NOT FOR PUBLICATION UNTIL RELEASED BY THE
HOUSE ARMED SERVICES COMMITTEE
EMERGING THREATS AND CAPABILITIES SUBCOMMITTEE

STATEMENT OF

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BEFORE THE

EMERGING THREATS AND CAPABILITIES SUBCOMMITTEE

OF THE

HOUSE ARMED SERVICES COMMITTEE

ON

ADVANCING THE SCIENCE AND ACCEPTANCE OF AUTONOMY FOR FUTURE DEFENSE SYSTEMS

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Introduction

Chairman Wilson, Ranking Member Langevin, and distinguished members of the subcommittee, thank you for the opportunity to speak with you today. It is my pleasure to testify this morning beside Dr. Bornstein representing the Army, and Dr. Zacharias from the Air Force, as the Navy's first Deputy Assistant Secretary of the Navy for Unmanned Systems.

Chairman, I'm confident you will agree with me, by the conclusion of this hearing, that the research and development work the Navy and Marine Corps is conducting to improve autonomous capabilities in our future military systems is impressive, from the early research in cooperative behavior to autonomous takeoffs and landings of our unmanned aircraft. These innovations in autonomy, however, need to be nurtured and introduced in a manner which will gain the trust of our Sailors and Marines, and the public we are here to protect. In its significance, this is perhaps as much a military cultural evolution as it is a disruptive innovation. I hope the committee will come to appreciate the deliberate and disciplined nature in which the Navy and Marine Corps is investing time and resources in development and experimentation with this technology.

We are in the initial stages of creating a fully integrated manned and unmanned fleet. Unmanned technology will not replace our Sailors and Marines; instead it will unlock their full potential as we integrate unmanned technology with our total forces. Our focus is the establishment of an adaptable foundation that supports advances in related technology. It must also serve as a basis to develop interoperable, scalable and flexible capabilities for our military and allies to build upon as new threats emerge. This is imperative in order to stay ahead of our adversaries.

The Naval Research and Development Establishment (NR&DE), which includes the Naval Laboratories, Warfare Centers, Systems Centers, and the Office of Naval Research, has a long history of pursuing and embracing autonomous technologies to advance Naval warfighting capability. Leading scientists and engineers from across the NR&DE are working to understand how autonomous technologies should be developed and applied to realize a fully integrated manned and unmanned Fleet. In doing this, theDepartment of the Navy (DON) recognizes that we need to reach beyond our service and the Department of Defense (DoD), in partnership with

industry, academia and other government organizations such as the Department of Homeland Security's Federal Emergency Management Agency and U.S. Customs and Border Protection, USAID, and relief organizations such as the Red Cross to understand common applications and minimize unnecessary duplication of capability. Let us not forget, the Navy's mission encompasses everything from combat to peacekeeping to humanitarian assistance. I believe by partnering with these agencies that the Navy will not only retain the distinction of the world's premier naval power, but will continue to be America's guardian of peace, enabling the safe travel of people and goods to meet the expanding demands of globalization and free peoples.

Among the uniformed services of the United States, the Navy is distinct in the multi-dimensional conduct of missions on all fronts: in the air, on land, and on and under the sea. Given this unique mission set, the DON must maintain a diverse portfolio to deliver this capability in all domains, and we see autonomy as a technology to provide our systems greater utility so that man and machine can contribute. Since the notable successes of unmanned air systems in Desert Storm, the DON has continued to invest in this area, and has refined these investments to mature the technology we are discussing today - autonomy.

Many of you are familiar with the success that the Air Force has had with Global Hawk. The Navy has also taken note of its phenomenal persistence and capabilities, which have helped shape our investments in the MQ-4C Triton to provide the Navy with game-changing persistent maritime and littoral Intelligence, Surveillance and Reconnaissance (ISR) data collection and dissemination capabilities. Triton will be a key component of the Navy's Maritime Patrol and Reconnaissance Force family of systems. In this case, when I say "family of systems" I am referring to the collaboration between the unmanned aircraft Triton, and the manned aircraft P-8A Poseidon. This marks a significant step in the teaming and collaboration of our unmanned and manned platforms to deliver a major part of the military's surveillance strategy. While teaming in this instance is controlled by man, it will provide the foundation to evolve our manned-unmanned concept of operations to introduce autonomy as the technology and trust continue to mature. In the area of collaboration, we are taking full advantage of autonomy for our tasking, collection, processing, exploitation and dissemination, or TCPED efforts, to allow us to rapidly deliver situational awareness to our forces. While we are using autonomy to support

our “big data” needs, we are continuing efforts to harden our networks and advance our cyber security capabilities.

Autonomy

Autonomy is a rich and dynamic area of research today both within the military and more widely across government, industry and academia. While autonomy holds the potential to transform the way we conduct military and humanitarian operations in the future, it is important to understand that the word 'autonomy' can often be misrepresented and misunderstood. For example, some define autonomous systems as any system that senses and reacts to its environment. Alternatively, autonomous systems can also be defined as those having intelligence-based capabilities that allow them to respond to situations that were not pre-programmed or anticipated. We have acknowledged this debate, and recognize there is a broad spectrum of autonomous behaviors which define a system's ability to sense, comprehend, predict, communicate, plan, make decisions, and take sequential actions to achieve its objectives as determined through interaction with humans and between autonomous systems.

In our quest to better understand and define autonomy, the Office of Naval Research (ONR) is conducting basic research in robotic interaction/human factors; machine reasoning, learning and intelligence; perception-based control and decision-making including scene/image understanding; bio-robotics; decentralized control; cognitive science, and neuroscience. These fundamentals are the keys to designing and ultimately enabling the learning or teaching of collaboration and teaming capabilities among autonomous systems and between human and unmanned systems. We must understand the abilities and limitations associated with such technology in order to develop tactics, techniques and procedures that will improve our military’s operational efficiency and effectiveness.

The DON sees autonomy research as a key tenant in the process of building a consolidated long term vision for unmanned and autonomous systems, and the associated roadmap and investment strategy that supports our vision. As we think about this investment strategy, we recognize that there is a dynamic commercial industry in autonomy upon which we can leverage in areas where civilian and military applications overlap. Naval investments will

then be focused on autonomous challenges such as overcoming the challenges of operating in extreme, adversarial, and unknown environments, in maritime domains in which perception, communications, and mobility may be different from what is assumed in many commercial applications, and focusing on interoperability and other critical supporting architectures for the successful teaming of unmanned systems with our manned forces.

Acquisition and Experimentation

This past April, the Secretary of the Navy announced he was appointing a new Deputy Assistant Secretary of the Navy (DASN) for Unmanned Systems (UxS), who would help bring together all the many stakeholders and operators who are currently working on this technology in order to streamline their efforts. Additionally, OPNAV Director, for Unmanned Warfare Systems (N99) was established so that all aspects of unmanned, in all domains, will be coordinated and championed. As of November 2, 2015, both organizations have been officially stood up. Prior to that, the ground work commenced over the summer and the two organizations have collaborated with DASN Research Development Test & Evaluation (RDT&E) to develop a cross-Department prototyping and experimentation approach that embraces innovation. This approach will be used to "pull" capability gaps from the fleet and will empower integrated teams of technical subject matter experts, and fleet operators to quickly evaluate emerging technologies, engineering innovations, and/or new warfighting concepts.

Working with DASN RDT&E, we will prioritize and identify which of these gaps will be filled through prototyping and experimentation in the near term, or make recommendations to for basic and applied research. These assessments will be done through collaboration among laboratories, academia, and industry to develop rapid prototypes for fleet experimentation and evaluation. Part of the assessments will include risk analyses of cost, schedule, and performance and human-machine trade spaces. This process supports the 2012 Defense Science Board's recommendations for a three-facet (cognitive echelon, mission timelines and human-machine system trade spaces) autonomous systems framework, and should be considered as the initial unmanned and autonomous framework the Navy and Marine Corps will utilize to inform both the requirements and acquisition communities. The DON prototyping and experimentation

approach will ultimately shape DON investments in order to unlock the potential of this new technology, and shape the way our warfighters evolve to a future concept of operation.

The Defense Science Board also recommended creating new developmental and operational test and evaluation techniques to address the unique challenges of autonomy that will build "trust" in autonomous systems. DASN UxS also recognizes new test and evaluation strategies need to be explored to include improving modeling and simulation with unmanned and autonomous systems in order to validate consistent behavior and "fail safe" protocols. Gaining trust in the predictability of autonomous systems presents new challenges, especially in an environment both fiscally constrained and rapidly emerging, but must be examined and adapted in order to rapidly field, train and equip our warfighters. Employment of such capability will afford our military both tactical and strategic advantages and awareness necessary prior to engagement with our adversaries.

A challenge we face with rapidly developing and testing future technologies comes from supporting our operators in theater with disruptive solutions that fall outside the input for the Planning, Programing, and Budget and Execution cycle. One of my roles will be to find ways to change the way we conduct "traditional" acquisitions when promising technologies prove to exploit our defensive edge. As you may be aware, in January 2009, we fielded Broad Area Maritime Surveillance-Demonstrator (BAMS-D) as a six month demonstration providing intelligence to the warfighter in NAVCENT. It now has flown over 17,000 flight hours in support of NAVCENT and CENTCOM.

This capability serves as the basis for the follow-on TRITON Program of Record, but has defied the traditional acquisition and fielding process. Perhaps we will explore similar options for fielding "interim" solutions in a deliberate fashion until follow-on enduring solutions can support current operations.

Collaboration and Teaming

In support of collaborating and teaming research, ONR is investing in swarming and more generally in decentralized control technologies that will give our commanders a competitive edge through the development of group behavior techniques and swarming

mathematical algorithms that are not easily disrupted by an adversary and may operate in both focused groups and over large, complex areas. The Control Architecture for Robotic Agent Command and Sensing (CARACaS) is an autonomy architecture extended to enable technology that enables multiple unmanned surface vehicles (USVs) to autonomously "swarm" adversaries' ships, or swarm to protect high-value naval assets. This technology gives our warfighters a clear and decisive advantage on the water, both in littoral and high seas environments, allowing us to potentially engage without use of lethal force, but rather simply overwhelm the adversary.

This autonomy technology was successfully demonstrated in the summer of 2014 on the James River. Five fully autonomous USVs with some tele-operation necessary for safety reasons (confined waterway) operated collaboratively to demonstrate the escort of high-value assets and then intercepted a potential threat by swarming the target. The possibilities for use of this technology include but aren't limited to: anti-piracy, anti-terrorism, disruption of adversary coastal operations, asymmetric operations and high value asset protection. In an Anti-Access/Area Denial (A2/AD) environment, it can deter hostile actions, damage aggressive adversaries and potentially destroy an opposing vessel. Imagine if this technology existed when the USS Cole was attacked, or when the US-flagged MV Maersk Alabama cargo ship was hijacked. Although other applications for this technology are still being contemplated, it is important for the committee to know this technology didn't happen overnight; it has been 10 years in the making.

We are continuing investments in this area and are looking toward unmanned aerial vehicles (UAVs) to explore collaboration and teaming in three dimensions by adding altitude as the third component. Most recently, under the sponsorship of the Consortium for Robotics and Unmanned Systems Education and Research program, the Advanced Robotic Systems Engineering Laboratory (ARSENL) at the Naval Post Graduate School (NPS) recently demonstrated the successful autonomous flight of 50 UAVs simultaneously. The 50 UAVs were launched and flown autonomously in two "sub-swarms" of 25 UAVs each. The swarms were monitored using ARSENL-developed swarm operator interfaces. The UAVs performed basic leader-follower cooperative behaviors, and exchanged information amongst themselves via wireless links. NPS is also exploring multi-domain swarming with elements under, on, and over the water.

Low-Cost UAV Swarming Technology (LOCUST) is another ONR project that is using the Coyote, a small expendable unmanned aircraft system (UAS) deployed from an A-size sonobuoy tube or Common Launch Tube that performs ISR missions, and will be the focus of this autonomy technology development and insertion. The Navy is also planning a ship-based demonstration with 30 Coyotes to form a tactical swarm within the next year.

Logistic UAVs

In support of operations in Afghanistan, the Marine Corps deployed two KMAX, unmanned helicopters which delivered 6,000 pounds of cargo per day, keeping trucks off the road and delivering necessary supplies while keeping our warfighters out of harm's way. Conducting logistics operations is critical to allowing our forces to remain mobile and sustainable. However, it's during these resupply operations we suffer fatalities due to Improvised Explosive Devices, and ambushes alike. Based on the success of the KMAX, the Navy is investing in the Autonomous Aerial Cargo/Utility System (AACUS). This technology focuses on autonomous obstacle avoidance for unprepared landing sites with precision landing capabilities, including contingency management until the point of landing. AACUS provides a goal-based supervisory control component such that any field personnel can request and negotiate a desired landing site. This system will communicate with ground personnel for seamless and safe loading and unloading. This technology is also designed to be platform agnostic based on open architecture framework that allows it to be integrated in either manned or unmanned rotary–wing aircraft which can be operated in austere weather or tightly manned constraints.

Undersea

Unlike the other Services which operate on and above the surface, the Navy's extensive operations in the undersea domain present another level of complexity for autonomy and persistence capabilities. In order to maintain naval dominance, the Navy must invest in undersea technologies. One of the greatest challenges of operating in the undersea domain is that the Global Positioning System (GPS) is not an effective navigation system throughout this domain.

To that end, the Navy is investing in the Large Displacement Unmanned Undersea Vehicle (LDUUV) Innovative Naval Prototype (INP). This vehicle is advancing the state of energy, autonomy and endurance technologies for long-endurance, multi-mission undersea vessels in the littorals. Autonomy development under this program includes investments to monitor and improve reliability, advanced algorithms for undersea sensing and avoidance, as well as advanced techniques to perform missions requiring precision navigation and timing in the absence of GPS. Technologies developed under the ONR LDUUV INP have informed, and will continue to inform the Navy LDUUV associated program of record (POR) and further advances will enable future missions envisioned for this new system. This capability, once deployed, will allow submarines to focus on high priority complex missions that require "man-in-the-loop" while the dull, dirty and/or dangerous missions are conducted by the LDUUVs.

Another area where the Navy is investing in technology is the Anti-Submarine Warfare Continuous Trail Unmanned Vessel program. ONR has teamed with the Defense Advanced Research Projects Agency to design, build and demonstrate a clean sheet unmanned X-ship. This technology will free manned search platforms from being tied down in an asset-intensive continuous trail. The autonomous technology to enable the platform's ability to sense, process and react or trail is challenging much of the early efforts that have focused on the platform's ability to execute the rules of the sea, otherwise known as COLREGS. COLREGS are the International Rules formalized for Preventing Collisions at Sea. The development of autonomous behaviors to interpret these rules, and to sense, perceive, and react, is well underway.

Supporting Architectures

Open architectures, networking, and cyber security will be critical for the successful integration of autonomous and unmanned systems with our manned forces.

Open System Architectures and Interoperability

As we continue to develop unmanned and autonomous systems we need to establish interoperability standards. Open Systems Architecture (OSA) is both a business and technical strategy for developing a new system or modernizing an existing one. In order to address future

changes to the system and to ensure those changes will be cost-effectively integrated, the Navy and Marine Corps have been evolving to utilize OSA and base design strategies on widely supported open standards.

Establishing an OSA acquisition framework for UAS ground control systems started with an Acquisition Decision Memorandum (ADM) by the Under Secretary of Defense for Acquisition, Technology and Logistics (USD(AT&L)) in 2009. That ADM directed that the design of future interoperable capabilities would adopt a "common DoD architecture."

As a result, in the air domain, the UAS Control Segment (UCS) architecture development effort was initiated to provide common control for unmanned systems. This architecture defines the rules and conventions for interoperable and interchangeable software components. It is based upon Service Oriented Architecture principles, and provides a common basis for acquiring, integrating, and extending the capabilities of the control systems for UASs, while removing proprietary restrictions to enable seamless and simplified integration and reuse of UAS applications.

This Government-owned model can be imported directly into the development environment of the software developer or system integrator. Compliance with this architecture affords the DoD an agnostic UAS Ground Control System that theoretically can operate any unmanned air platform variant, regardless of Service. The Government has developed and owns the UCS Repository market place for the ground control system. The repository is a web-enabled online application "App" store, where vendors may advertise their products for procurement by DoD Service PMO/PoR and their industry contractors who are looking for UCS solutions that are ready for integration and fielding. This repository is similar to the commercial personal Smartphone industry, where unique applications can be downloaded to suit individual user needs or productivity requirements. Government, industry, and academia are encouraged to list their developed UAS service or application on the website for procurement (industry and academia) or reuse. This architecture is essentially a business model that will provide flexibility for unmanned air system control segment subsystems and components, control costs for development, reduces integration time for new capabilities, allows reuse across Service and Joint UAS programs, where appropriate.

An example of how this architecture is employed can be found in the Navy's Air Common Control System (CCS). This system will be capable of operating all Navy UAS (Fire Scout, Triton, and UCLASS) by focusing on commonality, interoperability, modularity and competition. CCS's program is a software solution with instantiations for multiple hardware configurations, is UCS Architecture and Naval Interoperability Profile compliant, and is built on a Government-managed Open Commercial-Off-the-Shelf (COTS) Framework that is scalable and modular. The initial CCS vehicle management capability is planned for fielding on Triton in Fiscal Year 2019.

The Navy is also working on adapting domain agnostic architectures that will allow for interoperability in multiple domains. Operating in each domain presents unique physical challenges. Domain interoperability allows for the flow of information and the high-level integration of unmanned systems with our manned forces.

The DON and Army initiated an open technology framework for the real-time and flight safety aspects of UAS designs as well. The Future Airborne Capability Environment (FACE) has over 80 companies (and growing) participating in a consensus-based consortium, managed by the standards body, The Open Group. The FACE approach is a Government-industry software standard and business strategy for development and acquisition of affordable and reusable software systems that promotes innovation and rapid integration of portable capabilities across global defense programs. The FACE standard is now required in 12 Navy and 13 Army contracts. The Hardware Open Systems Technologies (HOST) is a companion technical hardware standard for developing a physical plug-and-play environment for avionics computer components that will be used to support FACE conformant software.

Together, the FACE and HOST standards are establishing an OSA path for the development of open UAV systems in the aircraft, while the UCS standard establishes an OSA path for the control of the aircraft and interoperability of the data that comes from them.

Cyber Security

Fundamentally, the heart of autonomous systems is the intelligent, learning and adaptive software embedded within them. As such, cyber threats are a natural concern to autonomous

systems. Just as the Navy is aggressively pursuing research in autonomy and autonomous systems, the Navy is also pursuing research in cyber strategies in parallel. The Navy is investigating both vulnerabilities and possibilities for cyber that are unique to autonomous systems.

ONR research is developing foundational cybersecurity technologies to enable cyber-attack-resilient warfighting platforms, both manned and unmanned. With a specific focus on automated and semi-automated solutions, the goal of the ONR cyber science and technology program is to make it possible for warfighting platforms to "fight through" current and future cyber-attacks while assuring Command & Control of our platforms at the tactical edge.

By studying what makes cyber exploits successful in the first place, we have focused our research efforts on protecting against entire classes of attacks at once. This strategy has been employed across the ONR cyber science and technology program, from resiliency to complex software, and better positions the DoD to effectively monitor, detect, assess, mitigate, and recover against today's and tomorrow's cyber threats.

Networking - Beyond Line of Sight – Anti-Access/Area Denial (A2/AD) Environment

With the need to plan for operations in a GPS-denied environment, we have initiated research in Beyond Line of Sight capabilities. The NPS Distributed Information Systems Experimentation research group recently completed an ambitious series of experiments at Naval Air Weapons Station China Lake designed to create a mobile internet architecture that facilitates defense command and control requirements as well as ISR dissemination. The project, called Beyond Line of Sight Command and Control (BLOS C2), seeks to create a self-forming, self-healing network with Type I encryption and anti-jamming capabilities that can survive in satellite-denied environments.

Conclusion

General Gray, the 29th Commandant of the Marine Corps said, “Like war itself, our approach to warfighting must evolve. If we cease to refine, expand, and improve our profession, we risk being out dated, stagnant, and defeated.”

Integration of unmanned and autonomous based technologies are going to be "game changers" for Naval Concept of Operations. These technologies will become force multipliers in all domains providing capability on both tactical and strategic levels. In order to achieve this capability, the Navy will continue to conduct research, develop prototypes and experiments, and field as appropriate in all relevant areas. We will develop tactics, techniques and procedures for countering adversary use of unmanned and autonomous capabilities and specifically, include adversary use of autonomous systems in war games, simulations and exercises not constrained by U.S. Rules of Engagement.

It is our charge to push and maintain naval superiority by providing every advantage to our Sailors and Marines. This research will take time, resources, collaboration and risks. However, the Navy is committed. Planning and integrating these capabilities into our Fleet needs to be deliberate and robust in order to defeat our adversaries who do not play by our rules.

As Voltaire said, "With great power comes great responsibility" and pursuit of this technology must be disciplined with clearly articulated policies that will govern operation, and implementation. Our objective is to build capability that is not happenstance or reckless, rather sapient and judicious. The mission of the DON is to maintain, train and equip combat-ready Naval forces capable of winning wars, deterring aggression and maintaining freedom of the seas, and autonomous systems will play an important part. To that end, we will maintain the trust of the people we are here to protect, and quell any speculation of a dystopian world in the making.

With the rise in instability of Middle East, a fundamental deterioration in U.S.-Russian relations and A2AD challenges in the pacific, the Navy is confronted with challenges around the world. Given any unintentional military incident or political miscalculation could inadvertently put the United States into hostilities on multiple fronts, the use of unmanned and autonomous technologies need to be considered when we are discussing future strategies. The use of these technologies will help maintain advantage over potential adversaries over long periods of time and retain peace where possible.