Fielding Unmanned Systems Warfighters Can Employ:
Leveraging Artificial Intelligence to Provide Augmented Intelligence

Tech Talk for AFCEA TechNet Asia-Pacific
November 12-16, 2018

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Executive Summary

One of the most rapidly growing areas of innovative technology adoption involves unmanned systems. The U.S. military's use of these systems—especially armed unmanned systems—is not only changing the face of modern warfare, but is also altering the process of decision-making in combat operations. These systems are evolving rapidly to deliver enhanced capability to the warfighter and seemed poised to deliver the next "revolution in military affairs." However, there are increasing concerns regarding the degree of autonomy these systems—especially armed unmanned systems—should have.

The Department of Defense has evolved a comprehensive *Unmanned Systems Integrated Roadmap* that forecasts the evolution of military unmanned systems over the next quarter-century. Concurrently, funding for unmanned systems is predicted to rise year-over-year for the foreseeable future. Indeed, as the DoD has rolled out a "Third Offset Strategy" to evolve new operational concepts and technologies to deal with emerging peer competitors, unmanned systems and artificial intelligence have emerged as key—even critical—components of that strategy. Indeed, the *National Defense Strategy* embraces these technologies as critical components in dealing with increasingly capable peer competitors.

One of the operational and technical challenges of fielding even more capable unmanned systems is the rising cost of military manpower—one of the fastest growing military accounts—and the biggest cost driver in the total ownership cost (TOC) of all military systems. Because of this, the U.S. military has sought to increase the autonomy of unmanned military systems in order to drive down total ownership cost.

As military unmanned systems have become more autonomous, concerns have surfaced regarding a potential "dark side" of having armed unmanned systems make life-or-death decisions. Some of these concerns emerge from popular culture, such as movies like *2001: A Space Odyssey*, *Her*, and *Ex Machina*. Whether the movies are far-fetched or not isn't the point, what *is* important is that the ethical concerns regarding employing armed unmanned systems are being raised in national and international media.

While the DoD has issued guidance regarding operator control of autonomous vehicles, rapid advances in big data, artificial intelligence and machine learning have exacerbated concerns that the military might lose control of armed unmanned systems. The challenge for unmanned systems designers is to provide the military not with completely autonomous systems, but with systems with augmented intelligence that offer the operator enhanced warfighting effectiveness.

The DoD can use the experience of the automotive industry and driverless cars to help shape the degree of autonomy in future unmanned systems. As testing of these vehicles has progressed, and as safety and ethical considerations have emerged, carmakers have tempered their zeal to produce completely autonomous vehicles and have looked to produce cars with augmented intelligence to assist the driver. Harnessing big data, artificial intelligence and machine learning to provide warfighters with unmanned systems with augmented intelligence—vice fully autonomous systems—may hold the key to overcoming the ethical concerns that currently limit the potential of military unmanned systems.

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Perspective

"I think I might agree with that, David. I mean, if what we mean is something that's going to change everything, I think autonomy is going to change everything."

> William Roper
> Director, Strategic Capabilities Office
> Office of the Secretary of Defense
> In an interview with David Martin on
> CBS *60 Minutes* "The Coming Swarm"
> January 8, 2017
> In response to a question from David Martin:
> "I've heard people say that autonomy is the biggest
> thing in military technology since nuclear weapons."

In his best-selling book, *War Made New*, military historian Max Boot notes, "My view is that technology sets the parameters of the possible; it creates the potential for a military revolution."[1] He supports his thesis with historical examples to show how technological-driven "Revolutions in Military Affairs" have transformed warfare and altered the course of history.

The U.S. military has embraced a wave of technological change that has constituted a true revolution in the way that war is waged. As the pace of global technological change has accelerated, the United States has been especially adept at inserting new technology to pace the threat. As Bruce Berkowitz points out in *The New Face of War*:

> Wartime experience suggests that the right technology, used intelligently, makes sheer numbers irrelevant. The tipping point was the Gulf War in 1991. When the war was over, the United States and its coalition partners had lost just 240 people. Iraq suffered about 10,000 battle deaths, although no one will ever really be sure. The difference was that the Americans could see at night, drive through the featureless desert without getting lost, and put a single smart bomb on target with a 90 percent probability.[2]

While both books cited are over a decade old, what they say about technology remains on point regarding the ways that the U.S. military has embraced new technologies. Today one of the most rapidly growing areas of innovative technology adoption by the U.S. military involves unmanned systems. In the past several decades, the U.S. military's use of unmanned aerial vehicles (UAVs) has increased from only a handful to more than 10,000, while the use of unmanned ground vehicles (UGVs) has exploded from

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[1] Max Boot, *War Made New: Technology, Warfare, and the Course of History 1500 to Today* (New York: Gotham Books, 2006), pp. 318-351. See also, Bruce Berkowitz, *The New Face of War: How War Will Be Fought in the 21st Century* (New York: The Free Press, 2003).

[2] Bruce Berkowitz, *The New Face of War: How War Will Be Fought in the 21st Century* (New York, The Free Press, 2003), pp. 2-3. Berkowitz does not restrict his examples to just one conflict, noting further; "The same thing happened when the United States fought Yugoslavia in 1999 and the Taliban regime in Afghanistan in 2001. Each time experts feared the worst; each time U.S. forces won a lopsided victory."

zero to more than 12,000. The use of unmanned surface vehicles (USVs) and unmanned underwater vehicles (UUVs) is also growing, as USVs and UUVs are proving to be increasingly useful for a wide array of military applications. The exploding use of military unmanned systems (UxS) is already creating strategic, operational, and tactical possibilities that did not exist a decade ago.

The expanding use of armed, unmanned systems is not only changing the face of modern warfare, but is also altering the process of decision-making in combat operations. Indeed, it has been argued that the rise in drone warfare is changing the way we conceive of and define "warfare" itself. These systems have been used extensively in the conflicts in Iraq and Afghanistan, and will continue to be equally relevant—if not more so—as the United States' strategic focus shifts toward the Indo-Asia-Pacific region and the high-end warfare this strategy requires.

While these unmanned systems are of enormous value today and are *evolving* to deliver better capabilities to the warfighter, it is their promise for the future that causes the most excitement. Indeed, these systems have created substantial anticipation in policy, strategy, military, industry and academic circles. However, an increasing amount of this buzz involves concerns—many legitimate—regarding the extent of autonomy military unmanned systems ought to have.

These concerns have surfaced in major media, most notably in Google discontinuing their work on DoD's Algorithmic Warfare Cross-Functional Team, otherwise known as Project Maven.[3] Beyond these headline-grabbing stories, a great deal of thoughtful work has been published regarding the efficacy of using unmanned systems, especially lethal unmanned systems, in warfare.[4] Unless or until these concerns are addressed, the enormous potential of these technological marvels may never be realized.

The Plan for Military Autonomous Systems

At the highest levels of U.S. policy and strategy documents, unmanned systems are featured as an important part of the way the Joint Force will fight in the future. The most recent *Quadrennial Defense Review* (*QDR*) notes, "Continuing a trend that began in the late 1990s, U.S. forces will increase the use and integration of unmanned systems." Elsewhere in the *QDR*, unmanned systems are identified as: "Maintaining our ability to project power." Importantly, the *QDR* highlights unmanned systems as a key part of the DoD's commitment to innovation and adaptation.[5]

The U.S. Department of Defense's vision for unmanned systems is to integrate these systems into the Joint Force for a number of reasons, but especially to reduce the risk to human life in high threat areas, to deliver persistent surveillance over areas of interest, and to provide options to warfighters that derive from the inherent advantages of unmanned technologies—especially their ability to operate autonomously. The *National Defense Strategy* embraces these technologies as critical components in dealing with increasingly capable peer competitors, and notes, in part, "The Department will invest

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[3] See, for example, Daisuke Wakabayashi and Scott Shane, "Google Will Not Renew Pentagon Contract That Upset Employees," *The New York Times*, June 1, 2018, accessed at: https://www.nytimes.com/2018/06/01/technology/google-pentagon-project-maven.html

[4] See, for example, P.W. Singer, *Wired for War* (New York: Penguin Press, 2009), Bradley Jay Strawser, Ed. *Killing by Remote Control: The Ethics of an Unmanned Military* (Oxford, UK, Oxford University Press, 2013), William Arkin, *Unmanned: Drones, Data, and the Illusion of Perfect Warfare* (New York, Little, Brown and Company, 2015), and Larry Lewis and Dianne Vavrichek, *Rethinking the Drone War* (Quantico, VA, Marine Corps University Press, 2016)

[5] *Quadrennial Defense Review* (Washington, D.C.: Department of Defense, 2014).

broadly in military application of autonomy, artificial intelligence, and machine learning, including rapid application of commercial breakthroughs, to gain competitive military advantages."[6]

Because unmanned systems are used by all the military Services, the Department of Defense publishes a roadmap to provide an overarching vision for the military's use of unmanned systems. The most recent roadmap, the *DoD Unmanned Systems Integrated Roadmap 2017-2042*, highlights the ways in which unmanned systems will help the joint warfighter, noting, "DoD envisions unmanned systems seamlessly operating with manned systems to compress the warfighters' decision-making process while reducing the risk to human life." The Roadmap goes on to provide DoD's vision for unmanned systems, and calling out four areas of primary focus: Interoperability, Autonomy, Network Security, and Human-Machine Collaboration.[7]

As the *QDR* and *Unmanned Systems Integrated Roadmap* both note, unmanned systems are especially important assets in those areas where the U.S. military faces a peer competitor with robust defenses. The *Joint Operational Access Concept* identifies, "Unmanned systems, which could loiter to provide intelligence collection or fires in the objective area," as a key capability that is especially valuable in areas where an adversary has strong defenses that can limit access to U.S. and coalition forces.[8] Unmanned systems are a key component in executing the United States AirSea Battle Concept (now re-branded as the Joint Concept for Access and Maneuver in the Global Commons, or JAM-GC) in high threat areas such as the Western Pacific, where adversary defensive systems pose an unacceptably high risk to manned aircraft and surface platforms.

The Need for "Offset" Strategies

The Department of Defense has initiated a "Third Offset Strategy," to ensure that the United States retains the military edge against potential adversaries. An "offset" strategy is an approach to military competition that seeks to asymmetrically compensate for a disadvantaged position. Rather than competing head-to-head in an area where a potential adversary may also possess significant strength, an offset strategy seeks to shift the axis of competition, through the introduction of new operational concepts and technologies, toward one in which the United States has a significant and sustainable advantage.

The United States was successful in pursuing two distinct offset strategies during the Cold War. These strategies enabled the U.S. to offset the Soviet Union's numerical advantage in conventional forces without pursuing the enormous investments in forward-deployed forces that would have been required to provide overmatch soldier-for-soldier and tank-for-tank. These offset strategies relied on fundamental innovations in technology, operational approaches and organizational structure to compensate for Soviet advantage in time, space and force size.

The first of these offset strategies occurred in the 1950's, when President Eisenhower sought to overcome Warsaw Pact's numerical advantage by leveraging US nuclear superiority to introduce battlefield nuclear

[6] The *National Defense Strategy* (Washington, D.C.: Department of Defense, 2018), accessed at:
https://dod.defense.gov/Portals/1/Documents/pubs/2018-National-Defense-Strategy-Summary.pdf
[7] *DoD Unmanned Systems Integrated Roadmap 2017-2042* (Washington, D.C.: Department of Defense, 2018). See, "Pentagon Unmanned Systems Integrated Roadmap 2017-2042, in *USNI News*, August 30, 2018 at:
https://news.usni.org/2018/08/30/pentagon-unmanned-systems-integrated-roadmap-2017-2042 for summary of the Roadmap as well as a link to the document.
[8] Department of Defense, *Joint Operational Access Concept*, (Washington, D.C.: January 17, 2012).

weapons—thus shifting the axis of competition from conventional force numbers to an arena where the United States possessed an asymmetrical advantage. This First Offset Strategy provided stability and offered the foundation for deterrence.

The second of these offset strategies arose in the late 1970's and early 1980's with the recognition that the Soviet Union had achieved nuclear parity. The Second Offset Strategy sought to create an enduring advantage by pursuing a new approach to joint operations—leveraging the combined effects of conventional precision weapons, real-time, long-range, ISR (intelligence, surveillance, reconnaissance) sensor capabilities that supported real-time precision targeting, and the joint battle networks that permitted these capabilities to be synchronized and executed over the full breadth of the battlespace.

At the time of the introduction of the Second Offset Strategy in the early 1980's, the United States was the only nation with the knowledge and capacity to develop, deploy, and successfully execute the intelligence, surveillance and reconnaissance capabilities, the space-based systems, and the precision weapons that supported this approach. Today, competitors such as Russia and China (and countries to which these nations proliferate advanced capabilities) are pursuing and deploying advanced weapons and capabilities that demonstrate many of the same technological strengths that have traditionally provided the high-tech basis for U.S. advantage, such as precision-guided munitions. This growing symmetry between U.S. technical capabilities and near-peer potential competitors was seen during Russian power-projection operations in Syria.[9]

The emergence of increasing symmetry in the international security environment led to a decision by the United States to begin considering the mix of technologies, system concepts, military organizations, and operational concepts that might shift the nature of the competition, and give the United States an edge over potential adversaries. This set of capabilities provides the basis for a Third Offset Strategy. As was true of previous offset strategies, a Third Offset Strategy seeks, in a budget constrained environment, to maintain and extend the United States' competitive technological and operational advantage by identifying asymmetric advantages that are enabled by unique U.S. strengths and capabilities. A Third Offset Strategy ensures that our conventional deterrence posture remains as strong in the future as it is today and establishes the conditions to extend that advantage into the future.

In explaining the technological elements of the Third Offset Strategy, then-Deputy Secretary of Defense Robert Work emphasized the importance of emerging capabilities in unmanned systems, big data, artificial intelligence and machine learning. He pointed out that these technologies offer significant advantage to the Joint Force, enabling the future force to develop and operate advanced joint, collaborative human-machine battle networks that synchronize simultaneous operations in space, air, sea, undersea, ground, and cyber domains.[10] Artificial intelligence will allow new levels of autonomy—

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[9] The widely reported Russian operations in Syria included an increased use of unmanned systems. See, for example, John Grady, "Experts: Syrian War Prompting Russians to Expand Unmanned Systems," USNI News, October 9, 2017, accessed at: https://news.usni.org/2017/10/09/experts-syrian-war-prompting-russians-expand-unmanned-systems?utm_source=USNI+News&utm_campaign=91248db1ff-USNI_NEWS_DAILY&utm_medium=email&utm_term=0_0dd4a1450b-91248db1ff-231544033&mc_cid=91248db1ff&mc_eid=93a1fd6ad6

[10] It is important to note that the concept of man-machine teaming is not as new as some of its proponents often allege. See, for example, the 1960 paper by J.C.R. Licklinder, entitled, "Man-Computer Symbiosis, accessed at: http://groups.csail.mit.edu/medg/people/psz/Licklider.html

the limited delegation of decision-making authority—within joint battle networks, leading to entirely new opportunities for human-machine collaboration and combat teaming.[11]

It is difficult to overstate the prominence of technologies such as unmanned systems and artificial intelligence in the Third Offset Strategy and especially in the Strategy's Long Range Research and Development Plan (LRRDP).[12] That said, there is strong component of this strategy that emphasizes keeping humans in the loop when using unmanned systems with increasingly sophisticated artificial intelligence capabilities. Indeed, human-machine collaboration is an imperative that is emphasized in extant Third Offset Strategy documentation as well as in speeches and interviews with senior DoD officials.[13] While a deep-dive into the full details of the technology thrusts of the Third Offset Strategy is beyond the scope of this paper, it is important to note that the Strategy's primary technical line of effort is focused on the concept of Human-Machine Collaboration and Combat Teaming. The five basic building blocks of this concept are:[14]

- **Autonomous deep learning systems**, which will leverage machine learning to operate "at the speed of light" in areas where human reaction time is too slow, such as cyber-attacks, electronic warfare attacks, or large missile raid attacks.

- **Human-machine collaboration**, which will allow machines to help humans make better decisions faster. Secretary Work cited the F-35 Joint Strike Fighter and the Naval Integrated Fire Control Counter-Air (NIFC-CA) as examples of these concepts.

- **Assisted human operations**, which will focus on the ways in which man and machines can operate together, through tools such as wearable electronics, exoskeletons, and combat applications to assist warfighters in every possible contingency.

- **Advanced human-machine combat teaming**, which will focus on humans working with unmanned systems in cooperative operations; one example is the operation of the Navy's P-8 Poseidon with an MQ-4C Triton. Going forward, the next level of teaming will examine swarming tactics and cooperative autonomy.

- **Network-enabled, cyber-hardened autonomous weapons**, which will be resilient to operate in an electronic warfare and cyber environment. A current example includes the tactical Tomahawk Block IX, whose targets can be updated in-flight.

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[11] Deputy Secretary Work's interview with David Ignatius at "Securing Tomorrow" forum at the *Washington Post* Conference Center in Washington, DC, March 30, 2016.

[12] The importance of artificial intelligence and autonomy to all aspects of society, and especially to military operations, has been well-documented at the international and national level. See, for example, Executive Office of the President, National Science and Technology Council, Committee on Technology, *Preparing for the Future of Artificial Intelligence*, October 2016, Office of the Secretary of Defense for Acquisition, Technology and Logistics, *Report of the Defense Science Board Summer Study on Autonomy*, June 2016

[13] See, for example: Statement by Mr. Stephen Welby, Assistant Secretary of Defense for Research and Engineering on the Third Offset Strategy, Statement by Dr. Arati Prabhakar, Director, Defense Research Projects Agency (DARPA), on Strategy and Implementation of the Department of Defense's Technology Offset Initiative, and Statement by Dr. William B. Roper Jr. Director, Strategic Capabilities Office, Strategy and Implementation of the Department of Defense's Technology Offsets Initiative in Review of the Defense Authorization Request for Fiscal Year 2017, all before the Subcommittee on Emerging Threats and Capabilities, Armed Services Committee, United States Senate, April 12, 2016.

[14] Remarks by Deputy Secretary of Defense Robert Work at the Center for New American Security Defense Forum, December 14, 2015.

Knowledgeable outside observers have referenced the Third Offset Strategy and have highlighted the importance of unmanned systems in achieving U.S. strategic goals. In his article in *Foreign Policy*, "The New Triad," Admiral James Stavridis, former Supreme Allied Commander Europe, identified unmanned systems as one of the three pillars of this New Triad, noting, "The second capability in the New Triad is unmanned vehicles and sensors. This branch of the triad includes not only the airborne attack "drones"…but unmanned surveillance vehicles in the air, on the ground, and on the ocean's surface…Such systems have the obvious advantage of not requiring the most costly component of all: people."[15]

The U.S. Navy has been on the forefront of UxS development. The 28th CNO Strategic Studies Group (SSG) spent one year examining this issue, and its report spurred increased interest in—and emphasis on—unmanned systems Navy-wide. Leveraging the SSG's work, recent Navy focus has emphasized the need to enhance UxS command and control (C2) capabilities to allow one sailor to control multiple systems in an attempt to lower Total Ownership Costs (TOC) of unmanned systems. This link between increased autonomy and decreased TOC has become an important theme in Navy UxS development.

Clearly, the Navy's leadership is committed to unmanned systems. The former-Chief of Naval Operations *Sailing Directions* noted, "Over the next 10 to 15 years…unmanned systems in the air and water will employ greater autonomy and be fully integrated with their manned counterparts."[16] The importance of unmanned systems to the U.S. Navy was highlighted the in an article in *U.S. Naval Institute Proceedings*' where Admiral Jonathan Greenert noted that payloads, including unmanned systems, will increasingly become more important than platforms themselves.[17]

More recently, the importance of unmanned systems to the U.S. Navy's future has been highlighted in a series of documents, ranging from the revised *A Cooperative Strategy for 21st Century Seapower*, to *A Design for Maintaining Maritime Superiority*, to the May 2017 Chief of Naval Operations *The Future Navy* white paper. The later document presents a compelling case for the rapid integration of unmanned systems into the Navy Fleet, nothing, in part:

> There is no question that unmanned systems must also be an integral part of the future fleet. The advantages such systems offer are even greater when they incorporate autonomy and machine learning… Shifting more heavily to unmanned surface, undersea, and aircraft will help us to further drive down unit costs.[18]

The U.S. Navy's commitment to—and dependence on—unmanned systems is seen in a series of "Future Fleet Architecture Studies." In each of these studies: one by the Chief of Naval Operations Staff, one by the MITRE Corporation, and one by the Center for Strategic and Budgetary Assessments, the proposed Navy future fleet architecture had large numbers of air, surface, and subsurface unmanned systems as part of the Navy force structure.[19]

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[15] Admiral James Stavridis, "The New Triad," *Foreign Policy*, June 20, 2013. Admiral Stavridis argues that the "New Triad" consists of special operations forces, unmanned vehicles, and cyber-capabilities.

[16] Jonathan Greenert, *Sailing Directions*, accessed at: http://www.navy.mil/cno/cno_sailing_direction_final-lowres.pdf.

[17] Jonathan Greenert, "Navy 2025: Forward Warfighters," *U.S. Naval Institute Proceedings*, December 2011 and Jonathan Greenert, "Payloads Over Platforms: Charting a New Course," *U.S. Naval Institute Proceedings*, July 2012.

[18] The Future Navy (Washington, D.C.: Department of the Navy, May 2017) accessed at: http://www.navy.mil/navydata/people/cno/Richardson/Resource/TheFutureNavy.pdf

[19] See, for example, Navy Project Team, *Report to Congress: Alternative Future Fleet Platform Architecture Study*, October 27, 2016, MITRE, *Navy Future Fleet Platform Architecture Study*, July 1, 2016, and CSBA, *Restoring American Seapower: A New Fleet Architecture for the United States Navy*, January 23, 2017.

Of equal interest to U.S. Navy leadership—and to the Chief of Naval Operations in particular—is the impact marrying artificial intelligence and machine learning to unmanned systems. At last year's Current Strategy Forum in Newport, Rhode Island, our Chief of Naval Operations, Admiral John Richardson, talked about the OODA Loop first made popular by U.S. Air Force Colonel John Boyd in the 1950s. Admiral Richardson used the OODA (Observe, Orient, Decide and Act) Loop as a way of discussing the kinds of new technologies the U.S. Navy was fielding.[20] When the CNO used the OODA Loop in his remarks in Newport, he suggested that the Navy was mining new technologies to help with the Orient and Decide aspects of this taxonomy.[21] These are areas that will greatly benefit from technologies like big data, artificial intelligence and machine learning, especially when married with unmanned systems. He also emphasized, that, until recently, these technologies hadn't yet mature to the point where they could help make strides with the Orient and Decide phases of the OODA Loop.

The Challenges for Autonomous Systems – Total Ownership Costs

Well over a decade ago, in their report, *Roles of Unmanned Vehicles*, the Naval Research Advisory Committee highlighted the bright future and enormous potential for unmanned systems, noting, "The combat potential of UVs (unmanned vehicles) is virtually unlimited…There is no question that the Fleet/Forces of the future will be heavily dependent upon UVs."[22] In the years following the NRAC report, the U.S. military has been working with industry and academia to make unmanned vehicles more-and-more autonomous. There are compelling reasons for this effort.

As described in the previous *Unmanned Systems Roadmap*, there are four levels of autonomy: Human Operated, Human Delegated, Human Supervised, and Fully Autonomous. However, the that *Roadmap* noted that in contrast to automatic systems, which simply follow a set of preprogrammed directions to achieve a predetermined goal, autonomous systems "are self-directed towards a goal in that they do not require outside control, but rather are governed by laws and strategies that direct their behavior."[23]

One of the most pressing challenges for the DoD is to reduce the prohibitively burdensome manpower footprint currently necessary to operate unmanned systems. Military manpower makes up the largest part of the total ownership cost of systems across all the Services.[24] But how expensive *is* military

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[20] Richard Burgess, "CNO: Precision Era Gives Way to Decision Era," Seapower Magazine Online, June 13, 2017, accessed at: http://seapowermagazine.org/stories/20170613-CNO.html. When Admiral Richardson discussed the OODA Loop last year, he said the Navy has already invested heavily in the Observe and Act parts of Boyd's taxonomy. He further noted that until the advent of emerging technologies such as big data, machine learning, and artificial intelligence, we couldn't do much about the Orient and Decide aspects, but today we can.

[21] Colonel John Boyd created what every Naval Aviator knows today as the OODA Loop. OODA stands for "Observe, Orient, Decide and Act." Boyd's key concept was that of the decision cycle or OODA Loop, is the process by which an individual reacts to an event. According to this idea, the key to victory is to be able to create situations wherein one can make appropriate decisions more quickly than one's opponent. Colonel Boyd's construct was originally a theory of achieving success in air-to-air combat, developed out of Boyd's energy-maneuverability theory and his observations on air combat between MiG-15s and North American F-86 Sabres in Korea. Harry Hillaker (chief designer of the F-16) said of the OODA theory, "Time is the dominant parameter. The pilot who goes through the OODA cycle in the shortest time prevails because his opponent is caught responding to situations that have already changed."

[22] Naval Research Advisory Committee, *Roles of Unmanned Vehicles* (Washington, D.C.: Naval Research Advisory Committee, 2003).

[23] *FY 2013-2038 Unmanned Systems Integrated Roadmap*.

[24] Well over a decade ago, in its report, *Navy Actions Needed to Optimize Ship Crew Size and Reduce Total Ownership Costs* (GAO-03-520, Jun 9, 2003) the Government Accountability Office noted, "The cost of a ship's crew is the single

manpower? To better understand this compelling need to reduce these manpower requirements, it is important to understand the costs of manpower in the U.S. military writ large.

Military manpower accounts comprise the largest part of the TOC of military systems across all the Services. Additionally, military manpower costs are the fastest growing accounts, even as the total number of military men and women *decrease*. According to an Office of Management and Budget report, military personnel expenditures have risen from $74 billion dollars in 2001 to $153 billion dollars in 2018, an increase of almost 115 percent.[25] Mackenzie Eaglen and Michael O'Hanlon have noted that between fiscal year 2001 and 2012, the compensation cost per active-duty service member increased by 56%, after being adjusted for inflation.[26]

An IHS-Jane's analysis of the U.S. Defense Budget highlighted the high—and growing—costs of military manpower, as well as the factors driving these costs. Jane's analysis highlighted the fact that in spite of predicted decreases in the number of military personnel across the Future Years Defense Plan (FYDP), military manpower costs are predicted to rise at least through FY-21. The report noted:

> Since the nadir of US defence spending in 1999, personnel expenditures have increased faster than other categories of expenditure, save RDT&E, rising by 39% in real terms by FY06. Military Personnel have enjoyed: five years of pay rises at or around 1.5% - higher than those in the general economy and the pay hike requested for FY16 was 1.3% and for FY17 it is 1.6%; increases in pay for middle grades to improve retention of skilled personnel; improved housing benefits; and substantial increases in retirement benefits…These personnel figures do include mandatory military pensions, but they do not include DoD civilian pay, which is accounted for in the O&M accounts in the US. DoD FY16 Military Personnel funds were USD148.5 billion in constant dollars or 23.9% of the budget and MilPers percentage is expected to rise to 25.5% by FY21.[27]

Lessons learned throughout the development process of most unmanned systems—especially unmanned aerial systems—demonstrate that unmanned systems can actually *increase* manning requirements. Indeed, the Air Force has estimated that the MQ-1B Predator requires a crew of about 168 personnel,

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largest cost incurred over the ship's life cycle." This was *before* a decade of military pay increases. See also Connie Bowling and Robert McPherson, *Shaping The Navy's Future*, (Washington, D.C.: Accenture White Paper, February, 2009) accessed at**:** http://www.accenture.com/us-en/Pages/service-public-service-shaping-navys-future.aspx**,** for one of a growing number of reports detailing the reasons manpower is the driving factor increasing total operating costs of U.S. Navy ships. This report notes**, "**The active duty force, for instance, has stabilized and is projected to stay at 317,000 personnel for the next six years. Yet over this same period, the inflation adjusted cost of the force is projected to grow by 16.5 percent due to the rising costs of benefits, including service member and family health care."

[25] The Congressional Budget Office report, *Costs of Military Pay and Benefits in the Defense Budget*, accessed at: https://www.gpo.gov/fdsys/pkg/BUDGET-2018-TAB/pdf/BUDGET-2018-TAB.pdf, is just one of many reports that note that costs of military pay have been increasing faster than the general rate of inflation and wages and salaries in the private sector. The report identifies this as just one factor making manpower accounts an increasingly large part of the military budget. See also, Mackenzie Eaglen and Michael O'Hanlon, "Military Entitlements Are Killing Readiness," *Wall Street Journal*, July 25, 2013. A number of think tank studies have presented even more dire-even apocalyptic-scenarios as military manpower costs rise. See, for example, Todd Harrison, *Rebalancing Military Compensation: An Evidence-Based Approach*, (Washington, D.C.: Center for Strategic and Budgetary Assessments, July 12, 2012), which notes in its first finding: "The all-volunteer force, in its current form, is unsustainable. Over the past decade, the cost per person in the active duty force increased by 46 percent, excluding war funding and adjusting for inflation. If personnel costs continue growing at that rate and the overall defense budget remains flat with inflation, military personnel costs will consume the entire defense budget by 2039."

[26] Eaglen and O'Hanlon, "Military Entitlements Are Killing Readiness."

[27] Jane's U.S. Defense Budget, November 16, 2016, accessed at ihs.com.

while the MQ-9 Reaper requires a crew of 180 and the RQ-4 Global Hawk relies on 300 people to operate it. As General Philip Breedlove, then-Vice Chief of Staff of the Air Force, emphasized, "The number one manning problem in our Air Force is manning our unmanned platforms."[28] An article in the *Armed Forces Journal* summed up the dilemma in this way, noting, "The military's growing body of experience shows that autonomous systems don't actually solve any given problem, but merely change its nature. It's called the autonomy paradox: The very systems designed to reduce the need for human operators require more manpower to support them."[29]

An article in the U.S. Army's *Acquisition, Logistics and Technology Journal* written by a U.S. Marine Corps officer who worked with unmanned military robots in Afghanistan highlighted the challenges involved in trying to reduce the personnel footprint required to operate military unmanned vehicles:

> In recent years, unmanned systems (UMS) have proliferated by the thousands in our Armed Forces. With increasing pressure to cut costs while maintaining our warfighting edge, it seems logical that UMS could reduce manpower and its associated costs while ensuring our national security. Unfortunately, while the recent UMS proliferation has improved our warfighting edge, it has not led to manpower reductions. Instead, UMS have *increased* our manpower needs—the opposite of what one might expect.
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> Two primary reasons that the proliferation of UMS has increased manpower needs are, first, that the priority for UMS is risk reduction, not manpower reduction; and, second, that current UMS are complementary to manned systems. Instead of replacing manned systems, UMS have their own manpower requirements, which are additive overall.[30]

Compounding the TOC issue, the data overload challenge generated by the proliferation of unmanned aircraft and their sensors has created its own set of manning issues. In fact, the situation has escalated so quickly that many doubt that hiring additional analysts will help ease the burden of sifting through thousands of hours of video. A former Vice Chairman of the Joint Chiefs of Staff complained that a single Air Force Predator can collect enough video in one day to occupy nineteen analysts, noting, "Today an analyst sits there and stares at Death TV for hours on end, trying to find the single target or see something move. It's just a waste of manpower."[31] The data overload challenge is so serious that it's widely estimated that the U.S. Navy will soon face a "tipping point," after which the Navy will no longer be able to process the amount of data that it's compiling.[32]

More recently, this data overload issue has been addressed in a wide-range of reports and articles. Here is how an active duty naval officer looked at the issue in an October 2018 article in *U.S. Naval Institute Proceedings*:

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[28] Quoted in Lolita Baldor, "Military Wants to Fly More Sophisticated Drones," *Associated Press,* November 4, 2010. General Breedlove's statement has been echoed as recently as this year, with U.S. Air Force officials noting that they do not have enough operators to field all the UAS in the Air Force inventory.

[29] "Why 'Unmanned Systems' Don't Shrink Manpower Needs," *Armed Forces Journal*, October 1, 2011, accessed at: http://armedforcesjournal.com/the-autonomy-paradox/.

[30] Major Valerie Hodgson, "Reducing Risk, Not Manpower: Unmanned Systems Bring Lifesaving Capabilities, but Saving Money in Personnel Has Yet to be Achieved," *U.S. Army's Acquisition, Logistics and Technology Journal*, Jan-Mar 2012.

[31] Ellen Nakashima and Craig Whitlock, "Air Force's New Tool: 'We Can See Everything,'" *Washington Post*, January 2, 2011.

[32] The ISR "tipping point" has been noted in a TCPED study by the Office of the Chief of Naval Operations and PMW 120 (Battlespace Awareness and Information Operations), an independent Navy Cyber Forces study, and the NRAC study from summer 2010.

Further complicating the battlespace awareness problem is the sheer quantity of information produced by organic, theater, and national collection sensors. Four elements of data overload make battlespace awareness so challenging: variety, volume, velocity, and veracity. The various types of raw data available and the resulting combinations of that data (variety) increase exponentially over time, and the amount of usable data available (volume) makes it difficult to know in advance which combinations may have intelligence value. Sensors also produce these large quantities of data faster than ever before (velocity), and often without the power necessary to process it at near-real-time speed. This can create trust issues (veracity) when intelligence is not available because of system latency. The sensor data overload needs autonomous technological solutions for a SAG to maintain battlespace awareness.[33]

Looking to the future of unmanned systems development, while acknowledging that technology breakthroughs may reduce the manning footprint of some military unmanned systems, some see a continuation—or even an increase—in manning required for unmanned systems. Here is how a Professor of Military and Strategic Studies at the United States Air Force Academy put it:

> The corresponding overhead costs in training for pilots, sensor operators and maintainers, fuel and spare parts, maintenance, and communications are not cheaper for unmanned systems than for manned alternatives. Advances in ISR will increase manpower costs as each additional sensor will require additional processing and exploitation capacity…The manpower and infrastructure costs associated with UAVs will prevent it from becoming the universal replacement to all manned military aircraft missions.[34]

With the prospect of rising costs of military manpower, and the increased DoD emphasis on total ownership costs, the mandate to move beyond the "many operators, many-joysticks, one-vehicle" paradigm that has existed during the past decades for most unmanned systems is clear and compelling. Indeed, the *DoD Unmanned Systems Integrated Roadmap 2017-2042*, put the desired goal this way:

> Greater autonomy will also remove the need for constant input from human operators. In the future, it is desirable to have each operator control multiple unmanned systems, thus shifting the human's role from operator towards mission manager.[35]

The DoD and the Services are united in their efforts to increase the autonomy of unmanned systems as a primary means of reducing manning and achieving acceptable TOC, as well as achieving other benefits unmanned systems perform as they undertake the "dull, dirty, and dangerous" work previously done by manned systems. For the U.S. Navy, this need to reduce manning is especially acute. As Chief of Naval Operations, John Richardson, noted at a military-industry conference:

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[33] Jacob Wilson, "Distributed Lethality Requires Distributed (Artificial) Intelligence," U.S. Naval Institute Proceedings, October 2018, accessed at: https://www.usni.org/magazines/proceedings/2018-10/distributed-lethality-requires-distributed-artificial-intelligence.

[34] Michael Fowler, "The Future of Unmanned Aerial Systems," in *Global Security and Intelligence Studies*, Vol. 1: No. 1, Article 3. Available at: http://digitalcommons.apus.edu/gsis/vol1/iss1/3.

[35] *DoD Unmanned Systems Integrated Roadmap 2017-2042*.

Talent is becoming more expensive. We can't operate under a cost construct that requires more-and-more people. We have to drive down total operating costs. The manning profile on new platforms needs to be less than on the ones they are replacing.[36]

The Department of Defense has embraced advances in big data, artificial intelligence, machine learning and other emerging capabilities to in an effort to enable unmanned systems to have an increased degree of autonomy. A recent "JASON" report, *Perspectives on Research in Artificial Intelligence and Artificial General Intelligence Relevant to DoD*, put the value of AI this way:

> AI technologies are of great importance to DoD missions. Defense systems and platforms with varying degrees of autonomy already exist. More importantly, AI is seen as the key enabling technology (along with human computer interactions of various kinds) of a ″ Third Offset Strategy″ that seeks for the U.S. a unique, asymmetric advantage over near-peer adversaries.[37]

But this drive for autonomy begs the question as to what this imperative to increase autonomy may comport and what, if any, downside occurs if we push autonomy too far. Is there an unacceptable "dark side" to too much autonomy?

The Dark Side of Unmanned Systems Autonomy

One of the most iconic films of the last century, Stanley Kubrick's *2001: A Space Odyssey* had as its central theme, the issue of autonomy of robots (the unmanned vehicles of the time). Few who saw the movie can forget the scene where astronauts David Bowman and Frank Poole consider disconnecting HAL's (**H**euristically programmed **AL**gorithmic computer) cognitive circuits when he appears to be mistaken in reporting the presence of a fault in the spacecraft's communications antenna. They attempt to conceal what they are saying, but are unaware that HAL can read their lips. Faced with the prospect of disconnection, HAL decides to kill the astronauts in order to protect and continue its programmed directives.

While few today worry that a 21st century HAL will turn on its masters, the issues involved with fielding increasingly-autonomous unmanned systems are complex, challenging and contentious. Kubrick's 1968 movie was prescient. A half-century later, while we accept advances in other aspects of unmanned systems improvements such as propulsion, payload, stealth, speed, endurance and other attributes, we are still coming to grips with how much autonomy is enough and how much may be too much. This is arguably *the* most important issue we need to address with respect to military unmanned systems over the next decade.

These ongoing debates have spawned a cottage industry of books that attempt to address the issue of AI, autonomy, and unmanned systems, especially armed military unmanned systems. Books such as *Wired for War*, *Killing by Remote Control, Drones, Data and the Illusion of Perfect Warfare*, *Rethinking the*

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[36] Remarks by Chief of Naval Operations, John Richardson, at the Sea Services Panel, AFCEA/Naval Institute "West" Conference, February 8, 2018.
[37] JASON Report, *Perspectives on Research in Artificial Intelligence and Artificial General Intelligence Relevant to DoD* (McLean, VA: The MITRE Corporation, January 2017), accessed at: https://fas.org/irp/agency/dod/jason/ai-dod.pdf.

Drone War and *Army of None* represent just a sample of the books that seek to address this complex issue in a thoughtful manner.[38]

Unmanned systems will become more autonomous in direct proportion to their ability to sense the environment and adapt to it. This capability enables unmanned systems to achieve enhanced speed in decision making and allows friendly forces to act within an adversary's OODA (Observe, Orient, Decide, and Act) loop.[39] As the environment or mission changes, the ability to sense and adapt will allow unmanned systems to find the optimal solution for achieving their mission, without the need to rely on *constant* human operator oversight, input and decision-making. But while we need unmanned systems to operate inside the enemy's OODA loop, are we ready for them to operate without our decision-making—to operate inside *our* OODA loops?

In an article entitled, "Morals and the Machine," *The Economist* addressed the issue of autonomy and humans-in-the-loop this way:

> As they become smarter and more widespread, autonomous machines are bound to end up making life-or-death decisions in unpredictable situations, thus assuming—or at least appearing to assume—moral agency. Weapons systems currently have human operators "in the loop", but as they grow more sophisticated, it will be possible to shift to "on the loop" operation, with machines carrying out orders autonomously.
>
> As that happens, they will be presented with ethical dilemmas. Should a drone fire on a house where a target is known to be hiding, which may also be sheltering civilians? Should a driverless car swerve to avoid pedestrians if that means hitting other vehicles or endangering its occupants? Should a robot involved in disaster recovery tell people the truth about what is happening if that risks causing a panic?
>
> Such questions have led to the emergence of the field of "machine ethics," which aims to give machines the ability to make such choices appropriately—in other words—to tell right from wrong. More collaboration is required between engineers, ethicists, lawyers and policymakers, all of whom would draw up very different types of rules if they were left to their own devices.[40]

Bill Keller put the issue of autonomy for unmanned systems this way in his Op-ed, "Smart Drones," in the *New York Times*:

> If you find the use of remotely piloted warrior drones troubling, imagine that the decision to kill a suspected enemy is not made by an operator in a distant control room, but by the machine itself. Imagine that an aerial robot studies the landscape below, recognizes

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[38] See, for example, Peter Singer, *Wired for War*: The Robotics Revolution and Conflict in the 21st Century (New York, Penguin Press, 2009), Bradley Strawser and Jeff McMahan, *Killing By Remote Control: The Ethics of an Unmanned Military* (Oxford, U.K.: Oxford University Press, 2013), William Arkin, *Data and the Illusion of Perfect Warfare* (New York: Little Brown and Company, 2015), Larry Lewis and Diane Vavrichek, *Rethinking the Drone War* (Washington, D.C., Center for Naval Analysis, 2016), and Paul Scharre, *Army of None: Autonomous Weapons and the Future of War* (New York, W.W. Norton and Company, 2018).

[39] See previous footnote on the OODA loop.

[40] "Flight of the Drones: Why the Future of Air Power Belongs to Unmanned Systems," *The Economist*, October 8, 2011.

hostile activity, calculates that there is minimal risk of collateral damage, and then, with no human in the loop, pulls the trigger.

Welcome to the future of warfare. While Americans are debating the president's power to order assassination by drone, powerful momentum—scientific, military and commercial—is propelling us toward the day when we cede the same lethal authority to software.[41]

More recently, while it may seem counterintuitive, concerns about autonomous machines and artificial intelligence are also coming from the very industry that is most prominent in developing these technological capabilities. The author of a *New York Times* article entitled, "Robot Overlords? Maybe Not," Alex Garland, director of the movie "Ex Machina," talked about artificial intelligence and quoted several tech industry leaders.

The theoretical physicist Stephen Hawking told us that "the development of full artificial intelligence could spell the end of the human race." Elon Musk, the chief executive of Tesla, told us that A.I. was "potentially more dangerous than nukes." Steve Wozniak, a co-founder of Apple, told us that "computers are going to take over from humans" and that "the future is scary and very bad for people."[42]

The Department of Defense is addressing the issue of human control of unmanned systems as a first-order priority and has issued policy direction to ensure that humans *do* remain in the OODA loop. A directive by then-Deputy Secretary of Defense Ashton Carter issued the following guidance:

Human input and ongoing verification are required for autonomous and semi-autonomous weapon systems to help prevent unintended engagements. These systems shall be designed to allow commanders and operators to exercise appropriate levels of human judgment over the use of force. Humans who authorize the use of, or operate these systems, must do so with appropriate care and in accordance with the law of war, applicable treaties, weapon system safety rules and applicable rules of engagement. An autonomous system is defined as a weapon system that, once activated, can select and engage targets without further intervention by a human operator.[43]

These are the kinds of directives *and* discussions that are—and should be—part of the dialogue between and among policy makers, military leaders, industry, academia and the science and technology community as the design and operation of tomorrow's autonomous systems are thoughtfully considered. As then-Deputy Secretary of Defense Robert Work noted during his remarks at the Center for New American Security Defense Forum, "We believe, strongly, that humans should be the only ones to decide when to use lethal force. But when you're under attack, especially at machine speeds, we want to have a machine that can protect us."[44]

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[41] Bill Keller, "Smart Drones," *The New York Times*, March 10, 2013.
[42] Alex Garland, "Alex Garland of 'Ex Machina' Talks About Artificial Intelligence," *The New York Times*, April 22, 2015.
[43] Deputy Secretary of Defense Ashton Carter Memorandum, "Autonomy in Weapon Systems," dated November 21, 2012, updated on May 8, 2017 accessed at: http://www.defense.gov/. See also, "Carter: Human Input Required for Autonomous Weapon Systems," *Inside the Pentagon*, November 29, 2012 for a detailed analysis of the import of this memo.
[44] Remarks by Deputy Secretary of Defense Robert Work at the Center for New American Security Defense Forum, December 14, 2015.

More recently, in an address at the AFCEA/Naval Institute "West" Conference, the Navy's budget director, Rear Admiral Dietrich Kuhlmann, put the question of how the Navy can best use big data, artificial intelligence and machine learning this way: "How do we leverage AI, not to produce autonomous platforms that kill people, but to give commanders the edge in combat?"[45] Indeed, the essence of what the U.S. Navy—and by extension, the U.S. military—wants to do with big data, machine learning and artificial intelligence is not to launch Terminator-like unmanned systems downrange against our adversaries with no human oversight, but to help operators make faster, more-informed decisions.

Military operators will *always* be in the loop, and will be *assisted* by big data, machine learning and artificial intelligence. What the military wants to achieve with these cutting-edge technologies – whether applied to unmanned systems or to other aspects of warfighting – is to get inside the adversary's OODA loop. The Honorable James Geurts, Assistant Secretary of the Navy for Research, Development and Acquisition, put it this way at a military-industry conference, "If a force can harness AI to allow decision makers to make decisions faster than the adversary, it will win every time."[46]

It is one thing to issue policy statements, but quite another to actually *design* autonomous systems to carry out the desired plan. This is a critical point from a policy perspective, because although one can choose to abdicate various levels of decision-making to an autonomous machine, one cannot escape responsibility for the resulting actions. In highly autonomous systems, the system becomes opaque to the operator and these operators frequently ask questions such as: What is it doing? Why is it doing that? What's it going to do next?[47] It is difficult to see how an operator can fulfill his or her responsibility for the autonomous system's actions if these questions are being asked.

Trying to determine what degree of autonomy is desired and how to achieve it is not a trivial undertaking and—in Albert Einstein's words—will require a new way of "figuring out how to think about the problem."[48] And importantly, most informed discussion begins with the premise that adversaries who intend to use UxS against United States' interests will *not* be inhibited by the kinds of legal, ethical and moral strictures the United States adheres to. Designing the right degree of autonomy into our unmanned systems is *the* central issue that will determine their success or failure.

Designing in the *Right* Degree of Autonomy

Most of us are familiar with the children's fable, *Goldilocks and the Three Bears*. As Goldilocks tastes three bowls of porridge she finds one too hot, one too cold, and one just right. As the DoD and the Services look to achieve the optimal balance of autonomy and human interaction—to balance these two often-opposing forces and get them "just right"—designing this capability into tomorrow's unmanned systems at the outset, rather than trying to bolt it on after the fact, may be the only sustainable road ahead. If we fail to do this, it is almost inevitable that concerns that our armed unmanned systems will take on

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[45] Rear Admiral Dietrich Kuhlmann, AFCEA/Naval Institute "West" Conference, February 6, 2018.

[46] The Honorable James Geurts, Assistant Secretary of the Navy for Research, Development and Acquisition, Keynote Remarks, AFCEA/Naval Institute "West" Conference, February 6, 20-18.

[47] The issue of "explainability" of autonomous systems has been addressed in both the professional and popular literature. See, for example, Cliff Kuang, "Can A.I. Be Taught to Explain Itself?" *The New York Times*, November 21, 2017, accessed at: https://www.nytimes.com/2017/11/21/magazine/can-ai-be-taught-to-explain-itself.html.

[48] Wilber Shramm and William Porter, Men, *Women, Messages and Media: Understanding Human Communication* (New York: Harper and Rowe, 1982).

"HAL-like" powers and be beyond our control will derail the promise of these important warfighting partners.[49]

A key to building the right degree of autonomy in unmanned systems intended for military use is to be mindful of the old saying, "where you stand depends on where you sit." Users and those who design unmanned systems often approach what they are trying to accomplish from different—often demonstrably different—points of view. A Naval Research Advisory Committee report identified four distinct points of view that must be reconciled in designing unmanned systems with the right degree of autonomy.

- **User View:** Can I give this platform a task, and trust it to accomplish it without constant attention? Can it recognize and deal with unexpected events or ambiguous tasking?

- **Robotics View:** Can I build a practical robot that does the right thing at the right time? Can I dynamically control, navigate, actuate, and instrument my robot? Can it manage and fuse data?

- **Machine Learning View:** Can my machine interpret complex sensors? Can it understand spoken language, interpret gestures, or recognize people or objects?

- **Cognitive View:** Can I make a machine that replicates elements of human intelligence like cognition, inference, and reasoning?[50]

Another important consideration in designing the right degree of autonomy in our military unmanned systems is to not over-reach in what we want these systems to accomplish. Said another way, in our efforts to enable unmanned systems to have more autonomy and to undertake more-and-more complex tasks—a worthwhile goal—it is important not to sacrifice system reliability. The increasingly complex sensing and intervention tasks unmanned systems are being asked to accomplish cannot succeed unless basic vehicle navigation and control tasks the unmanned system must perform are not sacrificed in the quest for the platform to do "just one more thing."

Dr. Thomas Curtin has suggested "Seven Core Competencies" required for fundamental autonomy (survival) and higher order autonomy (mission accomplishment) in unmanned vehicles:

- **Navigation**: Accurately ascertaining position and planning and following a route

- **Environmental Adaption**: Sensing the surrounding medium and re-positioning for advantage

- **Stationary Object Identification in Cluttered Environments**: Distinguishing non-moving signatures in noise

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[49] We have addressed this issue in a number of professional journals. See, for example, George Galdorisi and Rachel Volner, "Keeping Humans in the Loop," *U.S. Naval Institute Proceedings*, February 2015, George Galdorisi, "Designing Autonomous Systems for Warfighters," *Small Wars Journal*, August 2016, and George Galdorisi, "Producing Unmanned Systems Even Lawyers Can Love," *U.S. Naval Institute Proceedings*, June 2018.

[50] Naval Research Advisory Committee, *How Autonomy Can Transform Naval Operations* (Washington, D.C., Department of the Navy, October 2012), accessed at: http://www.nrac.navy.mil/docs/NRAC_Final_Report-Autonomy_NOV2012.pdf.

- **Moving Object Identification in Dispersed Environments**: Distinguishing moving signatures with scattered, intermittent indicators

- **Object Manipulation/Intervention**: Physical interaction with an object external to the vehicle

- **Object (Payload) Delivery/Retrieval**: Deploy or retrieve an object on or within the vehicle

- **Multi-objective Optimization with Multiple Constraints**: Continuously analyze trade-offs and decide on best course of action to accomplish a mission in an evolving situation

While Dr. Curtin's hierarchy of design factors evolved from his work with unmanned surface systems and unmanned undersea systems, they apply equally as well to all unmanned systems. The important point he makes is that as designers attempt to build more complex missions into these systems, oftentimes the most basic functions—like navigation and communication—are overlooked, resulting in mission failure.[51] For military unmanned systems, which must perform tasks in an "unstructured environment," the two primary attributes the system must have are: self-sufficiency—the ability to take care of itself—and self-directedness—the ability to act without outside control.[52]

The capabilities required to find this "just right" balance of autonomy in military unmanned systems must leverage many technologies that are still emerging. The military knows what it *wants* to achieve, but often not what technologies or even capabilities it *needs* in order to field UxS with the right balance of autonomy and human interaction. A key element of this quest is to worry less about what attributes—speed, service ceiling, endurance, and others—the machine itself possesses and instead focus on what is *inside* the machine. The Defense Science Board report, *The Role of Autonomy in DoD Systems*, put it this way:

> Instead of viewing autonomy as an intrinsic property of unmanned systems in isolation, the design and operation of unmanned systems needs to be considered in terms of human-systems collaboration…A key challenge for operators is maintaining the human-machine collaboration needed to execute their mission, which is frequently handicapped by poor design…A key challenge facing unmanned systems developers is the move from a

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[51] Dr. Thomas Curtin, "Autonomy Through Competition," presented at the 2016 MTS/IEEE Oceans Conference, Monterey, CA, September 20, 2016. Dr. Curtin's "back to basics" is eerily prescient. In year following his presentation, the U.S. Navy suffered a string of accidents – two of them fatal – involving their manned vessels, prompting the Navy's top leaders to order the Navy Fleet to reemphasize skills such as basic seamanship and navigation, and other fundamental operational skills. See, for example, Eric Schmitt, "Navy Returns to Compasses and Pencils to Help Avoid Collisions at Sea," *The New York Times*, September 27, 2017, accessed at: https://www.nytimes.com/2017/09/27/us/politics/navy-orders-safety-operational-standards.html?_r=0 andSam LaGrone and Ben Werner, "Investigation: USS Fitzgerald, USS John McCain 'Avoidable' Collisions Due to Lapses in Basic Seamanship," *USNI News*, November 1, 2017. Accessed at: https://news.usni.org/2017/11/01/investigation-uss-fitzgerald-uss-john-mccain-avoidable-collisions-due-lapses-basic-seamanship?utm_source=USNI+News&utm_campaign=8c8aa4606b-USNI_NEWS_DAILY&utm_medium=email&utm_term=0_0dd4a1450b-8c8aa4606b-230420609&mc_cid=8c8aa4606b&mc_eid=157ead4942, "Navy Says Fatal Collisions Were Caused by 'Avoidable' Blunders,: The New York Times, November 1, 2017, accessed at: https://www.nytimes.com/2017/11/01/us/politics/navy-collisions-avoidable.html?_r=0, and Bryan McGrath, "What we Learned From the Navy's Collision Inquires," *War on the Rocks*, November 2, 2017, accessed at: https://warontherocks.com/2017/11/what-we-learned-from-the-navys-collision-inquiries/.

[52] Why 'Unmanned Systems' Don't Shrink Manpower Needs," *Armed Forces Journal*, October 1, 2011

hardware-oriented, vehicle-centric development and acquisition process to one that emphasizes the primacy of software in creating autonomy.[53]

One need only attend an industry conference where unmanned systems are being displayed at multiple booths to understand that today the emphasis is almost completely on the machine itself. What is inside is typically not a primary consideration. But as the Defense Science Board notes, it is software that is the primary driver of capabilities. For example, the manned F-35 Lightning has ten billion lines of computer code and there is human supervision by the pilot. How many lines of code will need to be built into an unmanned system to get the balance of autonomy and human interaction just right?

Some of the controversy regarding military unmanned systems stems from a lack of precision in terminology. One way to help clarify this ambiguity is to ensure that when the word autonomy is used, it refers to the relationship between the person and the machine. Machines that perform a function for some period of time, then stop and wait for human input before continuing, are often referred to as semiautonomous or as having a *human in the loop*. Machines that can perform a function entirely on their own but have a human in a monitoring role, with the ability to intervene if the machine fails or malfunctions, are often referred to as human-supervised autonomous or *human on the loop*. Machines that can perform a function entirely on their own with humans unable to intervene are often referred to as fully autonomous or *human out of the loop*. This suggests that we need to recalibrate some of the debate on autonomous weapons to more accurately distinguish between increased autonomy *in* weapons and autonomous weapons. In this sense, autonomy is not about the intelligence of the machine, but rather its relationship to a human controller.[54]

For the relatively small numbers of unmanned systems that will engage an enemy with a weapon, this balance is crucial. Prior to firing a weapon, the unmanned platform needs to provide the operator—and there must be an operator in the loop—with a "pros and cons" decision matrix regarding what that firing decision might entail. When we build that capability into unmanned systems we will, indeed, have gotten it just right and the future of military unmanned systems will be bright.

Into the Future with Unmanned Systems, Big Data, Artificial Intelligence and Machine Learning

We began this paper with the thesis that unmanned systems and artificial intelligence have the potential to critical partners to the Joint warfighter. But this can only happen if the rapid—some would say galloping—technological advances in unmanned systems, big data, artificial intelligence and machine learning take into account valid moral and ethical considerations regarding their use. Perhaps most importantly, as senior U.S. Department of Defense officials have emphasized, from the U.S. DoD perspective, unmanned systems must *always* have the option for human control and verification, especially when it comes to the use of lethal force by unmanned systems with artificial intelligence.

This goes directly to the issue of man-machine teaming and what it means to military operators. Perhaps the best way to address this is to consider one of the most recognized photographs from World War II. Taken by First Lieutenant John Moore of the U.S. Signal Corps, the photo depicts General Dwight Eisenhower talking with men of the 101st Airborne division on June 5, 1944, the day before the invasion

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[53] Defense Science Board, *Task Force Report: The Role of Autonomy in DoD Systems*, July 2012.
[54] Paul Scharre, "Centaur Warfighting: The False Choice of Humans Vs. Automation," accessed at: https://sites.temple.edu/ticlj/files/2017/02/30.1.Scharre-TICLJ.pdf

of Normandy. Previously, Eisenhower had been briefed by Air Marshal Leigh-Mallory that the 101st was one of two units that would suffer 80% casualties during the invasion.

Those who study the impact of unmanned systems on military operations—especially those who are strong advocates of unmanned systems—can look at this photo and can envision General Eisenhower speaking not with American airborne soldiers, but with robots that he will send into battle. Those who fear unmanned systems might picture the American airborne soldiers as the photo depicts them, but instead of General Eisenhower, they would envision a robot commanding the soldiers—clearly an untenable situation. But those who thoughtfully consider the impact of unmanned systems on military operations would envision General Eisenhower addressing a team of American airborne soldiers standing with their robot partners.

These unmanned systems with big data, artificial intelligence and machine learning are especially important to the military users. Those responsible for the concepts, research, development, building, fielding and use of these systems might be well-served to look into the commercial trade space, to the automobile industry, for best-practices examples. It is here that we may well find that vital customer feedback that indicates what drivers *really* want. And while not a perfect one-to-one match, this analogy can suggest what kinds of unmanned systems supported by big data, artificial intelligence and machine learning industry should offer to the military.[55]

Automobiles are being conceived, designed, built and delivered supported by increasing degrees of big data, artificial intelligence and machine learning. It is worth examining where these trend lines are going. Put a bit simplistically, automobiles can be broken down into three basic categories:

- A completely manual car—something your parents drove
- A driverless car that takes you where you want to go via artificial intelligence[56]
- A car with augmented intelligence

The initial enthusiasm for driverless cars has given way to second thoughts regarding how much a driver may be willing to be taken completely out of the loop. One article in particular, in the *New York Times*, "Whose Life Should Your Car Save?" captures the concerns of many. An excerpt from this article captures the essence of the public's concern with driverless cars, and by extension, with other fully autonomous systems:

> We presented people with hypothetical situations that forced them to choose between "self-protective" autonomous cars that protected their passengers at all costs, and "utilitarian" autonomous cars that impartially minimized overall casualties, even if it meant harming their passengers. (Our vignettes featured stark, either-or choices between saving one group of people and killing another, but the same basic trade-offs hold in more realistic situations involving gradations of risk.)

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[55] Dr. Peter Singer, author of *Wired for War*, put it this way in an April 27, 2017 address to the AFCEA C4ISR Symposium in San Diego, California, "What is playing out in driverless cars is also playing out in military UxS. You will never be able to 'engineer out' all of the ethical dilemmas surrounding the use of military UxS."

[56] While the term, "driverless car," is used generally to refer to automobiles with varying levels of artificial intelligence, the most generally accepted rule of thumb is that used by the Society of Automotive Engineers (SAE) in referring to these vehicles lists six levels of driving automation: no automation, drive assistance, partial automation, conditional automation, high automation and full automation. See: https://web.archive.org/web/20170903105244/https://www.sae.org/misc/pdfs/automated_driving.pdf.

A large majority of our respondents agreed that cars that impartially minimized overall casualties were more ethical, and were the type they would like to see on the road. But most people also indicated that they would refuse to purchase such a car, expressing a strong preference for buying the self-protective one. In other words, people refused to buy the car they found to be more ethical.[57]

As the study referenced in this article—as well as an increasing number of analyses and reports indicate—there is a growing consensus among consumers that drivers want to be "in the loop" and that they want semi- and not fully-autonomous cars. That may change in the future…but perhaps not. And it should help inform how we think about military unmanned systems.

Extrapolating this every-day example to the military unmanned systems, we believe—and we think the available evidence, including some of the most cutting-edge work going on today—strongly suggests that warfighters want *augmented* intelligence in their unmanned machines.[58] That will make these machines more useful and allow warfighters to control them in a way that will go a long way toward resolving many of the moral and ethical concerns related to their use. The aforementioned JASON report highlighted *augmented* intelligence as the way that AI can best support the human operator, noting, "The use of AI to augment human performance is a key application area for DoD and is closer to real implementation than AGI."[59]

This augmented intelligence would provide the elegant solution of enabling warfighters to use unmanned systems as partners, not separate entities. Fielding autonomous deep learning systems that enable operators to teach these systems how to perform desired tasks is the first important step in this effort. This will lead directly to the kind of human-machine collaboration that transitions the "artificial" nature of what the autonomous system does into an "augmented" capability for the military operator.

Ultimately, this will lead to the kind of advanced human-machine combat teaming that will enable warfighters—now armed with augmented intelligence provided by their unmanned partners—to make better decisions faster with fewer people and fewer mistakes. This will also keep operators in-the-loop when they need to be, for example, when lethal action is being considered or about to be taken, and on-the-loop in more benign situations, for example, when an unmanned aerial system is patrolling vast areas of the ocean during a surveillance mission.

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[57] Azim Shariff, Iyad Rahwan and Jean-Francois Bonnefon, "Whose Life Should Your Car Save?" *The New York Times*, November 6, 2016. See also Aaron Kessler, "Riding Down the Highway, with Tesla's Code at the Wheel," *The New York Times*, October 15, 2015.

[58] The term "augmented intelligence," is beginning to appear in professional journals. See, for example, Scott Swift, "Master the Art of Command and Control," *U.S. Naval Institute Proceedings*, February 2018, where Admiral Swift notes: "Furthermore, there is a greater and exceedingly useful role that technology can play in the service of C2. It is found in the emergence of artificial intelligence, or what some refer to as intelligence amplification, others as intelligence augmentation. These terms refer to the use of machines to better inform decisions, not to replace or marginalize decision makers." Article accessed at: https://www.usni.org/magazines/proceedings/2018-02/master-art-command-and-control. Said another way, at the February 2018 AFCEA.USNI "West" Symposium, Lieutenant General Robert Wood, AFCEA Executive Vice President for Defense, noted: "We need the augmented intelligence AI can provide."

[59] JASON Report, *Perspectives on Research in Artificial Intelligence and Artificial General Intelligence Relevant to DoD*. AGI refers to Artificial General Intelligence a research area within AI that seeks to build machines that can perform any task that humans might do.

But this generalized explanation begs the question—what would augmented intelligence *look like* to the military operator. What tasks does the warfighter want the unmanned system to perform as they move beyond artificial intelligence to provide augmented intelligence to enable the Soldier, Sailor, Airman or Marine in the fight to make the right decision quickly in stressful situations where mission accomplishment must be balanced against unintended consequences?

Returning to our discussion of the OODA loop, the ability of big data, artificial intelligence a machine learning to help commanders enhance their speed of decision, the first step in the is process, Observe, requires a well-nuanced awareness of the battlespace. Battlespace awareness requires the capability to automatically correlate relevant active and passive information from organic and nonorganic sensors with intelligence at all classifications and compartments for presentation to the commander. Most analysis looks backward in time to interpret data. Predictive analytics seeks to identify the relationships underlying threat behavior; quite different from the correlation-based forecasting models of today.[60] Augmented intelligence can lead directly to refined predictive analysis regarding any contacts an unmanned system uncovers.

Consider the case of a ground, surface, subsurface or aerial unmanned systems conducting a surveillance mission. Today, an operator receives streaming video of what the unmanned systems sees, and in the case of aerial unmanned systems, often in real time. But this requires the operator to stare at this video for hours on end (the endurance of the U.S. Navy's MQ-4C Triton is thirty hours). This concept of operations is an enormous drain on human resource, often with little to show for the effort.

Using basic augmented intelligence techniques, the MQ-4C can be trained to deliver only that which is interesting and useful to its human partner. For example, a Triton operating at cruise speed flying between San Francisco and Tokyo would cover the five-thousand-plus miles in approximately fifteen hours. Rather than send fifteen hours of generally uninteresting video as it flies over mostly empty ocean, the MQ-4C could be trained to only send the video of each ship it encounters, thereby greatly compressing human workload.

Taken to the next level, the Triton could do its own analysis of each contact to flag it for possible interest. For example, if a ship is operating in a known shipping lane, has filed a journey plan with the proper maritime authorities, and is providing an AIS (Automatic Identification System) signal; it is likely worthy of only passing attention by the operator, the Triton will flag it accordingly. If, however, it does not meet these criteria (say, for example, the vessel makes an abrupt course change that takes it well outside normal shipping channels), the operator would be alerted immediately. As this technology continues to evolve, a Triton MQ-4C—or other UxS—could ultimately be equipped with detection and classification algorithms that have the potential to lead to automatic target recognition, even in unfavorable weather conditions and sea states.

For lethal military unmanned systems, the bar is higher for what the operator must know before authorizing the unmanned warfighting partner to fire a weapon—or as is often the case—recommending that higher authority authorize lethal action. For example, consider the case of military operators managing an ongoing series of unmanned aerial systems flights that have been watching a terrorist and waiting for higher authority to give the authorization to take out the threat using an air-to-surface missile fired from that UAS.

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[60]Wilson, "Distributed Lethality Requires Distributed (Artificial) Intelligence,"

Using augmented intelligence, the operator can train the unmanned aerial system to anticipate what questions higher authority will ask prior to giving the authorization to fire, and provide, if not a point solution, at least a percentage probability or confidence level to questions such as:

- What is level of confidence this person is the intended target?

- What is this confidence based on?
    - Facial recognition
    - Voice recognition
    - Pattern of behavior
    - Association with certain individuals
    - Proximity of known family members
    - Proximity of known cohorts

- What is the potential for collateral damage to?
    - Family members
    - Known cohorts
    - Unknown persons

- What are the potential impacts of waiting verses striking now?

These considerations represent only a subset of the kind of issues operators must train their unmanned systems armed with lethal weapons to deal with. Far from ceding lethal authority to unmanned systems, providing these systems with augmented intelligence and leveraging their ability to operate inside the enemy's OODA loop, as well as ours, enables these systems to free the human operator from having to make real time—and often on-the-fly—decisions in the stress of combat. Designing this kind of augmented intelligence into unmanned systems from to outset will ultimately enable them to be effective partners for their military operators.

This focus on augmented intelligence brings us full-circle back to some of the concerns raised by Deputy Secretary of Defense Robert Work. He noted that when the enemy is attacking us at "machine speeds," we need to exploit machines to help protect us. The importance of augmented intelligence in the man-machine symbiosis was highlighted in a recent U.S. Air Force *Technology Horizons* report which noted: "Although humans today remain more capable than machines for many tasks, natural human capacities are becoming increasingly mismatched to the enormous data volumes, processing capabilities, and decision speeds that technologies offer or demand. Closer human-machine coupling and augmentation of human performance will become possible and essential."[61] Building unmanned systems with augmented intelligence that can partner with operators in this effort is what will ultimately ensure that the unmanned systems we build reach their full potential to help our warfighters win in combat.

Enhancing the Dialogue Among Unmanned Systems Stakeholders

In many ways, technology has driven mankind's progress, but each new advance has posed troubling questions. Unmanned machines that become more autonomous through the use of big data, artificial

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[61] *Technology Horizons: A Vision for Air Force Science and Technology 2010-2030*, accessed at: http://www.defenseinnovationmarketplace.mil/resources/AF_TechnologyHorizons2010-2030.pdf

intelligence and machine learning are no different. The sooner the questions of moral agency discussed here are answered, the easier it will be for our warfighters to enjoy the full benefits that unmanned systems can deliver as warfighting partners. As we noted earlier in the *Economist* article we cited, more collaboration is required between policymakers, engineers, ethicists and lawyers and all of whom would draw up very different types of rules if they were left to their own devices.

As one way of establishing and sustaining this kind of informed dialogue, in 2011, then-Undersecretary of the Navy Robert Work established the Naval Postgraduate School (NPS) Consortium for Robotics and Unmanned Systems Education and Research (CRUSER). The impetus behind creating this organization was to establish and nourish a collaborative environment and community of interest for the advancement of unmanned systems (UxS) education and research endeavors across the Navy, Marine Corps, and Department of Defense.

CRUSER represents an initiative designed to build an inclusive community of interest around the application of unmanned systems in military operations. CRUSER seeks to catalyze these efforts, both internal and external to the Naval Postgraduate School, by facilitating active means of collaboration, providing a mechanism for information exchange among researchers and educators with mutual, collaborative interests. This process is designed to foster innovation through directed programs of operational experimentation, and supporting the development of educational ventures.

CRUSER deals with a broad array of issues related to emerging unmanned systems technologies, and integrates much of the successful research, education, and experimentation efforts in UxS currently ongoing at NPS and across the military enterprise. Controls, sensors, design, architectures, human capital resource requirements, concept generation, risk analysis, cyber-security, and field experimentation are just a few of the areas where CRUSER has equities. The success of this collaborative organization is measured not only in its growing membership and focused research and enhanced experimentation, but in the inclusiveness of its dialogue among academics, industry professionals, military officials, and the policy and legal communities.

CRUSER workshops explore a number of issues relating to unmanned systems, from examining the ethics of employing autonomous or semi-autonomous systems; to exploring detailed cost models for autonomous or semi-autonomous maritime systems, to looking at the future of warfare dominated by unmanned systems. These events put critical (non-technological) issues under the spotlight for examination by hundreds of academics, warfighters and policy makers. An important aspect of CRUSER's research involves unmanned aerial systems. For example, CRUSER researchers have worked to develop operational risk methodologies for enhancing UAV flight safety. This has led to CRUSER successfully flying the world's first fifty-UAV autonomous swarm.[62]

One of CRUSER's close partners in unmanned systems development is Space and Naval Warfare Systems Center Pacific (SSC Pacific). As the Navy's C4ISR (command, control, communications, computers, intelligence, surveillance and reconnaissance) Center of Excellence, SSC Pacific has a decades-long history of working with unmanned systems in all four domains: land, air, surface and undersea. Over four hundred scientists and engineers at SSC Pacific work on over forty distinct unmanned systems projects.

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[62] Details on the Naval Postgraduate School's CRUSER Consortium can be found at: https://my.nps.edu/web/cruser.

The primary focus of SSC Pacific's unmanned systems work involves equipping these systems with C4ISR capabilities that will enable them to be useful tools—and partners—for our U.S. military warfighters. Key to this work is to enable our warfighters—especially those operating unmanned systems—to make better decisions faster with fewer people and fewer mistakes. Innovation plays a key role in this effort, and SSC Pacific's scientists and engineers are increasingly in demand to provide these state-of-the-art solutions. As The Honorable Frank Kendall, then-Undersecretary of Defense for Acquisition, Technology and Logistics put it:

> SSC Pacific is one of the Department of Defense's most important engines of innovation. Our biggest investments in science and technology are in the laboratory systems, and they are going to accelerate technology.[63]

Among the most important unmanned systems projects at SSC Pacific are those involving advanced autonomy, sensor fusion, communications pathways, air, sea, and subsurface integration, swarming, autonomous deep learning systems, human machine collaboration, assisted human operations, advanced human-machine combat teaming, network-enabled autonomous weapons, and autonomous systems test and evaluation.

Importantly, an increasing focus of SSC Pacific's unmanned systems work involves partnering with DARPA (Defense Advanced Research Projects Agency) and ONR (Office of Naval Research) on unmanned systems projects. This effort typically involves work in the basic sciences in support of the Department of Defense's Unmanned Systems Roadmap. As each project evolves, SSC Pacific scientists and engineers take the unmanned system effort to the next level, from modeling and simulation, to test and evaluation, to fielding of various capabilities.

While not comprehensive, a partial listing of SSC Pacific's current work with unmanned systems shows the scope of the Center's innovative efforts in this area. Of note, these projects involve a wide range of collaborators and feature unmanned systems work in all four unmanned systems domains.

- ACTUV (ASW Continuous Trail Unmanned Vessel) Sea Hunter project
- LDUUV (Large Displacement Unmanned Underwater Vehicle) project
- DARPA CODE (Collaborative Operations in Denied Environment) swarm project
- ONR UxS Common Control Station project
- DARPA Cross-Domain Maritime Surveillance and Targeting
- ONR HAMMER (Heterogeneous Autonomous Mobile Maritime Expeditionary Robots)
- ONR Integrated Ground Technology Technologies for Expeditionary Environments
- PMS 408 Mk18 UUV Program (EOD for UUVs)
- MOCU (Multi-Operator Control Unit) project
- SSC Pacific Human-Autonomy Teaming project
- U.S. Navy MQ-4 Triton Unmanned Aircraft Systems Integration project
- U.S. Air Force Global Hawk project integration efforts

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[63] The Honorable Frank Kendall, Undersecretary of Defense for Acquisition, Technology and Logistics, roundtable remarks, August 24, 2016.

SSC Pacific has the core, in-house expertise, as well as a wide range of industry partners to develop, integrate, test and evaluate unmanned systems technologies from basic research to operational fielding. Much of this work directly supports the unmanned systems initiatives that are part of the U.S. military's Third Offset Strategy.

The Challenge and the Way Ahead

Industry *wants* to design and build unmanned systems the military customer will buy and use. The sooner the military officials signal the desire to field unmanned systems with *augmented* intelligence, the more likely it will be that warfighters in the field will have the optimally designed unmanned systems that will function in concert with human operators and manned systems with just the right degree of human oversight and control. From the United States perspective, the ultimate beneficiary will be the U.S. Joint warfighters and their allied and coalition partners who will then able to employ these systems within the constructs of the law of war and rules of engagement.

Military operators must be provided with unmanned systems where big data, artificial intelligence and machine learning are utilized in a way to ensure that the operator—whether he is in the loop, on the loop, or off the loop—knows what the unmanned system is doing. The warfighter must *never* have to ask the question: "What is the machine doing? Why is it doing that?" Said another way, every unmanned system must have *explainability* as a first-order criterion.

As unmanned systems are fielded that meet these requirements, the human must also be the dominant teammate. This isn't to say that the unmanned system can't do amazing things that are out of reach for a human. What it *does* mean is that the human operator must not be tempted to cede complete authority to the machine.

While this scenario might initially seem farfetched, concerns about this human-machine balance are already appearing in the informed literature. For example, two psychologists addressed the pernicious way that we allow technology to be too dominant:

> To navigate by GPS is to ensure a series of meaningless pauses at the end of which you do precisely what you are told. There is something deeply dehumanizing about this. Indeed, in an important sense this experience turns you into an automated device GPS can use to arrive at its destination.[64]

As another example of how much algorithms can have a "creeping dominance" on our lives, consider a recent article by a writer who studied Uber drivers entitled, most would say appropriately, "When Your Boss is an Algorithm. Here's how he explained the daily dilemma of the over one million Uber drivers in the United States and Canada:

> Data and algorithms are presented as objective, neutral, even benevolent: Algorithms gave us super-convenient food delivery services and personalized movie recommendations. But Uber and other ride-hailing apps have taken the way Silicon Valley uses algorithms and applied it to work, and that's not always a good thing.

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[64] Hubert Dryfus and Sean Dorrance Kelly, *All Things Shining: Reading the Western Classics to Find Meaning in a Secular Age* (Tampa, Florida, Free Press, 2011).

The algorithmic manager seems to watch everything you do. Ride-hailing platforms track a variety of personalized statistics, including ride acceptance rates, cancellation rates, hours spent logged in to the app and trips completed. And they display selected statistics to individual drivers as motivating tools, like "You're in the top 10 percent of partners!" Uber uses the accelerometer in drivers' phones along with GPS and gyroscope to give them safe driving reports, tracking their performance in granular detail. One driver posted to a forum that a grade of 210 out of 247 "smooth accelerations" earned a "Great work!" from the boss.

Surge pricing, which multiplies prices for passengers and earnings for drivers during periods of high demand, is another form of algorithmic management that encourages drivers to relocate to certain areas at certain times. The drivers get in-app notifications, heat maps and emails with real-time and predictive information about spikes in demand. A driver who wants to go home and is trying to log out might be prompted with an automatic message: "Your next rider is going to be awesome! Stay online to meet him."

Their experiences serve as a useful warning about the algorithms that are so closely integrated into our daily lives. Algorithms determine the news we see on Facebook and the search results we review on Google. And whenever we use a ride-hailing app, algorithms manage what we do as passengers, by controlling and manipulating the information we have about the price and location of available cars.[65]

If there is one area that this creeping dominance of technology cannot be allowed to occur, it is on the battlefield. Beyond allowing an unmanned system pick the wrong target and kill, main or hurt innocent civilians, the dehumanizing—and PTSD-inducing—impact of warfighters employing lethal unmanned systems is now being examined and analyzed. The available evidence suggests that the ways in which the U.S. military currently employs armed unmanned systems can have powerful—and negative— impact on those who operate these systems.[66]

The weight of available evidence today suggests that the optimal choice for human-manned-unmanned integration is to design systems that will combine human and machine intelligence to create hybrid cognitive architectures that leverage the advantages of each. Hybrid human-machine cognition can leverage the precision and reliability of automation, without sacrificing the robustness and flexibility of human intelligence. This will enable the human controller to fully leverage the advantages of automation, while still acting as a moral agent and fail-safe.[67]

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[65] Alex Rosenblat, "When Your Boss is an Algorithm," *The New York Times*, October 12, 2018. Accessed at: https://www.nytimes.com/2018/10/12/opinion/sunday/uber-driver-life.html.

[66] See, for example, Eyal Press, "The Wounds of the Drone Warrior," *The New York Times*, June 13, 2018. Accessed at: https://www.nytimes.com/2018/06/13/magazine/veterans-ptsd-drone-warrior-wounds.html and Robert Latiff, "Rebooting the Ethical Soldier," *The New York Times*, July 16, 2018. Accessed at: https://www.nytimes.com/2018/07/16/opinion/sunday/high-tech-warfare.html, for just two of the many articles exploring the challenges of the man-machine teaming between operators and unmanned systems that many today take for granted. Additionally, as one indication of how deeply this issue of the impact of lethal unmanned systems on those who operate them has seeped into the popular culture, it should come as little surprise that this was one of the key themes addressed in the 2018 Amazon Prime "Jack Ryan" series. In this series we meet U.S. Air Force drone operator "Victor" who is so distraught that his armed drone may have killed the wrong person that he travels to the Middle East to offer money to the family of the man killed.

[67] See Peter W. Singer, "In the Loop? Armed Robots and the Future of War," accessed at:

The U.S. Department of Defense—as well as the defense organizations in other nations—would also be well-served to expand efforts like CRUSER. This would ensure that all those with a stake in the use of unmanned systems by the military—not just those in uniform, but engineers, ethicists, lawyers and policymakers—can have input into the *design* process of unmanned systems. This will ensure that all stakeholders in the often-controversial issue of armed unmanned systems can be fully engaged at the outset. The ultimate result will be a more closely coordinated military-industry partnership that will deliver the right unmanned systems capabilities to the nation's warfighters.

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http://www.brookings.edu/research/articles/2009/01/28-robots-singer.