Executive Summary

Autonomy, both mobile and "at rest," is poised to revolutionize warfare as completely as steel, gunpowder, electricity, aviation, and computers did in prior generations. If we do not radically change the path we are on, America's adversaries will soon be able to defeat us in several arenas because of their rapidly increasing military capacity combined with their more aggressive fielding of autonomous capability. It follows that if the United States military does not accelerate the development and fielding of autonomous technology, the U.S. will cede military pre-eminence to those countries that do. Numerous reports conducted for the Department of the Navy, the Department of Defense, and our sister Services have endorsed the importance of autonomy and unmanned systems.

The commercial sector leads in the development of autonomous capabilities today. Advances in machine learning technologies, such as Deep Learning, underlie widely reported accomplishments such as the IBM Watson *Jeopardy* and AlphaGo victories over human champions. As the opportunities for financial gain or looming irrelevance become clear, industries as disparate as advertising, finance, automotive, cyber, medicine, aviation, and maritime transport are investing heavily in the development of autonomous and/or unmanned systems. Because industry is global, these investments are not exclusive to the United States.

A key finding of this study is that while the U.S. may currently have the advantage in autonomous systems, our adversaries are catching up. In some technical areas, our adversaries may already be ahead. The gap between defense and industry is growing – which in turn provides another vector for adversaries to leapfrog our autonomous capability. They might, for example, simply buy small U.S. entrepreneurial companies where much of the cutting edge technology is being developed.

A new element of the most advanced unmanned systems and autonomy at rest is software that "learns." In learning, autonomy software is transformed by the data used to train it. The code in many new autonomous systems is continuously rewritten by the data to which it is exposed. Because data is central to the creation and operation of autonomous systems, it is our greatest and most precious asset. Indeed, in industry, data ownership provides the key competitive advantage – think of Facebook. This leads to our first recommendation: **DoN must urgently develop an organizational data plan**. This plan must articulate the value of data to the DoN enterprise and should include processes to maximize that value and assign responsibilities. The key goal of the plan should be to enable the more rapid creation, evolution, and testing of learning systems in all areas of warfare from intelligence to operations. The plan must foster speed without relaxing cyber security.

Autonomous systems are complex, and some of the most advanced elements, such as Deep Learning elements, are effectively "black boxes". Consequently, Validation, Verification, and Accreditation (VV&A) of these systems is particularly challenging. Many of the mature VV&A methodologies for complex systems (e.g., those followed for deploying aircraft software), do not apply to autonomous systems. Furthermore, we believe that the ability to upgrade autonomous systems quickly may be essential for battlefield success, which presents new VV&A challenges. Accordingly, we recommend that **DoN create a world- class VV&A**

research program for autonomous systems by dramatically expanding the work being done by the DoD Autonomy Community of Interest. We note that cyber security, already a grave concern for DoN and all of DoD is an even more urgent concern for autonomous systems and must be integrated at every level in the VV&A effort. The threat is that an adversary might turn our own systems against us.

In our visits to Warfare Centers and Laboratories, we discovered an institutional tendency towards "one size fits all" risk mitigation procedures for obtaining operating clearances which seem to be hindering larger goals. Risk mitigation for a system that costs tens of millions of dollars clearly should be approached differently than it should for a system that costs only a fraction of that. Indeed, relaxed requirements and restrictions on lower cost systems provide a pathway to accelerate innovation and experimentation of new autonomous technologies. This should be exploited. Thus, our third recommendation is that **policies should enable rapid test and evaluation of autonomous systems, and restrictions on their early deployment and use should be commensurate with risk thus entailed**.

While advances in computer and networking technologies have been driven by industry for decades, the DoN procurement system remains structured around Cold War assumptions of the pre-eminence of government-funded technology. Lengthy approval processes that at times reach all the way back to Congress, effectively give more nimble adversaries and organizations a head-start measured in years. This dysfunctional system is eroding our technological edge and puts us at risk of losing a major military engagement in the future   Below we offer a series of recommendations designed to make use of powerful new procurement tools, to greater engage Navy and Marine Corps leadership in fielding autonomy capabilities, and to create an innovation ecosystem borrowing lessons learned from industry and the intelligence community. Specifically, we recommend:

- **Use Other Transactional Authority (OTAs) as forcefully directed by Congress, whenever possible.**
- **Demand plans from type commanders to leverage existing autonomy to generate new capability.**
- **Create a "Shark Tank" approach to internal Naval innovation funding within the DoN, and fund with an initial $50M pilot.**
- **Create Naval-oriented incubators in the Silicon Valley and the Boston areas.**
- **Create a DoN-owned venture firm with $30M patterned on In-Q-Tel.**

Autonomy is a fast moving domain, arguably still in its infancy. A heated battle for talent is already well under way, with companies like Uber hiring 40 university researchers from a single center, or with Toyota Research Institute announcing a one billion-dollar investment in autonomy. While DoD and DoN have nurtured many of the research activities that now underlie the explosion in commercial investment in autonomy, the government is currently losing the battle to hire the best minds. Consequently, **we recommend that DoN remove barriers to recruit and retain the best talent.** Today's hiring processes are slow, lack flexibility in minimum formal education requirements; and new hires are compensated poorly compared to industry. This jeopardizes hiring the best candidates. Further, incorporation of autonomy in education and training across the DoN must be expanded. Autonomy is not a stovepipe domain: it has applicability to all aspects of the Naval force.

We emphasize that elements of the DoD enterprise are mobilizing to these challenges. The Third Offset Strategy explicitly leverages advances in learning systems. The new Digital Warfare Office and the emerging Modeling and Simulation Enterprise are important steps towards organizing around the new imperatives.

However, these efforts are tiny compared to the opportunity and the threat. Given the breadth and importance of autonomy to the future of the Department of the Navy, **we recommend that the Secretary of the Navy be the Champion for Autonomy** in order to ensure funding and urgency are provided to enable the Navy and Marine Corps to stay ahead of all potential adversaries.

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