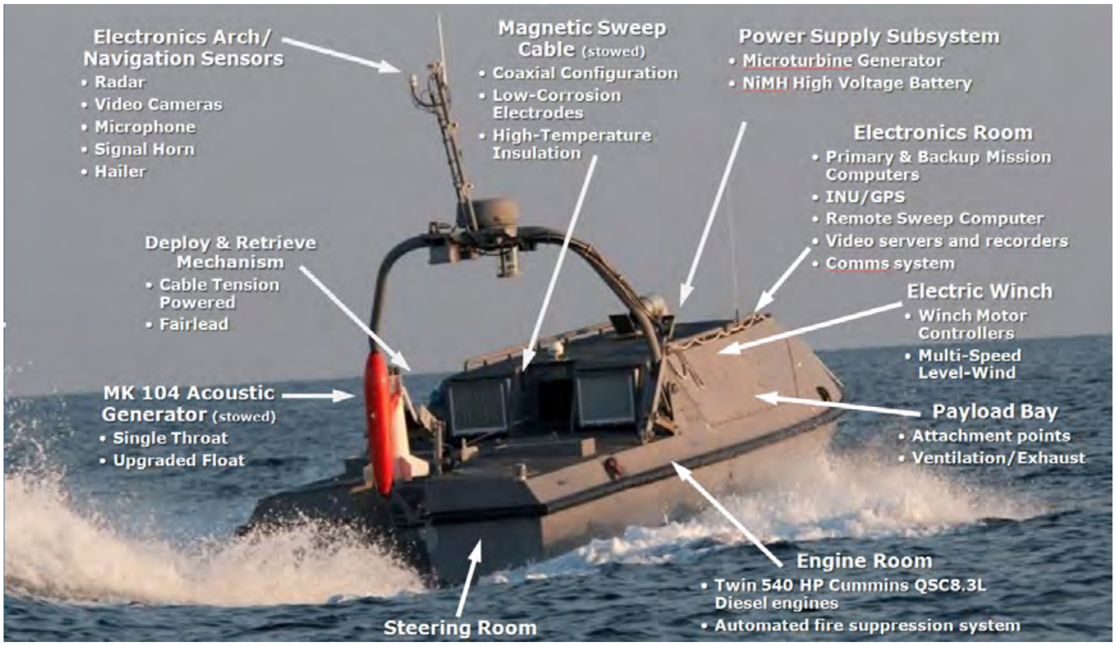
- Stabilized machine-guns
- Laser weapon
- Search radar
- Day time electro-optical video
- Infrared video
- LiDAR
- Color CCD camera
- Stereo EO/IR
- Laser rangefinder
- Correlation tracker
- Target designator
- Satellite communication
- Maritime navigation radar
- Panoramic camera
- Water cannon
- Noise projector
- Light blaster
- Laser illuminator
- Electronic warfare active sensors
- Sonar
- Microphone

Figure 22 - Multi-Beam Side Scan SONAR system, Towable by a USV



Source: Klein Associates, Inc[25]

Figure 23 - US Navy USV Hardware Overview



Source: Unmanned Systems Overview, US Navy, presented to The Maritime Alliance Conference in November 2010

5.1.1.5. Payloads, Modules & Mission Packages

Various payloads can be packaged to meet specific missions. The following are a few examples of possible payloads, delineated by mission:

- ❑ MCM
  - ➢ Launch and recovery of one or two AUV
  - ➢ Towed SONAR for mine detection
  - ➢ Side scan SONAR for detection and classification of bottom and moored mines
- ❑ ASW

[25] http://www.l-3klein.com/wp-content/uploads/2008/05/Klein-System-5900.pdf

- Tower array, low-frequency active SONAR in order to detect diesel-electric submarines from a long distance
- Folding Lightweight Active Sonar (FLASH) SONAR for detection and classification of submarines

- Harbor Patrol
  - Chemical detectors
  - Swimmer detection
  - Multi-beam echo-sounder
- Littoral Patrol
  - 360-degree radar
- Counter Smuggling
  - Shallow jet propulsion and rudderless steering for shallow water access
- Counter Terrorism
  - Swimmer detection
  - Stabilized gun
  - Laser weapon
- Anti-Piracy
  - Long Range Acoustic Device (LRAD)
  - Water cannon
  - Light
  - Laser weapon

5.1.1.6. Case Focus: USV Mission Package for ASW

Figure 24 - USV Equipped for ASW Missions

Source: Unmanned Systems Overview, US Navy, presented to The Maritime Alliance Conference in November 2010

Regarding this USV (above):

It provides non-persistent, long range, semi-autonomous ASW detection capability:

- Low Frequency Bi-static radar
- Mid Frequency Mono Static radar

It integrates ASW Mission Payloads

- USV Towed Array System
- Multi-static Off-board Source radar
- USV Dipping Sonar

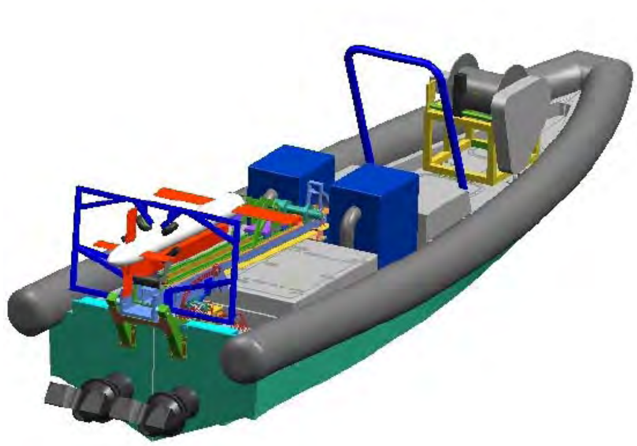
Two USVs could be operating together.

Craft Characteristic:

- Length: 36 ft
- Beam: 11.2 ft
- Full load displacement: 23,049 lbs
- Payload: 5000 lbs
- Engines: twin diesels, water jets (440 hp each)
- Towing: 1,600 lb at 20 kts
- Endurance: 24 hours +

5.1.1.7. Case Focus: USV Mission Package for MCM

Figure 25 - USV Equipped for MCM Missions



Source: Unmanned Systems Overview, US Navy, presented to The Maritime Alliance Conference in November 2010

Figure 26 - Spartan Scout Mine Detection Package

5.2. UUVs and UUSs

5.2.1. Unmanned Underwater Vehicle Sub-Systems

The major UUV sub-systems are:

- ❑ Pressure hull
- ❑ Hydrodynamic hull
- ❑ Ballasting
- ❑ Power and energy
- ❑ Electrical-power distribution
- ❑ Propulsion
- ❑ Main computer
- ❑ In-UUV network
- ❑ Navigation and positioning
- ❑ Obstacle avoidance
- ❑ Vehicle Control
- ❑ Communications
- ❑ Locator and emergency equipment
- ❑ Payloads

ROVs generally have fewer subsystems than AUVs. They often lack navigation and radio or acoustic communication systems, for example. ROVs use imaging systems, including external lighting, as primary sensors and require a manned control station for mission execution.

5.2.1.1. UUVs - Main Sub-Systems Elements

The main sub-system elements of UUVs are:

- Vehicle
- Control station: mission planning, data logging, data processing, health monitoring
- Communications

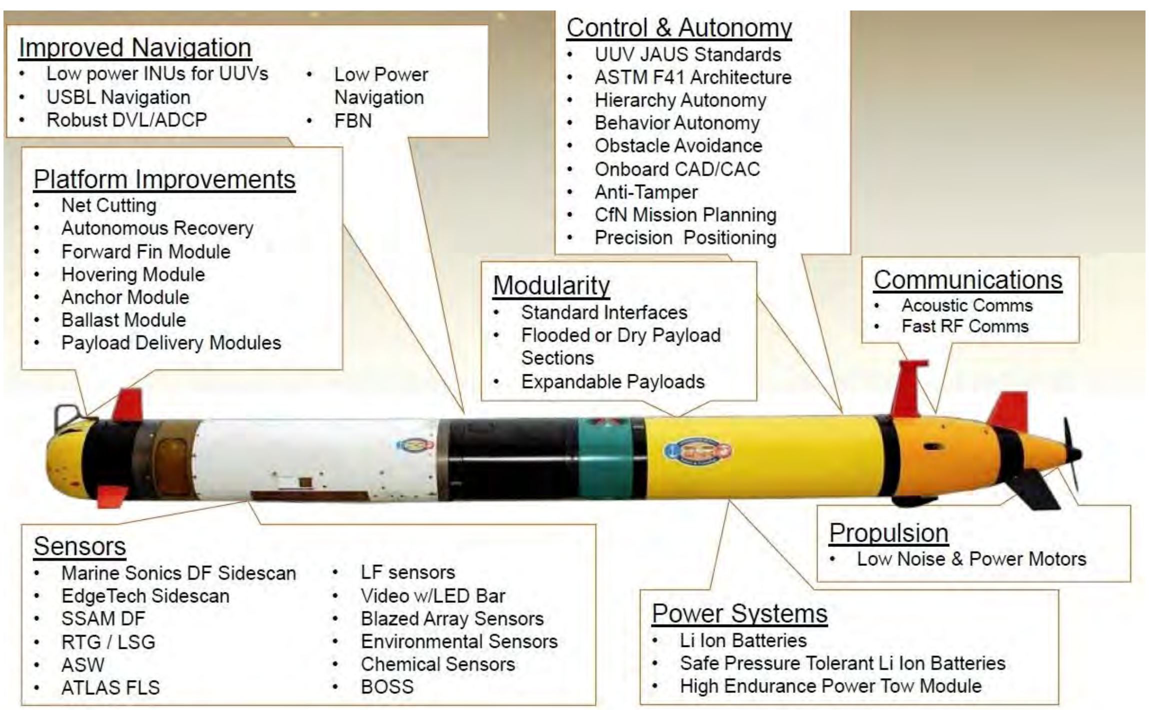
5.2.1.2. Case Focus: US Navy Man-Portable UUV

Covertness is one major attribute of underwater vehicles, be it submarines or UUVs. But logistics is another important attribute. A large UUV needs to have a crane to be transported, or bulky carrying platforms, a launch and recovery system, and a host ship or truck. That may impact the covert nature of the operation. Also, the need for such additional equipment leads to higher overall system costs, due to the necessary support infrastructure. It may also lead to deployment delays and may result in inability to deploy in shallow waters.

For short missions, such as a port inspection for mines, small UUVs can be quickly deployed and do the job.

Each military force has or will have a need for man-portable UUVs, such as to perform spot ISR missions. These small UUVs can also be use as preparation for expeditionary landing and other offensive situations.

Figure 27 - Man Portable and Light Weight UUV Technology



Source: Office of Naval Research, US Navy[26]

[26] http://auvac.org/uploads/publication_pdf/734_LDUUV%20INP%20Industry%20Day_posted%20version.pdf

5.2.1.3. AUV Launch and Recovery

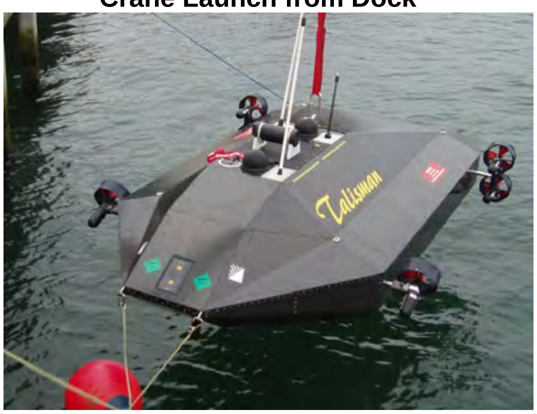
Launch –Launch systems enable deployment from a static or moving vessel (manned or unmanned), from a ground-based location (such as a port), or simply by a person putting a UUV into the water from a dock or boat. Launchers are adapted for a class of UUVs. UUV classes are determined by the weight and length of the UUV.

Figure 28 - Launch Systems of UUV

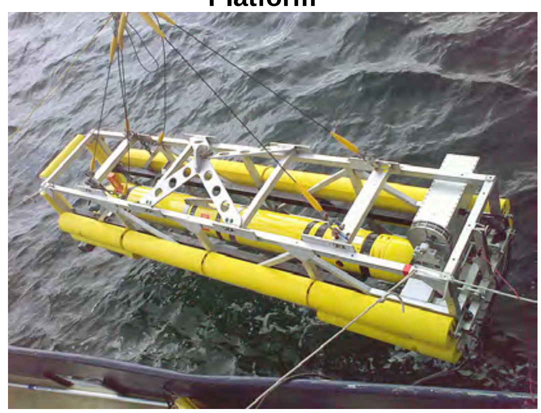
Side Launch Drop From Vessel[27]

Crane Launch from Vessel[28]

Crane Launch from Dock[29]



Crane lowering Housing Custom Fit Launch Platform[30]



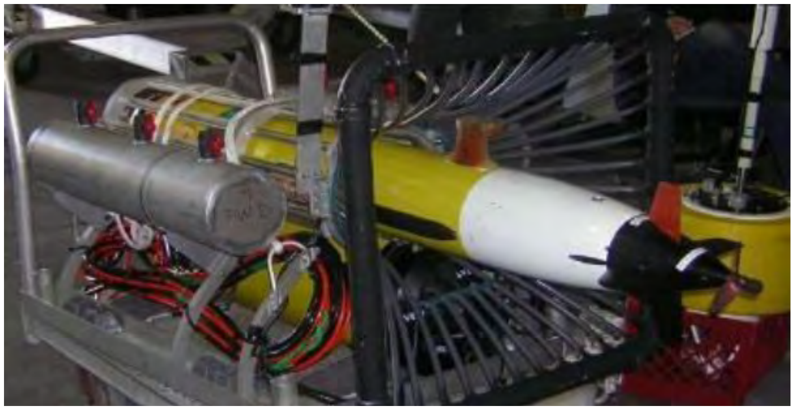
Launch and Recovery Ramp[31]

Manual launch from rubberized boat

[27] http://lannyland.blogspot.com/2009/03/robot-of-day-irobot-1ka-seaglider-deep.html
[28] http://www.navy.mil/navydata/cno/n87/usw/issue_15/wave.html
[29] http://warnewsupdates.blogspot.com/2009/10/growing-development-and-use-of-uuvs.html
[30] http://www.w54.biz/showthread.php?191-Mines-hunting-and-using
[31] The Security Network

Recovery –Recovery procedures are difficult, especially when the recovery system is moving such as with a submarine. Recovery systems are often uniquely designed to the "homing" procedure of a UUV. The recovery system is most often the same as the launch system.

Figure 29 - Submerged Recovery Station for Hydroid Remus



Source: US Navy, NAVSEA

In the case of a submarine UUV recovery, the submarine maneuvers to rendezvous with the UUV. Homing and docking SONAR guides the UUV towards the recovery arm, a unique docking mechanism that extends out of the ship's upper torpedo tube. After the UUV is captured, the recovery arm guides the UUV into the lower torpedo tube, and back into the submarine. Recovery of a UUV into a submarine in action has recently been accomplished, proving the technical maturity of UUV recovery systems by another underwater platform.

5.2.1.4. Mission-Specific Components

Depending on the AUV role, a variety of equipment can be integrated in the AUV:

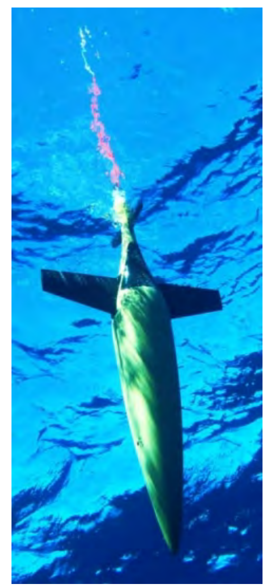
- Side-scan SONARs
- Multi-beam imaging SONARs
- Acoustic Doppler current profiler
- Water clarity sensor
- GPS
- Wi-Fi
- Synthetic Aperture Sonar
- Long range acoustic communication for shallow waters
- Forward looking SONAR
- Turbidity and current measurement sensor
- Ambient pressure sensor to measure depth
- Inertial Measurement Unit
- Magnetometer

- Conductivity probe (for salinity)
- Thermistor
- Oxygen sensor
- Sub-bottom profiler
- Electronic still camera
- Acoustic / iridium / freewave modem
- Underwater acoustic position system

5.2.2. Gliders

Gliders are a type of UUV. An underwater glider uses small changes in its buoyancy in conjunction with wings to convert vertical motion into horizontal motion, and thereby propel itself forward with very low power consumption. They can move underwater for many months and therefore cover long distances. In 2009, a glider went across the Atlantic Ocean. Gliders main uses so far have been to collect information about the water sampled during the journey, therefore giving valuable sea "profile" information in various geographical locations and at various depths. Gliders can be used to research water properties and underwater environmental conditions.

Figure 30 - SeaGlider, iRobot



In addition to traditional environmental and R&D uses, gliders are being adapted for defense applications, mostly because of the much greater endurance they offer compared to traditional UUVs.

Although gliders offer much more limited maneuverability and control than electric-propulsion AUVs, they will be used increasingly for:

- Communication nodes
- Acoustic surveillance, especially searching for quiet diesel-electric submarine for ASW applications
- Intelligence gathering

Because of their slow motion and small size, gliders are hard to detect. Long persistence and low-signatures make gliders an attractive ISR tool.

Increasing AUV persistence is such an urgent need that one can expect a near-term adoption of gliders with increased capabilities, until AUVs offer an endurance of more than 30 days.

5.3. Integration of UMS into Larger Operational Systems

5.3.1. System Architecture

The system's architecture is the technical framework and foundation on which the elements of the vehicles can interact and function together.

This architecture needs to be:

- **Robust:** to handle a broken component and adapt itself to function without it.
- **Scalable:** to enable the integration of additional modules and upgrades / downgrades of components.
- **Open:** to allow flexibility without requiring a re-design of the entire system's architecture.
- **Standardization:** for the system itself to be compliant to greater standards and to ensure a level of quality.

The system's architecture is the base that allows modularity, interoperability and scalability.

Well-designed system architecture allows:

- Joint operations
- Costs reduction
- Reconfigurability
- Ease of optimization
- Upgradability
- Repair-ability
- Mission centricity
- Maintainability
- Integration of the UUV into a larger operating force

5.4. Technology Gaps

5.4.1. Current Technology Challenges

UMVs (UUV or USV) are limited by:

- Endurance
- Integration of the command and control of a UMV into a ship or port authority command center
- Sharing of information and data amongst the stakeholders and the UMV
- Interoperability between systems
- Communications: enhanced underwater communication & robust communication links
- Short RF range for USV control / Affordable over-the-horizon communications
- Launch and recovery systems
- Autonomous adaptive control systems and autonomy, especially in autonomous navigation, collision avoidance, and cooperative behavior
- Sensor processing and real time data processing
- Reliability in the marine environment
- Sense and avoid capabilities

As many of the technological components and elements required to solve the technical challenges of a UUV and USV exist, the overall technical challenge is one of systems engineering and integration. Of course, those challenges must be overcome in a cost-effective manner.

5.4.1.1. Case Focus: MCM UUV Mission Versatility

Navies want UUVs to perform well in MCM operations in various waters and to detect (and possibly classify) various types of mines. This is a tough technical challenge. The RMS (Remote Minehunting System), a semi-submerged UUV developed by Lockheed Martin, has not shown good performance in shallow water. “Navy officials have found that a proficient crew can use the RMS to detect and classify moored mines in deep water, or find moored and bottom mines in shallow water. The system's shallow-water capability, however, is limited to locations where the bottom is smooth and the clutter density is low. The RMS, Navy officials say, is less capable of detecting mines under other conditions.”[32]

[32] John Keller, Dec 12 2010, Lockheed Martin to upgrade RMS minehunting underwater vehicle capability and reliability

Figure 31 - Remote Minehunting System

Source: Lockheed Martin[33]

It is a very tough challenge to develop one unique vehicle that is effective in a number of operational contexts. Sensors have their own range of confidence, beyond which results are not guaranteed. Using sensors with a wide operational range means they might be sub-optimal for 80% of the missions. Also, beyond the adaptive behavior of the system, the hardware has its own limitations.

5.4.1.2. USV: Autonomy Depends on Perception

Much like UGVs, USVs must be able to operate in dense environments. To safely navigate amongst surface traffic, which is a pre-requisite for navigation autonomy, USV must correctly perceive their environment. One type of sensor is usually not enough, so intelligent sensor fusion must take place. In addition, sea conditions vary drastically so as to make data acquisition and processing difficult. And the very diversity of potential encounters renders the "if then" logic scenario insufficient. Some UGVs stop advancing in front of high grass, perceiving the grass as an obstacle. Similarly, floating sea weed can be a "benign" artifact or hide an object that has been accumulating sea weed over its voyage.

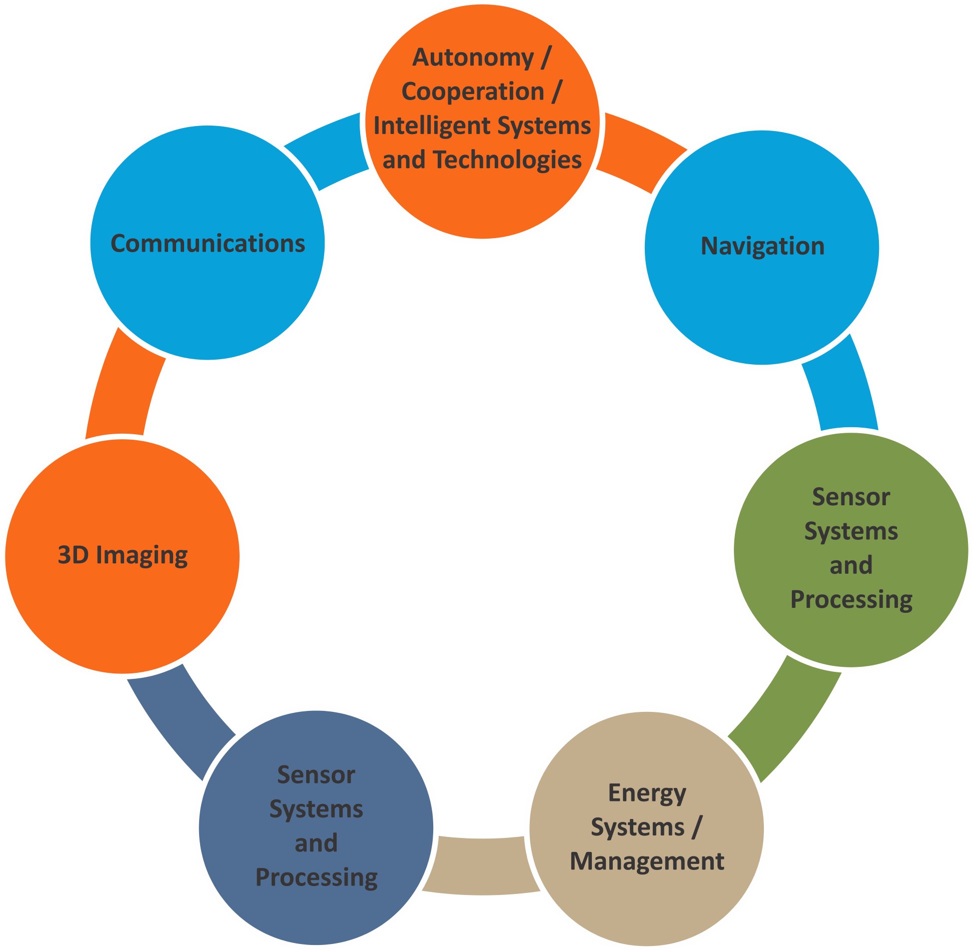
5.4.1.3. UUV Technology "Long Poles"

As Dr. Richard Blidberg points out in Brief History of AUV from the Beginning, an interesting aspect in UUV technology gaps is that, although there have been advances in many areas, a number of these developments still remain the "technology long poles" associated with AUV systems, i.e. limits in these technologies limit the capability of AUV systems generally.

Such long poles are:

[33] http://www.lockheedmartin.com/data/assets/ms2/pdf/RMS_Domestic_brochure.pdf

Figure 32 - AUV Technology Long Poles



Source: Dr. Richard Blidberg

For a relevant business opportunity, see Section: **Error! Reference source not found.**. We predict that the AUV long poles will be present for a while. The oceans are a particularly tough environment, into which many of the technologies developed over the last 50 years simply don't transfer well.

5.4.1.4. Technology Challenges for MCM and ASW UMV

Besides the long poles, specific functions require specific technologies.

The challenges currently facing MCM and ASW missions are:[34]

- Transitioning equipment to a small-scale production-level (producing few units)
- Weight reduction of active and passive sensing equipment
- Commonality of support equipment
- Open architecture computing
- Standardization of vehicle interfaces and of payload interfaces
- Common control

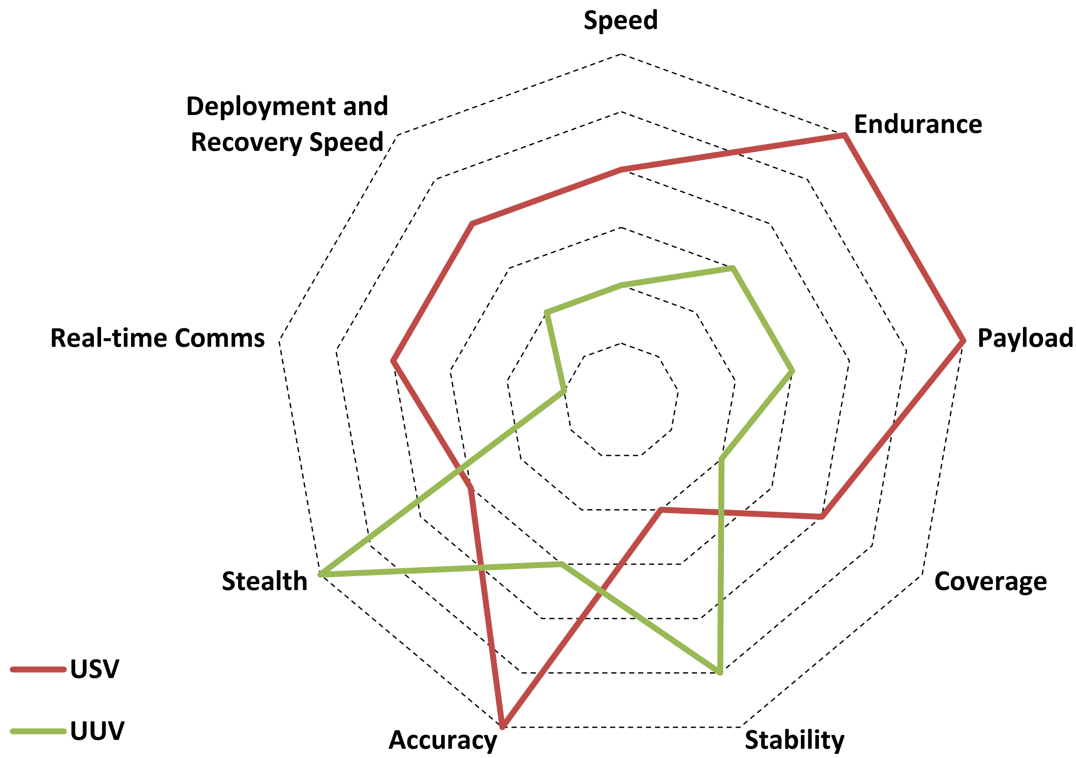
[34] US Navy

- Launch, Handling & Recovery that needs to be adapted on several vessels and reliable up to a sea state 5
- Off-board systems autonomy with reliable real-time exploitation

5.5. Characteristics Comparison amongst UMVs

Although this diagram is a bit dated, it provides valuable insight regarding the complementary nature of unmanned systems.

Figure 33 - UMV Characteristics Comparison Chart



Source: Unmanned Systems Overview, US Navy, presented to The Maritime Alliance Conference in November 2010

For a relevant business opportunity, see Section: **Error! Reference source not found.**.

Table 12 - Advantages and Disadvantages of UUV and USV

UMV Type	Advantage	Disadvantage
UUV	• Close underwater object inspection • Invisible / concealed by the seas • Quiet • Modular by design • Lower costs due to commercial and research customers • Higher academia and research contributors • Can act as a relay or mesh-network hub • Hard to detect / low signature • Already-established user based	• Acoustic communication limit range and bandwidth • EO does not work well underwater • High need for autonomy means slow development • Launch and recovery • Electric energy sources are heavy and of limited capacity • Subject to underwater currents
USV	• Large payloads enable a number of functions, including cargo • Large weight carrying ability enable long persistence • Radio communication enables remote control and full motion video • Bridge between underwater and air • Can act as relay to surface ships • Smaller footprint than a ship • Contact with air allows many propulsion engines options • Internal combustion engines • GPS and satellite communications • Diesel engines means refueling can be done anywhere • Accessible top deck enables quick reconfiguration • Access to commercial COTS parts from the surface vessels industry	• Rules of the road for surface traffic • Launch and recovery • Weight • Low acceptance • Dynamics of the sea surface pose challenging mechanical and structural problems

6. Current Markets by Application

This Chapter provides insight into currently available UMV markets in the security and defense sectors.

7. Current Markets by Region

This Chapter explores current UMV markets by geographic region. Such an analysis is desirable because market evolution in this sector is not homogenous across various regions, creating opportunities as well as risks.

8. Unmanned Maritime Vehicles – Current Vendors

The following two sections are a catalog of defense and security UMVs developed as of 2011. Many UMVs have a triple use commercial – research – defense/security. Many of those unmanned vehicles were developed based on government funding, which means that some of those UMVs never made it past the prototype stage, that some are obsolete, incomplete, on hold until funding continues the program, not for sale, and/or still in a developmental stage.

This is a very large sample but no list can ever be fully inclusive. It gives an idea of who is building UMVs, and of their rough design.

9. Future Uses

This chapter explores evolving UMV applications.

9.1. Future Uses - Defense

Note: This Section spans 32 pages.

9.2. Future Uses - Security

Note: This Section spans 13 pages.

9.3. Future Uses – Obstacles

Note: This Section spans 2 pages.

10. Future Technologies

Note: This Section spans 13 pages.

11. Global UMS Market Forecast by Market Segments – 2012-2020

This Chapter combines a quantitative and qualitative outlook of the global UMV market, through the end of the decade.

Note: This Section spans 20 pages.

12. Global UMS Market Forecast by Market Sectors – 2012-2020

Note: For obvious reasons we cannot include complete forecast tables and graphs in this sample. For clarity's sake, we present below several samples without data. To get a better idea of the analytic and predictive breadth of this report, please review the List of Tables and List of Figures.

Table 13 - Global UMS Market Forecast by Market Sectors by [$Millions] – 2012-2020

	2012	2013	2014	2015	2016	2017	2018	2019	2020	∑12-20	CAGR 12-20
Defense											
Security											
Total											

Table 14 - Americas USV Market Forecast by Market Segments by [$Millions] – 2012-2020

	2012	2013	2014	2015	2016	2017	2018	2019	2020	∑12-20	CAGR 12-20
Procurement											
Operations & Maintenance											
R&D											
Total											

Table 15 - Americas UMS for Defense Sector – Market Forecast by System Type by [$Millions] – 2012-2020

	2012	2013	2014	2015	2016	2017	2018	2019	2020	∑12-20	CAGR 12-20
USV											
UUV											
Total											

Table 16 - Scenario II – Global UMS Market Forecast by Region by [$Millions] – 2012-2020

	2012	2013	2014	2015	2016	2017	2018	2019	2020	∑12-20	CAGR 12-20
Americas											
Europe											
Asia											
Africa											
Total											