A Survey of Missions for

Unmanned Undersea Vehicles

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Summary

Background

The question central to this book is, *Which missions for UUVs appear most promising to pursue in terms of military need, risk, alternatives, and cost?* This question subsumes the following questions:

- What missions are advocated for UUVs?
- How great is the military need for these missions?
- What are the technical risks associated with developing UUVs for these missions? What are the operational risks of using UUVs for these missions?
- What, if any, are the alternatives to UUVs in conducting these missions? For example, would these missions be better performed by manned systems, semisubmersible unmanned vehicles, or fixed systems?
- What would be the cost of using UUVs to conduct these missions? For which missions are UUVs the most cost-effective alternative?

In examining military missions advocated for UUVs, we identified an unwieldy mission set: more than 40 distinct missions for UUVs are advocated in the Navy's 2004 *UUV Master Plan* alone. Using the Sea Power 21 construct as guidance, the master plan defines nine mission categories for UUVs and prioritizes them in the following order:

1. Intelligence, Surveillance, and Reconnaissance (ISR)
2. Mine Countermeasures (MCM)
3. Anti-Submarine Warfare (ASW)

4. Inspection/Identification
5. Oceanography
6. Communications/Navigation Network Node (CN3)
7. Payload Delivery
8. Information Operations
9. Time Critical Strike (TCS).[1]

Focusing on the highest priority mission category, ISR, the 2004 *UUV Master Plan* advocates the following possible ISR UUV missions:

- Persistent and tactical intelligence collection: Signal, Electronic, Measurement, and Imaging Intelligence (SIGINT, ELINT, MASINT, and IMINT), Meteorology and Oceanography (METOC), etc. (above and/or below ocean surface)
- Chemical, Biological, Nuclear, Radiological, and Explosive (CBNRE) detection and localization (both above and below the ocean surface)
- Near-Land and Harbor Monitoring
- Deployment of leave-behind surveillance sensors or sensor arrays
- Specialized mapping and object detection and localization.[2]

Operational need varies across these missions. For example, there is no need or advantage in using UUVs to collect atmospheric data (i.e., meteorology above the ocean surface). Similarly, endurance and other requirements for UUVs in tactical and persistent intelligence-collection missions differ.[3] Vehicle size and sensor capability requirements will likely vary across these missions. The missions also require

[1] U.S. Department of the Navy, *The Navy Unmanned Undersea Vehicle (UUV) Master Plan*, November 2004, p. 16.

[2] U.S. Department of the Navy, 2004, p. 9.

[3] Endurance for tactical ISR missions is projected to be less than 100 hours; endurance for persistent ISR missions is projected to exceed 300 hours (U.S. Department of the Navy, 2004, p. 22). The radius of operation for tactical ISR missions is projected to be 50–75 nm;

differing levels of UUV autonomy (loosely, the ability to accomplish mission tasks, such as vehicle movement and data collection, without human intervention). Alternatives to UUVs also differ by mission. For example, USVs might be attractive (or even preferred) for missions requiring continuous mast exposure but may be considered unsuitable for other missions. In short, an analysis of UUV need, risks, alternatives, and cost cannot be carried out at the level of the nine mission categories. Consequently, this study required examination of more than 40 distinct advocated UUV missions, each of which is tied back to one of the nine parent missions. This unwieldy mission set limited the depth to which we could evaluate UUV missions, and our efforts were further hampered by the fact that many missions are not well defined. For example, the 2004 *UUV Master Plan* does not discuss the duration or objectives of imaging intelligence missions, nor does it identify such requirements as onboard image processing and communications.

Our assessment of need was based to the extent possible on material provided by the Assessment Division, Office of the Chief of Naval Operations (OPNAV N81) on warfighter needs in the near and medium terms. We also interviewed operators to assess need. We found that the best match between warfighter needs and UUV capabilities is in MCM missions.

Risk in general could only be judged broadly. The absence in many cases of clearly defined operational objectives made it difficult to assess risk. Also, roughly half of the advocated missions are novel in the sense that no research and development efforts have been applied specifically to them. Absent preliminary research and development efforts, technical risk is unclear.

Limited availability of cost data also hindered this study. Most available UUV cost data relate to small-production vehicles or to larger prototype vehicles. Experienced RAND cost analysts could find no cost estimates for the relatively large and complex vehicles needed for many advocated missions. Extrapolation of costs from relatively small

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the radius of operation for persistent ISR missions is projected to be at least twice that distance.

and simple vehicles to relatively large and complex vehicles was deemed unwise.

In short, this roughly six-month research effort could not answer the study question with the depth and thoroughness desired. When identified, showstoppers (such as illegality, absence of need, or disqualifying technical or operational risks[4]) were flagged without further consideration in order to conserve study resources.

Recommended Missions

Based on this study, RAND recommends the following seven mission categories for UUVs.

MCM. The need for additional MCM capability within the U.S. Navy has been demonstrated by OPNAV N81 studies that show that the greatest need for such capability is in denied areas. MCM operations in denied areas can be conducted by launching autonomous undersea vehicles (AUVs)[5] from nuclear attack submarines (SSNs) operating within the denied areas or by launching longer-endurance AUVs from surface ships operating outside denied areas. Several new or emerging technologies promise to provide the endurance needed for MCM operations in denied areas using surface ships. Both the U.S. Navy and foreign navies have made significant progress in developing UUVs for MCM. Significantly, several foreign navies have fielded UUVs for MCM from surface ships. UUV capabilities and cost effectiveness have been demonstrated for this mission.

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[4] For example, the TCS mission as proposed violates the Strategic Arms Reduction Treaty. The use of AUVs as lane markers for amphibious operations under CN3 missions was strongly rejected by Marines we interviewed. Some missions required order-of-magnitude technology improvements deemed unachievable in the near to medium terms. Operational concepts for some proposed ASW missions for UUVs do not provide critical kill chains.

[5] AUVs are unoccupied submersibles (without tethers) that are powered by onboard batteries, fuel cells, or other energy sources. AUVs are intended to carry out preprogrammed missions with little or no direct human intervention (see Committee on Undersea Vehicles and National Needs National Research Council, *Undersea Vehicles and National Needs*, National Academies Press, 1996).

Missions to deploy leave-behind surveillance sensors or sensor arrays. The need for these missions is based on classified material contained in unpublished RAND Corporation research produced under the auspices of this study. The vehicle payload-capacity requirements for these missions are consistent with the payload capacities of AUVs now in development. The feasibility of deploying leave-behind acoustic arrays has been demonstrated by the Advanced Distributed System (ADS), which uses AUVs to deploy its sensor arrays. The level of autonomy required to emplace leave-behind sensors or sensor arrays has been further demonstrated by commercial systems capable of autonomously laying undersea cables or determining pipeline routes for commercial gas and oil developers. Also, autonomy requirements may be reduced when AUVs are directed to deploy packages at specified locations, such as outside ports. The alternative to an unmanned system for these missions is, by definition, a manned system, such as the Sea-Air-Land (SEAL) Delivery Vehicle (SDV) or the Advanced SEAL Delivery System (ASDS). Both the SDV and the ASDS depend on nuclear submarines for transportation into a theater, which limits mission responsiveness and the rate at which missions can be performed. Using SEALs to emplace packages in sensitive regions also entails human risk. The simplicity of the AUV used to deploy ADS arrays and the existence of commercial AUVs large enough to deploy a variety of surveillance sensors or sensor arrays suggest that AUVs for this mission would be affordable.

Near-land and harbor-monitoring missions. These missions could provide protection for special operations forces (SOF) in over-the-beach operations by (1) identifying areas with the lowest activity levels, (2) warning SOF operators of possible threats of detection, and (3) providing overwatch for caches of supplies and equipment as SOF operators conduct missions inland. Need for this mission is seen in the context of increasing dependence on SOF operations in countering militant extremists. The ability to conduct near-land and harbor monitoring for over-the-beach special operations was demonstrated in 2003 during Exercise Giant Shadow, suggesting that technical and operational risks for this mission are low. No manned- or fixed-system alternatives to AUVs are evident. The Navy has acquired several AUVs like the one used to demonstrate near-land and harbor monitoring for other missions. Although the cost of this vehicle is unknown, it is clearly affordable.

Oceanography missions. Gliders—AUVs notable for their endurance—can gather tactically useful oceanographic data under adverse weather conditions and significantly enhance the quality and quantity of oceanographic data available to warfighters. Gliders used today for oceanography cost only tens of thousands of dollars, can collect oceanographic data continuously while deployed for months at a time, and can be refueled at minimal cost. They are cheap enough to be considered expendable. Gliders being tested today are designed to last for years, during which time they could continually collect oceanographic data. The use of gliders in oceanography missions should be pursued.

Monitoring undersea infrastructure. The U.S. military depends on an extensive infrastructure of undersea communications cables, the Integrated Undersea Surveillance System, and instrumented undersea ranges. Undersea communications cables are critical because the alternative, satellite communications, provides only a fraction of the bandwidth of fiber-optic cables. However, undersea communications systems are vulnerable to the inevitable effects of aging and marine life, anchors, fishing nets, and malfeasance. (Note that the locations of undersea communications systems are public knowledge.) The risk associated with using AUVs to monitor undersea systems is considered low. To illustrate, in the summer of 1999, the Kokusai Marine Engineering Corporation used an AUV to inspect over 200 miles of undersea cable that crosses the Taiwan Strait. The survey produced a complete video recording of the cable and the surrounding seabed. A more-capable vehicle has since replaced the AUV used in this effort. Manned vehicles are the only alternative to unmanned vehicles for this type of monitoring mission. *NR-1*, the Navy's only nuclear deep-diving research submarine, is capable of this mission, but it was deactivated in November 2008. There is no plan to replace *NR-1* with another deep-diving submarine, and no other Navy vessel can conduct this mission. On the topic of cost, note that because undersea-cable inspection is a small but successful industry, this mission could be conducted via contract or the purchase or lease of an existing AUV.

ASW tracking missions. The need for ASW tracking missions, which detect the movement of potential adversary submarines out of port and possibly track their subsequent movements, has been debated as the U.S. Navy evolves its ASW concepts. If ASW tracking missions are needed, we believe that they could be conducted with AUVs. AUVs able to detect and classify threat submarines are being developed, and propulsion systems that enable tracking operations appear feasible. One such vehicle is now being tested. Technical risk is mitigated by developers' varied technological approaches, which include the use of novel sensors. SSNs, the only known alternative to AUVs for this mission, must operate undetected off enemy ports. *Los Angeles* (SSN-688)–class SSNs are the backbone of today's submarine force, and a total of 62 *Los Angeles*–class SSNs entered service between 1976 and 1996. Remaining *Los Angeles*–class SSNs will begin undergoing block obsolescence in the coming decade, however, and the procurement rate of *Virginia* (SSN-774)–class SSNs is not expected to maintain the current SSN force level. As the SSN force level declines significantly beginning in approximately 2015, using AUVs to perform relatively routine tasks (such as tracking threatening submarines) could free remaining U.S. SSNs for more-critical missions. If ASW tracking missions are indeed needed, we recommend that further development of AUVs for this mission be pursued in order to better understand their associated capabilities, costs, and risks.

Inspection/identification missions. These missions support homeland defense and antiterrorism/force protection needs through the inspection of ship hulls and piers for foreign objects (such as limpet mines and special attack charges). Inspection/identification also includes common activities such as underwater hull survey, ship husbandry, and repair. The need for identification/inspection missions will be long-standing. Terrorist threats against U.S. vessels are a real threat, as demonstrated by the attack on the USS *Cole*. Inspection/identification missions of both military and commercial vessels are increasingly being performed by UUVs instead of divers. Experience has demonstrated the cost effectiveness of using UUVs for inspection/identification missions.

UUVs and UUV Technologies

N81 also asked RAND to describe UUVs of interest and UUV technologies. We cannot summarize here all of the technical information presented later in this book, but we do wish to draw attention to the following technical findings:

- Autonomy in complex missions may include such tasks as judging the import of collected intelligence, developing hypotheses and plans to test them, and developing situational awareness for self-protection.[6] Situational awareness will be needed in order for AUVs to operate in high-threat areas or areas where there is a high risk of incidental detection (e.g., visual detection by fishermen). There is a high level of technological risk in developing AUVs to autonomously conduct complex SIGINT, ELINT, MASINT, and IMINT missions.[7] The current state of AUV autonomous capability for ISR is reflected in AUVs' imperfect ability to recognize

[6] A survey of AUV developers conducted by the Association for Unmanned Vehicle Systems International and RAND in the spring of 2008 revealed that autonomy will be the greatest long-term challenge to the development of AUVs.

[7] Office of the Secretary of Defense, Joint Publication 1-02, *Dictionary of Military and Associated Terms*, April 12, 2001, as amended through June 13, 2007a, defines *SIGINT* as a category of intelligence comprising either individually or in combination all communications intelligence, ELINT, and foreign instrumentation SIGINT, however transmitted. *ELINT* is defined as technical and geolocation intelligence derived from foreign noncommunications electromagnetic radiations emanating from sources other than nuclear detonations or radioactive matter. *MASINT* is defined as technically derived intelligence that detects, locates, tracks, identifies, and describes the unique characteristics of fixed and dynamic target sources. MASINT capabilities include radar, laser, optical, infrared, acoustic, nuclear radiation, radio frequency, spectroradiometric, and seismic sensing systems as well as gas, liquid, and solid-materials sampling and analysis. *IMINT* is defined as the technical, geographic, and intelligence information derived through the interpretation or analysis of imagery and collateral materials. We note that although the 2004 *UUV Master Plan* treats SIGINT and ELINT as separate forms of intelligence, SIGINT is in fact a form of ELINT.

sailboats and their limited ability to recognize military vessels by their profiles.[8] Giant strides would be required to autonomously detect significant ship alterations, for example. We also observe that future autonomy performance will be limited by the AUVs' onboard computational power (which may be similar to levels found in most personal computers). For the foreseeable future, the development of autonomy needed for complex ISR missions, such as tactical SIGINT, will be highly technically challenging. Moreover, the ability to deal with unforeseen conditions, especially in complex environments, demands still more autonomy from AUVs. This is especially true in covert or clandestine AUV missions during which mission failure, loss of clandestine cover, and vehicle exploitation by adversaries are issues. Whereas AUVs conducting missions such as oceanography can deballast, return to the surface, and signal for help under conditions they cannot manage, AUVs in covert or clandestine missions have no such options. This is a broad and serious issue for advocated ISR missions for AUVs.

- Autonomy and communications bandwidth form a tradespace. However, communications bandwidth is limited, and the communications options open to AUVs tend to be slow. Moreover, stealth issues are associated with operating AUVs with masts exposed and broadcasting for long periods of time. These stealth issues can spill over to host vessels, such as SSNs.
- The second-greatest long-term technical challenge to AUV development is in the area of propulsion energy. Propulsion objectives stated in the 2004 *UUV Master Plan* would require order-of-magnitude improvements in propulsion technology. Such performance improvements may not come from spiral development of existing propulsion technologies.
- There are attractive and less-risky alternatives (such as USVs and unmanned aerial vehicles) for most of the ISR missions advocated

[8] Paul R. Arrieta, F. Chandler, F. Crosby, and J. Purpura, "Above Water Obstacle Detection for the Remote Minehunting System (RMS)," Naval Surface Warfare Center, briefing presented at the ONR/AUVSI Joint Review, Orlando, Fla., February 12, 2008.

for UUVs. On the topic of ISR missions, the Navy's *USV Master Plan* notes, "While the UUV option provides stealth beyond that associated with a USV, Semi-Submersible Vehicles (SSVs) can provide a nearly identical stealth profile, given that the ISR mission by definition requires extensive mast or antenna exposure."[9] The *USV Master Plan* also notes advantages for USVs in terms of availability, retasking, and persistence.

- The development of AUVs to be launched from SSN torpedo tubes is difficult and requires design compromises. For AUVs launched from torpedo tubes, the Naval Undersea Warfare Center of the Naval Sea Systems Command has described restrictions and requirements in the areas of start-up, weight and volume, neutral buoyancy, gas evolution and noise signature, safety, fuel and oxidizer choices, refueling, logistic fuels/sulfur, temperature, and endurance.[10] Implodable volume has also been cited as a certification issue. To this we add that the torpedo rooms of *Los Angeles*– and *Virginia*-class SSNs lack electrical-power distribution systems needed to recharge large, battery-powered AUVs. These inherent problems imply design compromises and additional costs for AUVs launched from torpedo tubes.

Other Recommendations

Other recommendations from this study treat a specific AUV program and the Navy's master plans for UUVs and USVs. The Mission-Reconfigurable Unmanned Undersea Vehicle System (MRUUVS) program is currently intended to develop AUVs that use the torpedo tubes of *Los Angeles*–class SSNs for launch and recovery. MRUUVS is intended to be modular and have modules for clandestine ISR and MCM missions. Predecessor programs to MRUUVS begun in 1994

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9 U.S. Department of the Navy, *The Navy Unmanned Surface Vehicle (USV) Master Plan*, July 2007b, p. 32.

10 Maria G. Medeiros, "Weapons and Vehicles Needs," briefing presented at CEROS Industry Day, Naval Undersea Warfare Center, November 13, 2007.

did not address SUBSAFE safety issues or field usable systems.[11] The current MRUUVS program also will not address those long-standing safety issues and will not field a usable system by 2013. As noted above, the development of AUVs to be launched from SSN torpedo tubes is difficult and requires design compromises. *Los Angeles*–class SSNs will undergo block obsolescence before MRUUVS can be fielded, meaning that a reduced number of SSNs will be available to deploy MRUUVS. MRUUVS will be incompatible with *Virginia*-class SSNs due to differences in torpedo doors, and further effort will be needed to make MRUUVS usable by *Virginia*-class SSNs as *Los Angeles*–class SSNs go out of service. We recommend that the MRUUVS program be cancelled or restructured with achievable, appropriate milestones.

The Navy's 2004 *UUV Master Plan* has been described as intended for the blue-water Navy. Several changes are recommended to improve the plan's broader utility. First, the 2004 *UUV Master Plan* and the subsequent *USV Master Plan* should be consolidated into a master plan for unmanned maritime systems (UMSs).[12] The 2004 *UUV Master Plan* and the *USV Master Plan* are stovepiped and display significant overlap in the missions they advocate for UUVs and USVs. Also, as noted above, the 2004 *UUV Master Plan* advocates too many missions for UUVs. Scrutiny of previous and projected research and development budgets for UMSs reveals that funding for research and development will be inadequate to develop most advocated UUV missions. It is revealing that the Office of the Secretary of Defense's *Unmanned Systems Roadmap* sees only four mission groups for each type of unmanned vehicle (i.e., aerial, ground, surface, and undersea).[13] To paraphrase 1993 congressional language, the Office of the Secretary of Defense and the Navy should establish priorities among various

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[11] SUBSAFE is a Navy quality assurance program intended to maintain the safety of the nuclear submarine fleet. All submarine systems exposed to sea pressure as well as those critical to flooding recovery are subject to SUBSAFE requirements. The MRUUVS program and its predecessors use a vehicle-recovery arm that is not certified SUBSAFE.

[12] Office of the Secretary of Defense, *Unmanned Systems Roadmap (2007–2032)*, Washington, D.C., December 10, 2007b.

[13] Office of the Secretary of Defense, 2007b, p. 23.

proposed UMS programs and establish affordable, cost-effective programs.[14] Questions like those addressed in this book should be used to select the most-promising missions for UMSs, and those missions (and their requirements) should be defined in more detail. We add that the *Unmanned Systems Roadmap* explicitly considers legal and treaty issues in down-selecting missions for unmanned vehicles. We recommend that the Navy adopt this practice.

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14 Federation of American Scientists, "UUV Program Plan," Web page, undated.