



DSB Task Force Report on Next-Generation Unmanned Undersea Systems

October 2016



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REPORT OF THE DEFENSE SCIENCE BOARD

STUDY ON
Next-Generation Unmanned Undersea
Systems

October 2016



Office of the Under Secretary of Defense
for Acquisition, Technology, and Logistics
Washington, D.C. 20301-3140

This report is a product of the Defense Science Board (DSB).

The DSB is a Federal Advisory Committee established to provide independent advice to the Secretary of Defense. Statements, opinions, conclusions, and recommendations in this report do not necessarily represent the official position of the Department of Defense (DoD). The Defense Science Board Study on Next-Generation Unmanned Undersea Systems completed its information-gathering in January 2016. The report was cleared for open publication by the DoD Office of Security Review on December 7, 2016.

This report is unclassified and cleared for public release.



**DEFENSE SCIENCE
BOARD**

**OFFICE OF THE SECRETARY OF DEFENSE
3140 DEFENSE PENTAGON
WASHINGTON, DC 20301-3140**

October 19, 2016

**MEMORANDUM FOR THE UNDER SECRETARY OF DEFENSE FOR
ACQUISITION, TECHNOLOGY & LOGISTICS**

**SUBJECT: Final Report of the Defense Science Board (DSB) Task Force on Next-
Generation Unmanned Undersea Systems**

I am pleased to forward the final report of the DSB Task Force on Next-Generation Unmanned Undersea Systems. This report offers important recommendations on how the Department can maintain and exploit its undersea advantage beyond the next decade and into the future.

This study proposes near- and mid-term unmanned undersea system concepts that have the potential to create important new capabilities to extend the U.S. undersea advantage by confronting potential adversaries with significant challenges. New areas of investment that are recommended include the adoption of commercial technologies, the development of new concepts of operations (CONOPS), and the acceptance of greater risk with larger numbers of low-cost assets. As the report explains, in the undersea domain, quantity has a quality all its own. Furthermore, this report recommends approaches that could facilitate rapid experimentation, operational demonstration of capabilities, and deployment of initial capabilities that show promise.

I fully endorse all of the recommendations contained in this report and urge their careful consideration and soonest adoption.

A handwritten signature in blue ink, appearing to read "Craig Fields", is positioned above the printed name.

**Dr. Craig Fields
Chairman**



**DEFENSE SCIENCE
BOARD**

**OFFICE OF THE SECRETARY OF DEFENSE
3140 DEFENSE PENTAGON
WASHINGTON, DC 20301-3140**

October 19, 2016

MEMORANDUM FOR CHAIRMAN, DEFENSE SCIENCE BOARD

SUBJECT: Final Report of the Defense Science Board Task Force on Next-Generation Unmanned Undersea Systems

The final report of the Defense Science Board Task Force on Next-Generation Unmanned Undersea Systems is attached. In accordance with its charter, the study focused on a select set of the nation's undersea warfare capabilities. The task force analyzed the capabilities with respect to their ability to maintain and potentially enhance the undersea advantage that the U.S. currently enjoys as well as the relevant roles and missions the capabilities could support to disrupt adversary strategies in the undersea domain. The study also reviewed technologies, capabilities, operating concepts, and processes that could facilitate the development of low-cost, rapidly deployed systems that would enable cost-imposing strategies on our adversaries.

The study highlights four findings associated with maintaining the undersea advantage currently held by the U.S.:

1. Creative use of unmanned undersea systems can enhance and provide new capabilities;
2. Acquisition of unmanned undersea systems requires new approaches;
3. Long-standing technological challenges are often a result of approaching unmanned undersea systems like submarines
4. Protection of critical undersea infrastructure remains a challenge

The findings, along with the accompanying recommendations, support the study's charter to suggest approaches for rapid experimentation and operational demonstration. The task force also considered how to deploy modest initial capabilities that are developed along with a path for capability evolution over time. This would allow capabilities to be fielded on a faster timeline and also allow new technologies to be integrated with existing systems more quickly.

The task force found that there are multiple missions in which unmanned undersea systems could complement and extend the capabilities of manned systems. In particular, many operationally important missions that are not currently conducted due to lack of assets could be taken on by unmanned systems. Moreover, in the undersea domain, quantity truly does have a quality all its own, and having large numbers of low-cost systems could provide significant operational capability.

During the past 20 years, undersea activity has increased, driven in part by the oil, gas, and oceanographic research communities, and has resulted in technological advances and the emergence of relatively inexpensive commercial undersea vehicles. The report discusses options for leveraging these commercial developments to create low-cost unmanned systems that would offer significant new capabilities.

The study established four potential reference missions and corresponding system concepts. Each of the concepts is amenable to a tiered system architecture, cascaded delivery, and novel concepts of operations that exploit commercial and other readily available unmanned undersea systems. The reference missions are intended to stimulate experimentation and the development of additional creative concepts that exploit low-cost commercial platforms. The four reference missions are as follows:

- Choke point control
- Surface action group interdiction
- Operational deception
- Anti-submarine warfare

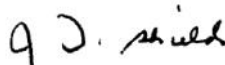
The report also suggests using the reference missions and a recommended experimentation framework to develop programs for meeting long-standing technological challenges for unmanned systems. The report provides options for addressing limitations that stem from approaching unmanned undersea systems from a submarine design perspective, particularly with the view that stealth is critical and must always be maintained by fielded systems.

The task force believes that many additional missions could be conducted through the use of low-cost unmanned undersea systems that could be fielded rapidly. These missions would not put human life at risk and, given the ability to provide redundancy and resilience through numbers, losing an individual platform would not be catastrophic. Such low-cost systems are well suited to being acquired in large numbers and, as a result, the development of these systems is not well aligned with large-scale acquisition processes used by DoD for platforms such as submarines, surface ships, and aircraft.

The task force believes that all of the recommendations contained in this report are important for ensuring the Department maintains its advantages in the undersea domain well into the future.



Dr. Ralph Semmel
Study Co-Chair



Mr. James Shields
Study Co-Chair

EXECUTIVE SUMMARY

Executive Summary

Rapidly advancing adversary capabilities, particularly those that employ anti-access and area-denial (A2/AD) strategies, pose a significant and increasing threat to U.S. operational and warfighting effectiveness in the air, in space, on land, and on the ocean's surface. The threat in the undersea domain is also increasing, but here the U.S. has a greater opportunity to retain an advantageous position to offset the burgeoning warfighting challenges it faces in other domains. This will require investment in new areas, adoption of commercial technologies to be used within a system of systems to support today's mission requirements, development of new concepts of operations (CONOPS), and acceptance of greater detection and loss risk to individual units mitigated by larger numbers of lower cost assets.

In October 2014, the Under Secretary for Acquisition, Technology, and Logistics (USD(AT&L)) requested that the Defense Science Board (DSB) review existing military and civil undersea systems and technologies and propose near- and mid-term unmanned undersea systems concepts that provide significant capability gains. Furthermore, the DSB was asked to consider methods for deploying initial capabilities with plans for capability evolution and to recommend approaches that facilitate rapid experimentation and operational demonstration. The DSB assembled a task force composed of national leaders in science and technology with expertise in undersea systems technology.

This report presents the key findings and recommendations of the task force deliberations. Four specific unmanned undersea system concepts that have the potential to create important new undersea capabilities and present potential adversaries with significant challenges are recommended along with the associated development and experimental programs for their validation. In addition to creating new capabilities, these system concepts illustrate important design principles that work around many of the long-standing technological issues that have limited unmanned undersea systems performance.

Creative Use of Unmanned Undersea Systems Can Enhance and Provide New Capabilities

A primary source of U.S. undersea advantage is the capability of our nuclear submarines and the skills of the sailors who operate them. However, the costs of these platforms limit the number of systems in the inventory, and there are many more missions than our assets can accommodate. In addition, the expansion of navies worldwide, particularly those with increased shipbuilding programs, along with the growing number of geographic regions of interest are increasing the stress on a limited fleet size and, over time, will put the U.S. advantage at risk.

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The task force found that there are numerous missions where unmanned undersea systems can complement and extend the capabilities of manned systems. In particular, many operationally important missions that are not currently addressed due to lack of assets could be assigned to unmanned systems. A key to the success of this approach is the design and development of unmanned systems that are inexpensive enough to be acquired in large quantities. In fact, undersea is a domain in which the notion of quantity having a quality all its own resonates deeply. Large numbers of inexpensive systems can create challenges that cost adversaries more to counter than they cost the U.S. to produce, resulting in cost-imposing impacts in addition to expanded U.S. capabilities.

Historically, the U.S. Navy has had a tendency, in its requirements process in particular, to treat unmanned undersea systems like submarines. The systems are expected to have the ability to perform multiple complex missions and to have a high degree of stealth, endurance, and autonomy, all of which tend to drive up costs significantly. This may be due to the “innovator’s dilemma” that results from the Navy’s exquisite capabilities in submarine technology and operations, which drives a continual pursuit of more capable systems accompanied by a difficulty in recognizing the disruptive potential of less capable systems in limited mission environments.¹ As a result, while many unmanned undersea vehicle (UUV) programs have been started, a significant number of them have been terminated due to cost growth, technological limitations, and schedule delays stemming from requirements creep (e.g., the Mission reconfigurable UUV and the Long-Term Mine Reconnaissance programs).

During the past 20 years, there has been an increase in undersea activity, driven, in part by the oil, gas, and oceanographic communities, that has resulted in technological advances and the emergence of relatively inexpensive commercial undersea vehicles. The task force believes that there is an opportunity to leverage these commercial developments to create low-cost unmanned systems that offer significant new capabilities in combination with more focused and limited mission requirements. A promising approach for exploiting commercial systems, especially those with limited endurance, is to use new delivery concepts, such as prepositioning on the seabed or cascaded delivery. Cascaded delivery entails carrying smaller UUVs and unmanned undersea systems (UUSs) into an operational area by another larger system, such as a submarine, a surface ship (manned or unmanned), an airplane, or a larger UUV. In many cases, the carried systems can be readily available commercial technologies adapted to the mission requirements.

These new unmanned undersea systems will complement submarines by operating in collaboration with them and, in selected missions, performing more tasks than submarines. In those missions where the unmanned undersea system must be more autonomous, manned supervision through undersea communication or by surfacing periodically to close an airborne communication link (radio frequency (RF) or optical) with a remote human supervisor will still be possible. The ability

1 C.S. Christensen, “The Innovator’s Dilemma: When New Technologies Cause Great Companies to Fail,” Harvard Business School Press, 1997.

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to communicate periodically can reduce some of the technological requirements and risks associated with the autonomous subsystem that often slows the development and subsequent fielding of systems.

The task force established four potential reference missions (discussed in Chapter 3) as a starting point for developing a framework and infrastructure to promote innovation and experimentation:

- ℵ Choke point control
- ℵ Surface action group interdiction
- ℵ Operational deception
- ℵ Anti-submarine warfare

For each reference mission, the task force developed a candidate system concept emphasizing relatively large numbers, low-cost, cascaded delivery, and distributed payloads that deliver effects above and below the water line that have the potential to provide meaningful capability. Each of the system concepts is amenable to tiered system architectures and CONOPS that exploit commercial UUVs. A resulting framework for unmanned undersea innovation will institutionalize the use of reference missions (those presented here and others) as a way to stimulate the development of creative system concepts that emphasize low-cost exploitation of commercial platforms. The concepts will be validated through modeling and simulation (M&S) and operational experimentation to facilitate rapid deployment.

The task force recognizes the military value of these candidate system concepts will need to be validated through operational experimentation that will likely result in refinements to both system design and operational concepts. As a result, the task force makes the following five recommendations.

Recommendation 1

The Secretary of the Navy (SECNAV) and the Chief of Naval Operations (CNO) should task the Undersea Domain Lead, in collaboration with the Navy's Directorate for Unmanned Warfare Systems (OPNAV 99) and the Deputy Assistant Secretary of the Navy for Unmanned Systems (DASN(UxS)), to create a framework and infrastructure for mission innovation and experimentation.

To support this effort, the Undersea Domain Lead should develop a set of reference missions, such as the ones suggested in this report, to shape an experimental program and drive innovation.

The task force believes that setting a firm, non-tradable cost target for each concept at the definition stage is important for ensuring low-cost systems that can be acquired in large numbers. Incremental requirements creep, which too often drive up costs to the point where resulting

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systems are unaffordable, must be avoided and accepted only when a strong value proposition can be supported.

The task force also believes that undersea test ranges will need to be expanded with increased use of M&S to support cost-effective, multi-day, multi-vehicle experimentation. The framework should support an active culture of operational experimentation where exploration and risk are encouraged, failure is accepted, and active learning occurs in an environment that extends beyond choreographed demonstrations designed to validate pre-determined hypotheses. Finally, when new concepts are proven to have operational benefits, there should be a path to rapid deployment of the capability.

The task force recommends that the different projects within the experimental program be linked to reduce duplication. For example, if several concepts have similar deployment strategies, deployment may only need to be demonstrated once, and simpler deployment may be used in other experiments to save cost and build momentum. Furthermore, if there is an advantage to making a modification, such as the use of diesel-electric propulsion for enhanced endurance, to a commercial platform used by more than one concept, this modification need only be executed in one project. As a result, it should be possible to accelerate the development of low-cost unmanned undersea systems by sharing learning and operational lessons across all experiments.

Recommendation 2

The Under Secretary of Defense for Acquisition, Technology and Logistics (USD(AT&L)) and the Assistant Secretary of the Navy for Research, Development, and Acquisition (ASN(RDA)) should fund an experimental program led by OPNAV N99 to develop and validate operational unmanned undersea systems concepts.

The task force developed a candidate design for a concept in each of the four reference missions described in Chapter 3, along with the specific questions to be explored in an operational experimental program. The task force recommends that these designs be used as a starting point by OPNAV N99 to develop and recommend specific experiments to USD(AT&L) and ASN(RDA).

To ensure the success of the experimental program and ensure that the program results in rapid deployment of operational capability, each experiment should:

- ℵ Clearly articulate the questions to be explored, including what constitutes military value
- ℵ Leverage commercial platforms and proven payloads to get into the water rapidly
- ℵ Set a non-tradable, firm target cost per deployed system
- ℵ Limit each experiment to, at most, a two-year duration
- ℵ Establish a plan for seamless deployment, initially with residual assets, if results demonstrate military utility

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Acquisition of Unmanned Undersea Systems Requires New Approaches

The task force noted significant unmanned undersea systems activities across a large number of projects. Most of these projects are technology development and demonstration efforts with little coordination among them. Moreover, only a very small number of these systems have resulted in deployed assets that have an impact on the fleet.

Unmanned undersea systems development is not well-suited to the structured platform-centric acquisition processes used by DoD for large-dollar platforms such as submarines, surface ships, and aircraft. These processes are too slow and cumbersome to effectively acquire cost-constrained systems with limited operational lifetimes in large numbers. The history of cancelled programs, such as the Near-term Mine Reconnaissance System (NMRS), Long-term Mine Reconnaissance System (LMRS) and the 21-inch Mission Reconfigurable UUV (MRUUV) programs, indicate that when there is only a single unmanned system program being pursued at a time, the requirements grow and the system is ultimately expected to perform too many complex tasks. As a result, development and unit acquisition costs grow, the schedule is delayed, and the program is ultimately cancelled.

As previously discussed, the task force identified many missions that could be addressed through rapid fielding of lower cost systems. These systems can be either small UUVs based on commercial platforms acquired in large numbers or larger UUVs that are not carried by submarines. They can be used for cost-effective delivery in a cascaded architecture. A single major system, such as the LDUUV, is not likely to provide the robust capability or large numbers required. Instead, a portfolio of programs is more adaptable to meeting changing mission requirements.

As discussed in Chapter 2, the task force found several examples of successful rapid development and deployment including the Undersea Rapid Capability Initiative (URCI), the Mk 18 Mod 1 Swordfish and the Mod 2 Kingfish mine detection systems, and the Advanced Processor Build/Acoustic Rapid Commercial-off-the-Shelf (COTS) Insertion (APB/ARCI) programs for sonar signal processing. Each of these programs leverages commercial systems, encourages extensive interaction with fleet operators, and includes preplanning of block upgrades to enhance capabilities after rapid deployment of the initial system.

The task force is concerned that the Large Diameter UUV (LDUUV) Program may be headed down the same path of prior UUV programs that encountered acquisition problems and cancellation. While the task force recognizes that the requirements for LDUUV are important, the anticipated cost of a delivered system is high and will likely result in only a small number being produced, which will limit both experimentation and the number of simultaneous missions that can be supported during the next several years. An alternative evolutionary approach based on URCI and APB/ARCI principles and using low-cost COTS platforms with commercial and Government

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payloads will enable increased experimentation, support a large number of missions, and provide the Navy with a deeper understanding of and appreciation for the utility of unmanned undersea systems and related technology. The task force also believes that the LDUUV program is not adequately leveraging prior Navy research in autonomy that has created a government-owned architecture, such as the Maritime Open Architecture Autonomy (MOAA). Prior DoD studies on autonomy have stressed the importance of avoiding locking the government into acquiring autonomy software only from specific vendors by exploiting the advantages of open architectures and government ownership.²

The experimental program in Recommendation 2 should be structured to facilitate rapid transition by investigating the manufacturing, supportability, and transition issues in parallel with operational experimentation. The experiments should leverage the Joint Urgent Operational Needs (JUON) and Urgent Operational Needs (UON) processes to motivate concepts, and leverage assets from successful operational experiments in the fleet to provide initial capabilities. Furthermore, successful concepts should have a path to acquisition programs of record (POR) without the need for a complete restart. This can be facilitated by using experimental results for the analysis of alternatives (AoA) and requirements development, and by structuring the acquisition program to use existing commercial platforms rather than requiring new, unique platform designs.

The task force believes that the recent establishment of the DASN(UxS) and OPNAV N99 are positive steps to address the historical acquisition challenges associated with unmanned undersea systems. However, more resources and latitude in contracting are required. Consequently, the task force makes the following recommendation.

Recommendation 3

USD(AT&L) and ASN(RDA) should create an expanded undersea systems program portfolio that enhances mission agility and outpaces the threat.

The portfolio should include at least one program that is structured to accommodate rapid deployment, insertion of innovative concepts, and continual capability improvements with planned upgrades. It should leverage commercial unmanned undersea vehicles and exploit proven best-of-breed sensors, payloads, and relevant subsystem technology. The senior DoD acquisition leadership should support streamlining testing and evaluation (T&E) and logistics requirements in these programs to accommodate short system lifetimes and large numbers of potentially expendable systems.

The task force also suggests that ASN(RDA) reassess the scope of the LDUUV program in light of the recommended portfolio strategy for undersea systems and the lessons learned from previous UUV program that encountered difficulties.

² Defense Science Board, "Task Force Report on The Role of Autonomy in DoD Systems," July 2012; and Defense Science Board, "Summer Study Report on Autonomy," June 2016.

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Long-Standing Technological Challenges are Often a Result of Approaching Unmanned Undersea Systems Like Submarines

There are a number of broad concerns about technology limitations restricting the effectiveness of unmanned undersea systems:

- ⌘ *Communications* – The limited range and bandwidth of undersea acoustic links restrict the command and control, and manned and unmanned teaming options for undersea systems.
- ⌘ *Autonomy* – Long periods of isolation and limited communications pose significant challenges for the designers of unmanned undersea vehicle autonomy subsystems.
- ⌘ *Energy storage* – Despite significant investments that have been made in advanced storage and energy generation techniques, battery technology is a key constraint on mission duration.
- ⌘ *Deployment and situational recovery* – Deployment from submarine tubes or dry dock shelters constrains the diameter of unmanned undersea systems. Moreover, recovery either back into submarines or by surface ships is difficult and costly.

Table 1: Recommended Design Principles for Next-Generation Unmanned Undersea Systems

Design Principle	Current Approach and Limitations	New Strategies
Relieve burden of stealth	Mission duration limited by battery life Submerged communications yield limited bandwidth stressing C2 and autonomy	Mature diesel-electric propulsion provides extensive duration RF communication while snorkeling enhances human-system collaboration for C2 and autonomy oversight
Focus on system capabilities by exploiting commercial platforms	Custom-built UUVs responding to detailed requirements	Commercial UUVs provide lower cost, faster development, and focus on payloads and capability
Use cascaded deliver to reduce submarine burden	Submarines launch and recover UUVs	Cascaded operations to carry, tow, and deploy commercially derived systems
Consider expendable systems and self-recovery	Submarines launch and recover UUVs	Enable launch and recover from different platforms; allow for non-recovery

The task force reviewed the technology investments to address these limitations and found them to be worth continuing. It also developed a set of design principles (presented in Table 1) that work around the limitations to provide expanded near-term mission capability. These principles were developed by considering several of the longstanding requirements and focusing on narrow missions that could exploit existing commercial platforms. The design principles are described in the following paragraphs and are illustrated in application through the reference mission system concepts described in Chapter 3.

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The task force found that options for addressing these technology limitations have been restricted by predominately approaching unmanned undersea systems with a submarine design perspective, particularly with the view that stealth is critical and must always be maintained by fielded systems. Furthermore, submarines are fundamentally designed to be multi-mission and operate independently, whereas the optimal use of a UUS is in collaborative operations within limited mission sets that are bounded by the limited cognitive and energy sources for the UUS. Unmanned systems are generally most useful when they are used in large numbers; however, many current design concepts are too costly to acquire more than a small number of systems. This conundrum has occurred with the development of requirements for UUVs to have multi-mission complexity, “subsafe” requirements, and technological requirements such as stealth. These requirements require challenging technology solutions, inflate cost, and limit numbers.

The key to addressing affordable scalability is to create and use low-cost systems that can be acquired in large numbers. Low-cost can best be achieved by rethinking some of the constraints especially stealth and deployment timeframes that have made solutions to the long-standing technological issues complex and expensive. Stealth is less critical for low-cost unmanned systems as compared to exquisitely capable and expensive manned platforms. With no human life at stake and the ability to provide redundancy through numbers, losing an individual platform is not catastrophic. The efforts to bypass these technological issues should include the following:

- ⌘ *Communications/autonomy* – Relaxing the stealth constraint allows the system to surface periodically, which expands options for communications beyond acoustic channels to include broadband RF and optical channels. Intermittent broadband communications with the system will enable more robust human-to-system collaboration, and teaming with manned systems that will lower autonomy requirements, improve trust and confidence in the progress of the unmanned systems, and reduce costs.
- ⌘ *Energy storage* – Reducing the stealth burden introduces an option to exploit mature diesel-electric propulsion to significantly expand the endurance of unmanned undersea systems. The added risk of discovery associated with periodic surfacing for snorkeling is acceptable when the system is unmanned because it will dramatically lower costs and make system loss more tolerable. The study also identified concepts (see Chapter 3) that use at-sea replenishment to recharge batteries of low-cost commercial vehicles.
- ⌘ *Deployment and recovery* – One of the major costs of an unmanned undersea system is the design and certification for carriage on manned platforms, particularly submarines. At-sea recovery of unmanned undersea systems by submarines is also a difficult technological challenge. Consequently, the task force recommends exploring concepts that use unmanned systems to deploy, tow, and carry systems to theater; that launch and recover the unmanned systems from different platforms; and that make the unmanned undersea systems expendable to eliminate the recovery problem altogether.
- ⌘ *Collaborative systems design approach* – Designing unmanned undersea systems from the beginning to be part of a collaborative system that provides a capability can reduce costs

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by allowing specialization and eliminating redundancy. For example, a limited subset of vehicles in a large group can provide external navigation aids to the rest of the vehicles, eliminating the need for every vehicle to have a high-end navigation suite. Similarly, energy, data processing, and communications services can be concentrated in a few nodes that share the information with the rest of the group in order to greatly reduce the cost of the overall capability.

To foster a new perspective for overcoming these technological challenges, the task force makes the following recommendation.

Recommendation 4

OPNAV N99 should coordinate a broad-based design, development, and experimental effort to bypass traditional limitations for unmanned undersea systems.

While the task force recommends technological alternatives to enable near-term deployment of impactful capabilities, we also believe that the Department should continue robust development of undersea communications, trusted autonomy, and high-energy density sources. There are some promising emerging capabilities that, if successful, will expand the options for future undersea systems and can be deployed to upgrade systems developed in the near-term or enable new system concepts. There is significant value in separating technology development from rapid prototyping efforts, since putting the need to invent the future on the same acquisition path as large platforms has repeatedly resulted in schedule delays and cost growth.

Protection of Critical Undersea Infrastructure Remains a Challenge

The expansion of undersea activities during the past 20 years by the oil, gas, and oceanographic research communities has created challenges for the Department of Defense. These challenges stem from the global availability of low-cost undersea platforms, the availability of data from undersea research networks that can potentially compromise the Navy's undersea operations, and the need to protect commercial undersea infrastructure from attack.

Critical commercial undersea infrastructure, in particular, is difficult to protect because much of it, such as undersea cables and distributed sensor networks, are vulnerable and cover vast geographic areas. Many important military undersea assets have the same characteristics. The task force did not have the time or access to required information to address the protection of critical undersea infrastructure adequately in this study. Such a study will need to wrestle not only with technological challenges, but also with policy issues, as many of the relevant assets are privately owned and some, including cable-landing sites, are on U.S. soil. As a result, the Department of Defense will need to coordinate its actions with the Department of Homeland Security (including the Coast Guard) and private industry. It might also address the broader topic of how the U.S., both military and commercial, can address the potential challenges imposed by adversary use of UUS

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technologies. While a difficult topic, this is nonetheless a critically important issue that warrants thorough investigation. Consequently, the task force makes the following recommendation.

Recommendation 5

USD(AT&L) should commission a follow-on study to assess and make recommendations relative to the protection of U.S. critical undersea infrastructure.

It is important that the members of this task force have the appropriate clearances and board access to existing capabilities and plans for undersea infrastructure protection.

TERMS OF REFERENCE

Terms of Reference

ACQUISITION,
TECHNOLOGY
AND LOGISTICSTHE UNDER SECRETARY OF DEFENSE
3010 DEFENSE PENTAGON
WASHINGTON, DC 20301-3010

OCT 09 2014

MEMORANDUM FOR CHAIRMAN, DEFENSE SCIENCE BOARD

SUBJECT: Terms of Reference – Defense Science Board Task Force on Next-Generation
Unmanned Undersea Systems

Our military forces are facing serious challenges from rapidly advancing threat capabilities and employment of anti-access/area-denial (A2AD) strategies. In heavily denied A2AD environments, where our traditional operational and warfighting effectiveness is challenged in the air, on land and on the ocean's surface, the United States currently retains an advantage undersea. This undersea advantage should be exploited as a means of potentially offsetting the severe warfighting challenges in other domains.

The Defense Science Board Task Force on Next-Generation Unmanned Undersea Systems should review the nation's undersea warfare (USW) capabilities. The task force should explore roles and missions for candidate unmanned undersea systems with emphasis on leveraging the advantages in the undersea domain to disrupt adversary strategies both undersea and in other domains, focusing on technical capabilities and operational concepts that could result in low-cost, rapidly developed systems that enable cost-imposing strategies. The task force should review existing civil and military undersea systems and technology, and recommend approaches that could facilitate rapid experimentation and operational demonstration. In particular, the task force should consider how to deploy modest initial capabilities that are developed with a path for capability evolution over time as individual subsystem technologies mature.

I will sponsor the study. Dr. Ralph D. Semmel, Ph.D. and Mr. James D. Shields will serve as Co-chairmen of the study. CAPT J. Carl Hartsfield, USN will serve as Executive Secretary. CAPT James CoBell, USN will serve as the DSB Secretariat Representative.

The study will operate in accordance with the provisions of P.L. 92-463, the "Federal Advisory Committee Act" and DoD Directive 5105.04, the DoD Federal Advisory Committee Management Program." It is not anticipated that this study will need to go into any "particular matters" within the meaning of title 18, United States Code, section 208, nor will it cause any member to be placed in the position of action as a procurement official.

A handwritten signature in black ink, appearing to read "Frank Kendall".

Frank Kendall

STUDY MEMBERSHIP

Study Membership

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Mr. James Shields

Johns Hopkins University Applied Physics Laboratory
Private Consultant

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STUDY MEMBERSHIP

Ms. Stephanie Simonich

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LIST OF MEETINGS AND BRIEFERS

List of Meetings and Briefers

February 19-20, 2015

Undersea Systems Scene Setter

Jaymie Durnan, Senior Advisor, Principal Deputy ASD(R&E)

Navy UUV Analysis

Mr. Chuck Werchado & CAPT Peter Garvin, OPNAV N81

Undersea Dominance Strategy

VADM Mike Connor, Commander, Submarine Forces

Remarks on Study Purpose

Dr. Craig Fields – DSB Chairman

Maritime Surveillance Systems: Next Generation Investment Needs

CAPT Andrew Wilde, Program Manager, Maritime Surveillance Systems (PMS 485)

Undersea Platforms and Payloads

RADM Joe Tofalo, Director, Undersea Warfare Division (N97)

Unmanned Undersea Systems

Mr. Paul Siegrist, Deputy Director, Battlespace Awareness, OPNAV Information

Dominance Battlespace Awareness Division (OPNAV N2N6F2)

Funding Next Generation Unmanned Systems (NGUS) within the Trade Space

RADM Rick Breckenridge, Director, Warfare Integration Division (N9I)

Future Research in NGUS

Dr. Larry Schuette, Acting Director of Research, Office of Naval Research

March 25-26, 2015

PACFLT NGUS Perspective

ADM Scott Swift, Director, Navy Staff

ONI Threat Briefing

Paul Deal, Senior Analyst, Office of Naval Intelligence (ONI)

Dan Breedlove, Senior Analyst, Office of Naval Intelligence (ONI)

Joe Wilkerson, Senior Analyst, Office of Naval Intelligence (ONI)

Emerging Unmanned Undersea Systems and Capabilities

Mr. Ben Riley, Principal Deputy, Deputy Assistant Secretary of Defense for Emerging Capability & Prototyping

Disruptive Technology

William B. Roper, Jr PhD, Director, Strategic Capabilities Office

Relevant ONR Programs (PLUS, FMAUV Battery, FEDECO, FNC Overview)

Dr. Terri Paluszkiwicz, Program Manager, Office of Naval Research and

Dr. Mike Wardlaw, Head, Maritime Sensing Group, Office of Naval Research

Mine Threat and Unmanned Systems for Mine Warfare / ASW

Mr. Jerry Ferguson, Deputy, Naval Mine and Anti-Submarine Warfare Command

TUNA Program

LIST OF MEETINGS AND BRIEFERS

Mr. John Kamp, Program Manager, Strategic Technology Office, DARPA
UFP Program
Dr. Jeffrey Krolík, Program Manager, Strategic Technology Office, DARPA
ACTUV and Hydra programs
Mr. Scott Littlefield, Program Manager, Tactical Technology Office, DARPA
Naval Meteorology and Oceanography Command's Unmanned Maritime Systems:
Strategy & Capabilities
Dr. William Burnett, Deputy Commander/Technical Director, Naval Meteorology and Oceanography Command
Unmanned Systems for Non Traditional Theater ASW
Mr. Don Hoffer, Executive Director, Submarine Forces

May 6-7, 2015

NUWC Welcome and Opening Remarks
RDML Michael Jabaley, Commander, Naval Undersea Warfare Center
L-3 Advanced Programs
Mr. Steven M. Oxholm, Director, Strategic Operations, L-3 Advanced Programs
Liquid Robotics – Current and Future Unmanned Efforts
CAPT (Ret) Don Jagoe, Liquid Robotics
NUWC Technical Discussion
Autonomy – Mr. Phil Bernstein
Command and Control – Mr. Doug Ray
Power and Energy – Dr. Joe Fontaine & Mr. Clint Winchester
Undersea Constellation – Mr. Chris Egan
Hydroid Brief – Current and Future Unmanned Efforts
Mr. Duane Fotheringham, President, Hydroid, Inc
C&C Technologies Brief – Integrating with the Oil and Gas Industry
Mr. Peter Alleman, Vice President, Chief Scientist, C&C Technologies
Bluefin Robotics – Current and Future Unmanned Efforts
Dr. Richard Wilson
Applied Physical Sciences – Current and Future Unmanned Efforts
Dr. Scott Stickels, Chief Technology Officer, Applied Physical Sciences
NAVSEA Warfare Center Perspectives
Mr. Donald McCormack, SES, WFC ED on Future Unmanned Undersea Systems (UUS)
Mission Focus on Unmanned Undersea Systems
Mr. Seth Moyer
Review and Recommendations
Mr. Donald McCormack, SES, WFC ED
NUWC Tour

LIST OF MEETINGS AND BRIEFERS

June 11-12, 2015

APL Contributions In Unmanned Undersea Systems

*Mr. Christopher R. Watkins, Deputy Mission Area Executive, Johns Hopkins University
Applied Physics Laboratory*

Disruptive Innovation in Marine Robotics

*Mr. Andy Bowen, Principal Engineer, Director, National Deep Submergence Facility,
Woods Hole Oceanographic Institution*

*Dr. James Bellingham, Director, Center for Marine Robotics, Woods Hole
Oceanographic Institution*

Emerging UUV Capabilities and Challenges

*Dr. Jeffrey Weinschenk, Division Head of Special Projects & Underwater Robotics, The
Applied Research Laboratory-Penn State*

*Other attendees: VADM Paul Sullivan (USN retired), Director ARL and Dr. Russell
Burkhardt, Associate Director Undersea Weapons Office, ARL*

UUV Autonomy, Transparent Oceans

Mr. Joel Parry, Business Area Lead Maritime Warfare and ISR, Draper Laboratory

Design of Highly Reliable Undersea Vehicles

Mr. Rob Hammett, Principal member of the Technical Staff, Draper Laboratory

Enabling AUV Technologies

*Dr. Jordan Rosenthal, Assistant Group Leader, MIT Lincoln Laboratory, Advanced
Undersea Systems & Technology*

Cabled and Unmanned Systems Research at APL-UW

*Dr. Robert Miyamoto, Director for Defense and Industry Programs, Applied Physics
Laboratory/University of Washington*

Cooperative Vehicle Operations and Other Topics

*Dr. John Huckabay, Director, Advanced Technology Laboratory, Applied Research
Laboratories, The University of Texas at Austin*

June 22-23, 2015

Next Generation Unmanned Undersea Systems

Mr. Mark Munkacsy

Stakeholder Perspective on Next-Generation Unmanned Undersea Systems Briefing

*Frank Drennan, Director, Advance Programs and Undersea Warfare, Lockheed Martin
– Undersea Systems*

Next-Generation Unmanned Undersea Systems

*Dr. Alan Lytle, Vice President, Northrop Grumman Undersea Programs, NG Electronic
Systems (NGES) Sector*

Accelerating Performance Gains: Ideas for UUV Advanced Development

Mr. John Stapleton & Mr. David Kubik, Principal Professional Staff, JHU/APL

URCI Update / Future Areas

CAPT Carl Hartsfield, Executive Secretary

LIST OF MEETINGS AND BRIEFERS

Development and Applications for Dual-Mode Undersea Vehicle Proteus

Mr. Ross Lindman, Senior Vice President for Operations, Undersea Solutions Group

Very Large UUV Concept

CAPT David Knapp, USN (Ret.), Manager, Integrated Concepts

General Dynamics Electric Boat Brief

Mr. Karl M. Hasslinger

Unmanned Undersea Systems Discussion

Mr. Dan Tubbs, Deputy Director, Advanced Technology Programs, The Boeing Company

September 2-3, 2015

Unmanned Warfare Resource Sponsor Stand Up

CAPT Pete Garvin, Action Deputy, Unmanned Warfare Systems (N99B), OPNAV N99

October 28-29, 2015

Unmanned Warfare Systems

RADM Bob Girrier, OPNAV/N99