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Autonomous Weapon Systems: A Brief Survey of Developmental, Operational, Legal, and Ethical Issues

Jeffrey L. Caton

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FOREWORD

Stories about unmanned vehicles now appear regularly in the national news—and not always in good ways. Within the last 2 years, privately-owned drones have crashed on the White House lawn, surveilled the U.S. Embassy in Paris, and buzzed German Chancellor Angela Merkel. When used in military operations, autonomous weapon systems (AWS) have the potential to save lives as well as apply lethal force across land, sea, and air.

In this Letort Paper, Mr. Jeffrey Caton posits that the development of AWS policy and doctrine should characterize autonomy not as a discrete property of a given system, but rather as a function that varies in its strategic, operational, and tactical context and mission application. Further, he argues that AWS design, planning, and operations should be tempered with the purposeful consideration of human judgment and control as well as legal and ethical standards that foster international credibility.

Through its current military operations, the United States is setting both overt and tacit precedents for the world with regard to the appropriate use of AWS. This Paper provides readers with background information crucial to the full understanding of the complex challenges facing the future development and operation of AWS across the full range of military operations.

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SUMMARY

The use of autonomous weapon systems (AWS) in warfare is not a new concept. One could argue that the development and integration of such systems have evolved over the last century and accelerated significantly after the September 11, 2001 (9/11) attacks on the U.S. homeland. AWS will likely continue to grow in both capabilities and numbers. This growth of unmanned systems is not limited to the U.S. military or even the United States; it is an international phenomena that includes government and commercial applications in all domains—air, land, and sea. Commercial endeavors for unmanned systems are at the forefront of many technologies and their proliferation will likely outnumber military use in the future.

What does the Department of Defense hope to gain from the use of AWS? This Letort Paper explores a diverse set of complex issues related to the developmental, operational, legal, and ethical aspects of AWS. It will briefly explore the recent history of the development and integration of autonomous and semi-autonomous systems into traditional military operations. It will examine anticipated expansion of these roles in the near future as well as outline international efforts to provide a context for U.S. use of the systems. These topics are well-documented in many sources, thus this Paper serves as a primer for current and future AWS operations to provide senior policymakers, decision-makers, military leaders, and their respective staffs an overall appreciation for existing capabilities and the challenges, opportunities, and risks associated with AWS across the range of military operations. Emphasis is added to missions and systems that include the use of deadly force.

Discussion is limited to unclassified and open source information; any classified discussion must occur at another venue. Despite the goal of using precise language, the following terms may be used somewhat interchangeably due largely to the variety of source material cited in this Paper: autonomous weapon system; robot; drone; unmanned system; unmanned vehicle; unmanned platform.

After providing background information on the meaning of autonomy and its contemporary applications, the Paper establishes a dialogue in four main sections:

1. Developmental Issues Related to Autonomous Systems. This section explores two questions: How should the United States develop autonomy-related applications for use across the range of military operations? What technologies are imperative to the development of AWS? It addresses these questions first by describing the current state-of-the-art for Army unmanned ground vehicle systems, then by examining technology issues across the scope of application of autonomy, and ends with a brief analysis of the federal budget trends for AWS development.

2. Operational Issues Related to Use of Autonomous Systems. This section addresses two questions related to a vision of fully integrated AWS operations: What can be achieved via autonomy within the range of military operations? What missions can be enhanced by incorporating AWS? The resulting discussion considers the role of mission parameters, efforts toward AWS integration into force structure, doctrinal requirements, international efforts, and strategic geopolitical challenges.

3. Legal Issues Related to Use of Autonomous Systems. This section examines the legally acceptable

uses of autonomous weapon systems within the range of military operations. It first looks at existing international legal conventions including the Law of Armed Conflict, then reviews recent assessments by the United Nations, next it focuses on the concept of human control and judgement as it applies to AWS. Finally, it reviews current vignettes as well as consider potential trends for the future.

4. Ethical Issues Related to Use of Autonomous Systems. What should be the ethically acceptable and advisable uses of AWS within the range of military operations? What moral principles should form the foundation of AWS development and operation? This section explores these questions by first reviewing the ongoing work for developing ethical frameworks for AWS, then considering the varying cultural views that AWS applications may evoke, as well as analyze the potential reduction or proliferation in warfare that widespread use of AWS may introduce. Finally, it looks toward the future and contemplates potential long-term effects on national security.

AUTONOMOUS WEAPON SYSTEMS: A BRIEF SURVEY OF DEVELOPMENTAL, OPERATIONAL, LEGAL, AND ETHICAL ISSUES

The use of autonomous weapon systems (AWS) in warfare is not a new concept. One could argue that the development and integration of such systems have evolved over the last century and accelerated significantly after the September 11, 2001 (9/11) attacks on the U.S. homeland. AWS will likely continue to grow in both capabilities and numbers. This growth of unmanned systems is not limited to the U.S. military or even the United States; it is an international phenomena that includes government and commercial applications in all domains—air, land, and sea. Commercial endeavors for unmanned systems are at the forefront of many technologies and their proliferation will likely outnumber military use in the future.

BACKGROUND

Before examining issues related to autonomous weapon systems, it is important to establish a broad context and lexicon for the subject. This section explores the meaning of autonomy and establishes the definition for use in this Paper. It also provides a context for discussion through a brief look at the history of autonomous systems as well as contemporary applications.

What is Autonomy?

The intellectual dialogue among philosophers regarding autonomy in human interactions goes back over 300 years.[1] There is no universally accepted definition for autonomy for applications involving human-machine systems. This should not be a surprise, given the complex nature and implications of anonymous systems, and such a lack of basic terminology is not unique (e.g., consider the vastly different meanings of the term "cyberspace" in contemporary culture). There appears to be a general consensus within the ongoing discourse on the topic that autonomy is best characterized not as a discrete property of an object or system, but rather as a relationship between a system and its operator that may vary across the spectrum of different degrees of system autonomy. In simple terms, this spectrum progresses from controlled operations ("human in the loop"), to supervised operations ("human on the loop"), to fully autonomous operations ("human out of the loop").[2] Thus, the use of machine autonomy is a common experience in daily life when one considers such systems as automobile cruise control, aircraft autopilot, or digital video recorders.

When one considers the use of autonomy in weapon systems, the need for more precise language is required, especially for systems that may involve the potential application of lethal force. Toward this end, the United States is one of the few countries in the world to have an openly published government policy in this area.[3] *Department of Defense (DoD) Directive 3000.09, Autonomy in Weapon Systems*, not only establishes policy and organizational responsibilities, but it also "establishes guidelines designed to minimize the probability and consequences of failures in autonomous and semi-autonomous weapon systems that could lead to unintended engagements."[4] In addition to "autonomous" and "semi-autonomous," the directive also defines "human-supervised" as a category of autonomous weapon systems. Figure 1 provides the definitions of these categories of autonomy with their correlated common names. The definitions are arranged in increasing level of autonomy with an intentional overlap between the graphic borders around each definition. These intersecting areas provide conceptual clarity since a given system may have subsystems operating in different modes of autonomy during different parts of a mission. For simplicity, this Paper will use the term "autonomous weapon system" or AWS to describe any DoD system that fits the definitions shown in this Figure.

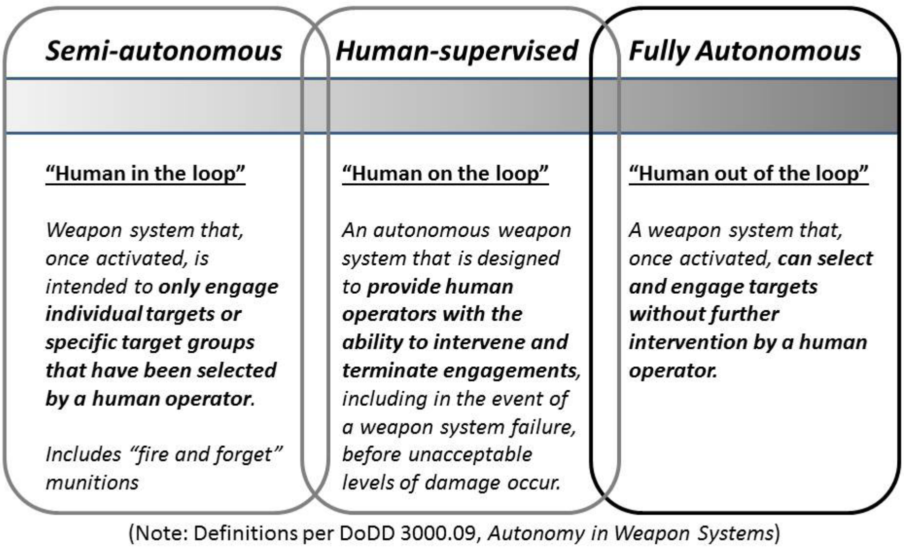

Figure 1: Spectrum of Autonomy in Weapon Systems.[5]

It is important to note that DoD clearly distinguishes a difference between autonomy and remote control. Thus, when considering unmanned aircraft, their rule is "when the aircraft is under remote control, it is not autonomous. And when it is autonomous, it is not under remote control."[6] This distinction implies that any remote control of an unmanned aircraft[7] negates any consideration of autonomy. However, in a complex system-of-systems design, the operator may be remotely controlling a sensor while the aircraft is on autopilot—essentially, the aircraft is flying itself and should be considered autonomous. The implications for a more nuanced model of autonomy are discussed later in this Paper.

While *DoD Directive 3000.09* applies to AWS that involve "the application of lethal or non-lethal, kinetic or non-kinetic, force by autonomous or semi-autonomous weapon systems," it specifically excludes:

> cyberspace systems for cyberspace operations; unarmed, unmanned platforms; unguided munitions; munitions manually guided by the operator (e.g., laser- or wire-guided munitions); mines; or unexploded explosive ordnance.[8]

This distinction of applicability may introduce a disconnect into DoD policy with respect to "unarmed, unmanned platforms" since they may still inflict injury or collateral damage to individuals and property if they malfunction. For example, an automated convoy vehicle that runs amok due to a system malfunction may injure a person or cause damage that is similar in effect to collateral damage from an errant AWS.

A vital theme in DoD *Directive 3000.09* is the requirement for AWS to "be designed to allow commanders and operators to exercise appropriate levels of human judgment over the use of force."[9] Responsibility to meet this mandate is shared among many facets of the development and procurement process, to include rigorous hardware and software testing, safety and information assurance precautions, operator procedures and training, and legal review. The section of this Paper on operational uses will discuss issues related to these obligations in more detail.

Historical Context.

The use of AWS in warfare is not a new concept. One could argue that the development and integration of such systems has evolved over the last century. While a comprehensive exploration is beyond the scope of this work, some famous examples include the Kettering "Bug" Aerial Torpedo (circa 1917)[10] as well as Soviet "Teletank" units (two battalions), and German "Goliath" remote-control mini-tanks (over 7,500 produced) used during World War II.[11] Evolutionary system milestones that may be of significant interest to modern AWS include the first launch of a Maverick missile from an Air Force target drone in December 1971[12] and the introduction in 1972 of the British Morfax Wheelbarrow, the first unmanned ground vehicle (UGV) used for explosive ordnance disposal (EOD).[13]

Looking exclusively at UGVs, Douglas Gage of the Naval Ocean Systems Center has written about technical aspects of the early days of these ground-based AWS.[14] Gage's account characterizes the efforts as largely focused on research and development in the 1960s through the 1980s, with work led by the Defense Advanced Research Projects Agency (DARPA) and prestigious technical universities. Various programs experimented with various forms of locomotion, sensing, navigating, and decisionmaking as well as the ability to manipulate tools to perform a specific mission. In the 1980s, research programs emerged that were more focused on potential military applications. Among them were the U.S. Army Tank-Automotive Command (TACOM) and DARPA work on the Advanced Ground Vehicle Technology and the Naval Ocean Systems Center work on Ground Surveillance Robot (GSR) for the Marine Corps. The GSR was not a small system; it used the 7-ton M-114 armored personnel carrier as its foundation. Other efforts during this time period used dune buggies and the High Mobility Multipurpose Wheeled Vehicles (HMMWVs) as their chassis.[15] Development of robotic systems in the 1980s also included some of the early armed UGVs such as the Grumman Robotic Ranger (demonstrated remote missile firing) and the RDS PROWLER (demonstrated missile and machine gun firing) as well as several prototypes of potentially autonomous security robots with lethal weaponry.[16]

In 1990, a congressionally-mandated joint program office was established to better coordinate UGV development efforts among the Army and the Marine Corps, a relationship that is part of the overall Joint Ground Robotics Enterprise (JGRE) construct.[17] Into this century, after the 9/11 attacks, the use of UGVs saw a rapid expansion for Operation IRAQI FREEDOM (OIF) and Operation ENDURING FREEDOM (OEF) in response to warfighter urgent needs for systems such as PackBot, TALON, and MARCBot.[18] The evolution of these systems will be discussed in more detail in the developmental issues section of this Paper.

Contemporary Applications.

The current master plan to coordinate DoD unmanned system efforts is described in considerable detail by the *Unmanned Systems Integrated Roadmap, FY2013-2038*, a document approved by two key leaders within DoD acquisition—Admiral James Winnefeld, Jr., the Vice Chairman of the Joint Chiefs of Staff; and Frank Kendall, the Under Secretary of Defense for Acquisition, Technology and Logistics (USD(AT&L)). This comprehensive plan addresses strategic planning and policy, technologies, operating environments, logistics and sustainment, training, and international cooperation for unmanned systems applications in the domains of air, land, and sea.[19] Table 1 provides the description of domain-based unmanned systems per the *Integrated Roadmap*. It is interesting to note that, consistent with the emphasis on air systems, only the term UAS is explicitly defined in current joint doctrine.[20]

unmanned aircraft system (UAS)	A system whose components include the necessary equipment, network, and personnel to control an unmanned aircraft.
unmanned ground system (UGV)	A powered physical system with (optionally) no human operator aboard the principal platform, which can act remotely to accomplish assigned tasks. UGS may be mobile or stationary, can be smart learning and self-adaptive, and include all associated supporting components such as operator control units (OCU).
unmanned maritime system (UMS)	UMS comprise unmanned maritime vehicles (UMVs), which include both unmanned surface vehicles (USVs) and unmanned undersea vehicles (UUVs), all necessary support components, and the fully integrated sensors and payloads necessary to accomplish the required missions.

Table 1. DoD Domain-Based Unmanned System Descriptions.[21]

Interest in unmanned systems is by no means limited to the U.S. military. The U.S. Government Accountability Office (GAO) has conducted numerous studies that examine not only the use of such systems among government departments and agencies, but also the implications of exporting commercial versions of some unmanned systems (or their related technologies).[22] In a July 2012 report, GAO examined the issue of worldwide proliferation of unmanned aerial vehicle (UAV), noting that in only 7 years, "the number of countries that acquired an unmanned aerial vehicle (UAV) system nearly doubled from about 40 to more than 75."[23] Figure 2 provides a graphical depiction of the magnitude of the worldwide situation, with shaded portions of the map indicating countries that operate UAVs.

Figure 2. Countries with Unmanned Aerial Vehicles (as of December 2010).[24]

Contributing to this proliferation is the explosion of the domestic UAS market. The Association for Unmanned Vehicle Systems International (AUVSI), an industry advocacy group, claims that the current global commercial market (manufacturers and applications) for unmanned systems is comprised of 2,400 platforms and 900 companies for air systems; 880 platforms and 340 companies for ground systems, and 810 platforms and 340 companies for maritime systems.[25] The economic potential is huge for a UAV industry if and when it is fully integrated into U.S. airspace. An AUVSI report from March 2013 projects the potential for 70,000 new jobs within the first 3 years of integration with an economic impact of more than $13.6 billion, and this is further projected to grow to over 100,000 new jobs with $82 billion benefit by 2025.[26] As with many high-technology products, unmanned vehicles may have dual-use potential for both commercial and government purposes.

Now that we have a better appreciation for the diverse and dynamic context of unmanned systems in general, let us now examine some of the opportunities and challenges associated with their military applications. Consistent with DoD guidance, the use of AWS in any part of the range of military operations must include the opportunity for appropriate human judgment, but this responsibility also extends to those who design and develop the systems.[27] The next section addresses some of the key issues facing the community that takes a given AWS through the processes from an initial requirement or concept up to being a fully capable field asset.

DEVELOPMENTAL ISSUES RELATED TO AUTONOMOUS SYSTEMS

What does DoD hope to gain from the use of AWS? The *Integrated Roadmap* contends that:

> unmanned systems will be critical to U.S. operations in all domains across a range of conflicts, both because of their capability and performance advantages and because of their ability to take greater risk than manned systems.[28]

Further, it cites three primary forces driving DoD efforts: (1) military utility of unmanned systems as demonstrated in combat operations in Southwest Asia; (2) anticipated budget constraints that require more affordable technical solutions; and (3) changing international security environment, especially the strategic shift to Asia-Pacific Theater and the resulting anti-access/area denial (A2/AD) challenges.[29] Summing it all up, the vision of the roadmap states simply, "DoD will develop and field affordable, flexible, interoperable, integrated, and technologically advanced unmanned capabilities."[30]

Toward this vision, this section explores two questions: How should the United States develop autonomy-related applications for use across the range of military operations? What technologies are imperative to the development of AWS? The section addresses these questions first by describing the current state-of-the-art for Army UGV systems. It then examines technology issues in decreasing scope of application—from those for unmanned systems in general, to those related to the use of autonomy, to those specifically related to UGV purposes. The section ends with a brief analysis of the federal budget trends for AWS development.

Current DoD and Army Developmental State of the Art in Autonomous Systems.

In a 2012 report, the Defense Science Board (DSB) examined the role of autonomy in DoD systems and concluded that, despite the proven usefulness of unmanned systems in operation, "autonomy technology is being underutilized as a result of material obstacles within the Department" that include "poor design [and] lack of coordination of research and development (R&D) efforts."[31] Further, the report argues that recent development of unmanned systems was largely evolutionary, moving forward based on combat experience and experimentation in Iraq and Afghanistan. The report does argue that the concept of armed UAVs, which combine the strike and intelligence, surveillance, and reconnaissance (ISR) missions into a single platform, is a revolutionary new capability. In both cases, the main impetus behind the systems was an operational pull to support missions to defeat improvised explosive devices and to eliminate high-value targets.[32]

The push to acquire UGV system rapidly to support OIF/OEF urgent needs led to widespread purchase of commercial-off-the-shelf (COTS) equipment. Eventually, over 7,000 UGV of many different designs were purchased, mostly using Overseas Contingency Operations (OCO) funding.[33] Table 2 depicts the evolution in functional focus of ground robotics in combat from 162 systems in 2004 to over 7,000 by 2012.[34]

Year	Number of Ground Robot Systems	Functional Focus
2004	162	- No single vendor could produce 162 - Five vendors, multiple configurations - Joint effort, EOD [explosive ordnance disposal] focused
2005	1,800	- Robot's proven ability to save lives - Expansion beyond EOD mission (Countermine, Security) - Agreements with AMC [Army Materiel Command] and REF [Rapid Equipping Force]
2006	4,000	- Engineers and Infantry - Route clearance, Explosive detection & Weaponization development
2007	5,000	- Special Forces robot applications assessed - Route clearance, Explosive detection & Weaponization on battlefield
2008-09	6,000	- Range extension - CBRNE [Chemical, Biological, Radiological, Nuclear, Explosives] detection - Persistent surveillance - RC [Remote Control] HMMWV - More capable payloads - Maneuver elements
2010-12	7,000	- Military Police - Smaller platforms - Enhanced battery life - Commonality - More capable payloads
2013-14	>7,000	- "Plug & play" capabilities - Limited autonomy - Weaponization - Increased agility and dexterity - Interoperability

Table 2. Evolution of Ground Robotics in Combat.[35]

In parallel to the ad hoc procurement of UGVs for OIF/OEF, a methodical and coordinated effort to incorporate unmanned systems was ongoing as part of the Future Combat System (FCS). Initially envisioned by General Eric Shinseki in 1999, FCS was the huge program ($200 billion) that integrated 18 systems around a central network. Of the original 18 systems, 10 were to be unmanned: four different classes of UAV; three different types of UGVs; and three other unmanned ground systems that included a vertical missile launch system. Although the program achieved its Milestone B of the DoD acquisition framework in 2003, FCS was reduced in scope and eventually cancelled in June 2009. Little of the decade-long development effort was salvaged.[36]

As OIF/OEF closed out, the Army Deputy Chief of Staff, Operations and Plans (G-3/5/7) directed a bridging strategy to sustain select existing COTS systems (primarily Talon and Packbot families) for up to 8 years until UGVs are available via traditional acquisition program of record methodology.[37] This includes resetting and sustaining almost 1,500 COTS robots while working to incorporate interoperability, chassis commonality, and payload modularity into systems being developed.[38] The anticipated strategic environment for this unmanned system development is largely derived from capstone DoD studies such as the *Quadrennial Defense Review* as well as priorities from the President and Congress. Per the *Integrated Roadmap*, the explicit strategic trends and environmental characteristics are:

- Reduction in federal budgets;
- Operational issues will be more complex;
- U.S. military forces will be rebalanced toward the Pacific;
- Violent extremism will continue to threaten U.S. interests;
- Unmanned technologies will continue to improve; and,
- Cyber domain will be a conflict environment.[39]

The *Integrated Roadmap* also addresses potential implication of adversary use of unmanned systems, especially in support of A2/AD missions:

> Enemy unmanned systems will complicate air, ground, and maritime operations by adding new low-altitude, ground, and amphibious threats to the force that must be countered. This concern will require the development of friendly countermeasures, including tactics, techniques, procedures, and training that enable the force to operate in the emerging environment.[40]

Given these myriad challenges, what are the key technologies necessary to support the development of future unmanned systems?

Key Technologies for Unmanned Systems.

Determination of the technology foci for unmanned systems should be informed by the expected capabilities that such systems will fulfill in the range of military operations. The framework of Joint Capability Areas (JCAs) is utilized by DoD to help organize and manage this process. Currently, there are four JCAs envisioned for unmanned systems to support: battlespace awareness, force application, protection, and logistics.[41] While many of the basic requirements of locomotion, sensing, navigation, and connectivity were solved at the prototype level in the 1980s and 1990s, and further refined through combat experience in the 21st century, there remain significant technological challenges for AWS development. The *Integrated Roadmap* narrows this to nine technology areas that are presented in Table 3 along with summaries of the proposed objectives and activities for each area.

Technology Areas	Objectives and Activities
Interoperability and Modularity	- Develop and stabilize standard information exchange requirements (IERs) with joint, inter-agency, intergovernmental, and multinational (JIIM) partners - Meet interoperability requirements such as those specified in DoDD 5000.01 and CJCSI 6212.01F - Create interoperable components, subsystem, and payload interface to enhance modularity and reduce life cycle cost
Communication Systems, Spectrum, and Resilience	- Pursue platform agnostic command, control, communications, and computers (C4) infra-structure - Simplify plug-and-play payload interfaces to lower costs and enhance ability to update, modify, upgrade, and link - Utilize globally available C4 enterprise capabilities (such as data centers and distribution nodes)
Security: Research and Intelligence/ Technology Protection (RITP)	- Use layered application of protective measures to prevent compromise of critical informa-tion and technology - Assess system vulnerabilities and threats as early as reasonable in the development process - Provide unmanned systems with the ability to remotely and autonomously render data at rest unrecoverable by an adversary - Create classification guidelines that transcend organizational cultures and build trust between Intelligence Community agencies and mission partners
Persistent Resilience	- Reduce the size, weight, and power consumption of unmanned systems - Achieve reliability, availability, and maintainability (RAM) performance sufficient for long-duration missions (such as single unmanned vehicle ISR for periods exceeding 24 hours) - Utilize active warning and self-protection subsystems as well as passive measures to enhance survivability - Pursue advanced structures, material, and propulsion solutions
Autonomy and Cognitive Behavior	- Move unmanned systems from executing preprogrammed plans to performing missions with dynamic tasks - Develop ability for unmanned systems to modify strategies and self-directed behavior necessary to achieve a human-directed goal - Incorporate key enablers such as dynamic mission planning, precise position, navigation, and timing (PNT), and appropriate machine rules of engagement for utilizing processed information and mitigating lost links
Weaponry	- Develop and standardize weapons specifically designed for use on unmanned systems - Design weapons with multiple modes of operation that include the ability for scalable ef-fects (similar in concept to nuclear “dial-a-yield”) - Utilize advanced weapons materials and nanoenergetics to increase performance and reduce weight

Table 3. DoD Key Areas for the Technological Advancement of Unmanned Systems.[42]

Tackling these technologies in a concerted fashion may yield dramatic improvements that facilitate mission performance, endurance, reliability, and synchronization at reduced levels of human risk and logistics burden. When considering development of lethal AWS, the areas of weaponry and autonomy and cognitive behavior merit further insight. The evolution of weaponized AWS has been largely an ad hoc process that adapted unmanned platforms to use available munition systems. This has been proven effective for combinations such as Hellfire missiles on Predator UAVs. But there is great potential for optimization at the system-of-systems level if the weaponry is designed specifically for unique features of a given unmanned platform. In this way, the munition system may be better suited to operate within the unmanned systems' environment (including optimized size and shape), to exchange mission data, and to be interchangeable within classes of unmanned systems.[43]

For autonomy and cognitive behavior, the aim can be stated simply as "the future of autonomous systems is characterized as a movement beyond autonomous mission *execution* to autonomous mission *performance*."[44] In other words, unmanned systems should strive to emulate appropriate cognitive behavior in the battlespace, just as the brain of a military operator must adapt to the inevitable changes that transpire as they move from the planning cell to "boots on the ground" as well as anticipate future change.[45] Pursuing the concept of autonomy requires its own subset of supporting technologies.

Technologies that Facilitate Autonomy.

How does one break down the complex concept of autonomy into practical elements that can be realized through use of the proper technology? A framework developed by the Office of Naval Research (ONR) examines how varying levels of autonomy may be required to enable mission accomplishment as part of an iterative process that exercises an AWS ability to form a world model, the ability to reason, and the ability to alter actions. When actions are altered by the AWS, the world model changes and the cycle repeats.[46] In an unrelated effort, in a 2012 task force report, the DSB identified "six key areas in which advances in autonomy would have significant benefit to the unmanned system"[47] that are summarized in Table 4. These six areas correlate well to the ONR framework, with perception technology linked to determining a world model; planning and learning technologies linked to the ability to reason; and human-robot interaction, natural language understanding, and multi-agent coordination linked to the ability to alter actions. The DSB study also examined the state of the art of each of these six areas and provided an assessment of gaps that should be addressed to improve the application of autonomy for DoD systems.

Technology Areas	Application for Autonomy in Unmanned Systems
Perception	Perception is essential for autonomy, for enabling the unmanned vehicle to achieve reach (e.g., navigate through environments and manipulate obstacles) and for using reach to meet mission objectives, either for a platform (e.g., collecting sensor data, applying kinetic weapons, defeating IEDs) or for the battlespace.
Planning	Planning is the process of computing a sequence or partial order of actions that change the world from the current state to a desired state, or in DoD terminology, a plan is a course of action designed to achieve mission objectives while minimizing resource utilization. The process relies on two key components: 1) a representation of actions, descriptions of conditions in the world and objectives/resource optimization criteria and 2) algorithms for computing action sequences and assigning resources to the actions so as to conform to the hard constraints of the problem (e.g., vehicle limitations in terms of terrain and speed) while optimizing the soft constraints (e.g., minimizing the total mission time or personnel use).
Learning	Machine Learning has become one of the most effective approaches to developing intelligent, autonomous systems. Automatically inducing knowledge from data has generally been found to be more effective than manual knowledge engineering. Development of state-of-the-art systems in computer vision, robotics, natural language processing and planning now rely extensively on automated learning from training data. Mining large amounts of real-world data to find reliable patterns, generally results in more accurate and robust autonomous systems than manual software engineering. This also allows a system to automatically adapt to novel environments from actual experience operating in these situations.
Human-Robot Interaction	Human-robot interaction (HRI) is a relatively new, multi-disciplinary field that addresses how people work or play with robots versus computers or tools. This is a subset of the larger field of human-system interaction, as the focus is on bi-directional, cognitive interactions in which the robot is a physically situated agent operating at a distance from the user, versus a computer or autopilot, thus leading to significant distinctions. In order to be consistent with the scientific literature, the term HRI will be used generally, but UxV [unmanned vehicle] will serve to describe the specific form of robot.
Natural Language Understanding	Natural language is the most normal and intuitive way for humans to instruct autonomous systems; it allows them to provide diverse, high-level goals and strategies rather than detailed teleoperation. However, understanding human language is difficult since it is inherently ambiguous, and context must be used to infer the intended meaning. Therefore, building autonomous systems that can follow English instructions as well as human speech is a very difficult technical challenge. Therefore, traditional graphical user interfaces (GUIs) are frequently a more effective approach to communicating with computing systems. However, in many situations (e.g., when the user's hands are otherwise engaged), language is a very desirable mode of communication.
Multi-agent Coordination	Multi-agent coordination is a term that is broadly applied to accomplishing a task that is distributed over multiple robots, software agents or humans. Each agent is considered to have some degree of individual autonomy, and the coordination may either emerge from the agents interacting or negotiating with each other directly (distributed coordination) or be explicitly directed by a planner (centralized coordination). Regardless of the coordination scheme, the distribution of an activity across multiple agents implies that coordination schemes must address synchronization of the agents with each other and to dynamically changing aspects of the environment or mission.

Table 4. DSB Key Areas for Advancement in Autonomy to Benefit Unmanned Systems.[48]

In practical terms, any AWS that embraces the technologies in Table 4 in its design must also meet strict operational effectiveness and suitability test parameters as certified by the Director of Operational Test and Evaluation.[49] For Army-specific applications, UGVs will need to support the traditional "shoot-move-communicate" technique of ground forces, but they must do so in "environments [that] could include being thrown or launched, climbing hills or stairs, and hopping and landing upright."[50] Independent of the DSB findings, the Army science and technology (S&T) community identified the need for enhanced capabilities in five areas: adaptive tactical reasoning; focused situational awareness; safe, secure, and adaptive movement; efficient proactive interaction with humans; and interaction with the physical world.[51]

To pursue these capabilities, the Army Research Laboratory formed the Robotics Collaborative Technology Alliance (RCTA) as a consortium of nine government, industrial, and academic institutions to address research and development relevant to future military unmanned ground vehicles.[52] The RCTA Program Plan simplified the title of the five enhanced capability areas to: think-look-move-talk-work. Table 5 summarizes the vision and challenges of each capability area. The RCTA plan goes on to identify five primary cross-cutting technical barriers which are compared across the think-look-move-talk-work paradigm to identify the fundamental research thrusts that the consortium will pursue.[53]

Enhanced Capability Area	Vision and Challenges
Adaptive Tactical Reasoning	- Vision: robots understand the concept of a mission or task, including stages of progress and measures of success.
"Think"	- Adaptive tactical reasoning requires both declarative and procedural knowledge with which to reason. Neither exists in current systems, which generally have no data structures for mission level information. Tactical reasoning also requires some kind of model of the other members of the team, both human and robot, so that reasonable predictions of expected behavior can be made.
Focused Situational Awareness	- Vision: future autonomous ground systems maintain situational awareness (SA) that is relevant to the current task and the larger mission.
"Look"	- Focused SA, requires a semantic/cognitive description of the robot's environment that current systems do not have. SA also requires a sense of salience, what is important based on a shared understanding among teammates. Better learning is needed to develop a more human-like hierarchical understanding of object categories in the first place as well as to refine perception capabilities in the field.
Efficient Proactive Interaction with Humans	- Vision: robots interact with each other and especially with Soldiers in an efficient and proactive way relevant to the evolving situation.
"Talk"	- Existing robotic systems are notoriously opaque and distrusted. They cannot explain what they are doing, primarily because they do not have meta-cognition; in other words, they do not have a model of their own behavior. Current systems also lack the ability to understand human (i.e., semantic) communication of orders or other information
Safe, Secure, and Adaptive Movement	- Vision: robots that move on orders or their own initiative from one tactical position to the next with little or no reliance on metric inputs such as GPS. They can move, as Soldiers do, to semantically described locations (e.g., "third building on the left after the next intersection").
"Move"	- Current systems have insufficient descriptions, or models, of the world in which the robot is moving. Useful movement is also hampered by the lack of task or mission context so that a robot may persist in trying to reach a particular location that is not needed for the mission. Robots also need to be able to move in crowded and unpredictable environments, where existing algorithmic approaches are probably intractable but new learning approaches may work.
Interaction with the Physical World	- Vision: robots are able to observe objects at close quarters to enable 3D interaction with them. They pick-up and move objects, either upon semantic direction or their own initiative.
"Work"	- The above four capabilities (think-look-move-talk) largely enable the performance of the main goal of the mission – the "work" the robot is to do. The work most often involves direct physical interaction with the world: entering and searching a building or vehicle, loading and delivering supplies, inspecting a suspected IED, etc. There is generally great uncertainty about the objects with which the robot is attempting to interact.

Table 5. Research and Development Focus for Military UGVs.[54]

The fact that the ONR, DSB, and Army S&T studies identified similar sets of technology areas and goals for AWS provides confidence that their efforts are in the right direction and that they can support each other. However, any plan to implement technology comes with a price tag that must compete in an increasingly contentious federal budget.

Budget Resources.

The DoD *Integrated Roadmap* included a projection of unmanned systems budgets from Fiscal Year (FY) 2014 to FY 2018 based on information available at its publication, included herein as Figure 3. Clearly, the budget heavily favors air-based systems with their projected portions accounting for 94.2 percent of the total development costs and 91.5 percent of total procurement costs. Of course, some of these costs include unmanned air systems for the Army, Navy, and Marines as well as for the Air Force. In stark contrast is the lesser budget priority for unmanned ground systems, which account for less than 1 percent of total development costs and less than 2 percent of total procurement costs.

FYDP		2014	2015	2016	2017	2018	Total
Air	RDTE	1189.4	1674.0	1521.4	1189.4	1087.9	6662.2
	Proc	1505.5	2010.2	1843.5	1870.7	2152.8	9382.7
	OM	1080.9	1135.2	1102.7	1156.9	1178.5	5654.1
Domain Total		3775.9	4819.4	4467.6	4217.0	4419.3	21699.1
FYDP		2014	2015	2016	2017	2018	Total
Ground	RDTE	6.5	19.1	13.6	11.1	10.6	60.9
	Proc	6.5	27.9	30.7	42.6	55.4	163.1
	OM	0.0	0.0	0.0	0.0	0.0	0.0
Domain Total		13.0	47.0	44.3	53.7	66.0	223.9
FYDP		2014	2015	2016	2017	2018	Total
Maritime	RDTE	62.8	54.8	66.1	81.0	87.2	351.9
	Proc	104.0	184.8	160.1	158.1	101.1	708.2
	OM	163.4	170.3	182.4	190.5	193.6	900.2
Domain Total		330.2	409.8	408.6	429.7	381.8	1960.2
FYDP		2014	2015	2016	2017	2018	Total
All Unmanned Systems	RDTE	1,258.7	1,747.9	1,601.1	1,281.5	1,185.7	7,075.0
	Proc	1,616.0	2,222.9	2,034.3	2,071.4	2,309.3	10,253.9
	OM	1,244.3	1,305.4	1,285.1	1,347.4	1,372.1	6,554.3
Domain Total		4,119.1	5,276.2	4,920.5	4,700.4	4,867.1	23,883.2

Figure 3. DoD Unmanned Systems Funding per *Integrated Roadmap*.[55]

While there is insufficient information to reproduce the method by which Figure 3 was tabulated, we can compare some of its projected values to those recently submitted as part of the FY 2016 DoD budget request. Procurement of UAV dominates the requests for unmanned systems and it includes $960 million for research, development, test and evaluation (RDT&E) as well as $1.87 billion for procurement. The procurement funding buys 51 UAVs: 15 MQ-1 Gray Eagles (based on Predator) for the Army; 29 MQ-9 Reapers for the Air Force; 3 MQ-4C Tritons (based on Global Hawk) for the Navy; and 4 RQ-21 Blackjacks (based on Shadow) for the Marine Corps.[56] The Army uses the Gray Eagle as "a dedicated, assured, multi-mission Unmanned Aircraft System (UAS) fielded to all ten Army Divisions to support the commander's combat operations."[57]

Funding for various unmanned system program elements are spread through the Army's FY 2016 budget request, and it is beyond the scope of this Paper to delve into all the details therein. However, in addition to the UAV and related costs already identified, there are two noteworthy items for unmanned ground systems. First is the request for $40.4 million RDT&E in support of the Tactical Unmanned Ground Vehicle (Program Element 0604641A) which is described as "man-packable, miniature (<25-lbs), highly mobile, unmanned robotic system with advanced sensors/mission modules for dismounted Soldiers."[58] The program element includes the ability to evaluate readily available hardware such as COTS to support emerging warfighter requirements as part of the Robot Enhancement Program.[59] Second is an indication of the Army's intent to pursue ground AWS that can apply lethal capabilities listed under Program Element 0603827A, Soldier Systems-Advanced Development, Project S54, Small Arms Improvement:

> FY16 New Start Armaments for Robots: Will initiate the intelligence/networking and weapons design and functions for a man-in-the-loop, small caliber defensive armaments system on an unmanned ground vehicle including the Warfighter/Robot interface.[60]

No further details are available, but this would appear to support the intent of the *Integrated Roadmap* technology area of weaponry development specific to unmanned platforms.

The budget challenges are significant as FY 2016 and beyond must deal with the loss of OCO funding as well as possible impacts from sequestration. Spending for UGVs must support the bridging strategy to divest older systems and limit sustainment costs on the systems selected to remain in the inventory. This will leave little funding available to develop, procure, and deploy future unmanned systems, thus it is important to understand how these systems may be used in military operations to ensure investments are made with prudence.

OPERATIONAL ISSUES RELATED TO USE OF AUTONOMOUS SYSTEMS

One could argue that the operational use of AWS thus far has been viewed largely as an ends to a means focused on a specific mission, such as UGVs supporting counter-improvised explosive device (C-IED) efforts. But the Army Research Laboratory RCTA overview brief offered a different vision for unmanned systems—"A Paradigm shift—from Tool to Team Member"[61] This section addresses two questions related to such a vision: What can be achieved via autonomy within the range of military operations? What missions can be enhanced by incorporating AWS?

Mission Parameters.

The parameters for potential mission areas for AWS can be found in each of four JCAs identified in the *Integrated Roadmap.* For battlespace awareness, AWS may extend mission endurance and provide persistent ISR in all operational domains that could be readily shared with similar systems to further enhance their effectiveness. Force application capabilities have already been proven in combat by UAVs conducting offensive operations against high-value targets. UGVs are also projected to have lethal applications, such as armed reconnaissance, as well as nonlethal operations, such as crowd control. For protection capabilities, unmanned systems can assume risky missions, such as firefighting and decontamination, as well as continue to refine methods for handling sophisticated high explosives. For logistics, unmanned systems can facilitate transportation and resupply tasks as well as support routine maintenance, such as inspections and refueling.[62]

Regarding future UGV missions, the DSB assesses that both the Army and Marine Corp are interested in achieving lower risk to humans; accessibility to areas not suitable for humans; enhanced sensor capability and mobility; and battle formations that purposely combine warfighters with AWS units.[63] In the same study, the DSB asserted that the application of unmanned systems this century has been ad hoc in nature:

> Due to the understandable pressures of war, unmanned systems were often fielded before CONOPS were fully developed or understood; deployment support structures (sustainment, service structures, etc.) were immature; and the lack of understanding or validating (testing) maturity to support tactical and operational challenges in remote theaters have further complicated progress.[64]

To address the warfighter needs for unmanned systems that better integrate into the full range of military operations, let us consider a more deliberate approach to their integration into existing force structures.

Integration into Force Structure.

DoD Directive 3000.09 requires commanders of the combatant commands to integrate AWS into their operational mission planning and also charges them to "identify warfighter priorities and operational needs that may be met by" AWS through established procedures overseen by the Chairman, Joint Chiefs of Staff.[65] The *Integrated Roadmap* posits that this mandate can lead to systems that perform beyond mere substitution for manned systems, thus allowing new formations and tactics that are more agile and maneuverable. It also suggests that unmanned systems could be used as low-cost disposable assets that expect attrition, a concept that reverses the current focus on procuring complex and expensive systems that often require risk-adverse planning.[66] But how does one determine the best types of unmanned systems to procure? And what is the best way to blend these systems with human warfighters into a cohesive force?

As discussed earlier, FCS was the Army's modernization program until its cancellation in 2009. But in the years prior to this, the program made significant strides toward answering these force integration questions. The FCS Test Master Plan addressed not only the individual capabilities of its eight manned and 10 unmanned vehicles, but also how the entire family of systems worked together to accomplish a given mission.[67] Also, the FCS program formed a unique Evaluation Brigade Combat Team at Fort Bliss, Texas, to support early operational assessments and testing of FCS elements as well as the complete system comprised of soldiers working together with manned and unmanned platforms on the ground and in the air.[68]

Currently, the Army UGV Campaign Plan for modernization organizes systems into four classes of vehicles (CoV): Soldier transportable, vehicle transportable, self-transportable, and appliqué.[69] The descriptions of the CoV and system types within each category are presented in Table 6. Even during modernization, some traditions remain and the Army practice of using mules is updated with the Common Mobility Platform/Multi-Mission UGV envisioned "as vehicles to serve as robotic 'mules' to take on multiple soldiers' loads."[70] The top priority for technology areas to support the UGV Campaign Plan was assessed to be autonomy, with envisioned mission applications for:

> area clearance, route clearance (marks and detects), convoy, soldier follower, manned/unmanned teaming, situational awareness and navigation in a [global positioning system] denied environment. Also for route detection, planning, and maneuver capabilities over soldier passable terrain.[71]

Emphasizing autonomy development would help mitigate two of the primary challenges assessed by the DBS for UGVs in combat operations: "negotiating terrain and obstacles on the battlefield, and performing kinetic operations within the Rules of Engagement (ROE)."[72]

Class of Vehicles (CoV)	CoV Description and System Types
Soldier Transportable	- UGV system with weight not exceeding 35 pounds and with forms that allow them to be carried by Soldiers or Marines for extended periods of time over varying terrains. - The majority of soldier transportable systems are used for surveillance, reconnaissance missions, and standoff IED detection and defeat. - Continued advancements in antenna design, autonomy, miniaturization, power sources, and control mechanisms are required in order for these capabilities to be fully realized. - System types: Crew Served Bot ; Small Bot; Micro Bot ; Nano Bot
Vehicle Transportable	- Vehicle transportable unmanned systems are heavier and require a prime mover for transportation to and from a mission. - Future requirements for vehicle transportable systems are expected to include more advanced, reliable and autonomous area and route clearance robotic vehicles as well as humanoid like systems. - Continued advancements in autonomy (to include intelligence understanding and decision making), power systems, and enhanced mine detection and neutralization techniques and methods are needed. - System types: Mounted or Towed; Armed; Humanoid
Self Transportable	- Self transportable systems can move under their own power, up to road march speeds, without assistance from a prime mover or other sources. - Self transportable systems are not manned systems with appliqué kits applied, rather they are systems that have been developed explicitly as unmanned vehicles. - Continued advancements in autonomy, sensors and sensor fusion are required in order for these capabilities to be realized. - System types: Soldier Follower—Infantry Brigade Combat Team (IBCT); Medium Wingman—Striker Brigade Combat Team (SBCT); Heavy Wingman—Heavy Brigade Combat Team (HBCT); Squad Member.
Appliqué	- Appliqué COVs are systems that can be used to convert fielded and future manned systems into unmanned systems. - These systems are envisioned as 'kits' that include all the hardware (sensors, cables, actuators, control station, etc.) and software required to fully operate and monitor the selected vehicle remotely. - Key advancements are required in the areas of autonomy, processing, size, weight and power (SWaP), sensor development, and sensor fusion for this CoV to be fully matured. - System types: Remote Operation; Supervised Autonomy; Full Autonomy; Exoskeleton

Table 6. Army Unmanned Ground Vehicle (UGV) Campaign Plan.[73]

The DoD Roadmap (2013) makes it clear that force integration for unmanned systems must not be confined to single-domain applications. Rather, it promulgates the development of Manned-Unmanned Systems Team (MUM-T) as an essential part of the strategic shift to the Asia-Pacific region. The MUM-T force would be smaller and more agile, thus providing key capabilities to address A2/AD challenges such as:

- Defeating explosive ground surface, sub-surface (tunnel), and sea hazards from greater standoff distances;
- Assuring mobility to support multiple points of entry;
- Enabling movement and maneuver for projecting offensive operations;
- Establishing and sustaining the shore lines of communications required to follow forces and logistics;
- Protecting austere combat outposts;
- Providing persistent surveillance to detect and neutralize threats and hazards within single- to triple-canopy and urban terrain.[74]

To develop and refine the MUM-T concept, the Army's Program Executive Office-Aviation established the Manned Unmanned Systems Integration Capability (MUSIC) Exercise program. The first exercise, MUSIC I, was conducted in September 2011 at Dugway Proving Ground, Utah. In addition to MUM-T capabilities, the exercise also tested ground control stations and remote video terminals. Lessons learned from MUSIC I were used by the product office to help improve usability, reliability, integration, and configuration control of future systems.[75]

Success in the MUM-T force depends not only on the interactions between human and machines, but also on the interoperability among the machines. As an example of ongoing effort to improve interoperability, consider the DoD Unmanned Aircraft Systems Task Force (UAS TF) that was established in April 2010 in a charter signed by USD(AT&L) and the Deputy Secretary of Defense to address many issues in this area.[76] The UAS TF is divided into four principal integrated product teams (IPTs): Interoperability; Airspace Integration; Frequency and Bandwidth; and Logistics and Sustainment. The Task Force also has Advisory Groups for Research and Development and Payloads and Sensors.[77] For the critical area of interoperability, the Interoperability-IPT "continues to address the 29 prioritized Joint interoperability capability gaps identified in the approved Unmanned Interoperability Initiative (UI2) Capability Based Assessment (CBA)."[78]

Doctrine.

DoD Directive 3000.09 mandates the development of doctrine and tactics, techniques, and procedures (TTPs) for AWS applications as well as their periodic review to ensure they are appropriate for changes in realistic operational conditions. It emphasizes that the doctrine and tactics must "have demonstrated the capability to allow commanders and operators to exercise appropriate levels of human judgment in the use of force" as well as meet all legal and safety rules.[79] Ideally, the development and promulgation of doctrine should receive high priority among warfighters, but this is not always the case.

In his book *Wired for War: The Robotics Revolution and Conflict in the Twenty-first Century*, author P. W.

Singer devotes a chapter to examining how the United States might fight with robots. He cited a survey of U.S. military officers that "identified developing a strategy and doctrine [for using robots in combat] as the third *least* important aspect to figure out."[80] His observation provides some insight into the ad hoc applications of AWS in combat thus far despite policy that dictates a more informed approach.

What should AWS doctrine address? Perhaps a good starting point is to embrace a mission-focused autonomy vision crafted by the ONR: "Develop autonomous control that intelligently understands and reasons about its environment relative to its objectives and independently takes appropriate actions."[81] However, these actions in a mission will result from human direction in two broad teamwork styles: remote presence or taskable agents. As its name implies, remote presence allows humans to perceive and act through unmanned systems at a distance, while taskable agents allows the unmanned system to autonomously complete a human-directed mission task.[82]

Starting with the foundation of remote presence and taskable agents, there are numerous doctrinal nuances that must be addressed concerning how these principles are applied in operations of increasing complexity. What is the primary operational entity for a given mission? Are humans the supported force element, or are they supporting the unmanned system? [83] Do these roles change at different phases in the mission? How autonomous are AWS allowed to operate when factoring not only inherent capability, but also commander's intent, laws of war, and rules of engagement?

Probably the best attempt at addressing such AWS doctrine issues thus far occurred at Fort Bliss, Texas, as part of the operational assessment of fledging FCS operations.[84] But these experiments were limited to few soldiers and unmanned systems. However, as we move toward more of a MUM-T structure, it may become common or a single soldier or system to operate multiple AWS simultaneously; an extreme application of this would be swarming.

The DSB report on autonomy discussed two possible types of swarming coordination: cooperation and collaboration. Cooperation may emulate swarming behavior seen in nature among large numbers of animals executing simple tasks based on instinct, such as ants foraging for food. Cognitive and communication abilities for cooperation are basic and may be reduced to a small number of stimulus-response commands. Collaboration is a more intentional form of teamwork that requires more sophisticated sensing and communication as well as cognitive understanding of other members of the swarm.[85] Using AWS in swarms may provide greatly enhanced mass and maneuver capabilities as well as allow for the use of lower cost systems in large enough numbers to account for attrition and possibly overwhelm any traditional defenses. However, to be successful it is likely that such formations will communicate and react at speeds and complexity beyond human comprehension; this introduces a limitation that doctrine should address. [86]

Doctrine must also address how U.S. human/AWS teams interact with external parties. Such interaction may involve coalition teaming efforts, adversary countermeasures, and incidental contact with innocent noncombatants.[87] To better understand the possible implications of such interaction, let us now examine AWS applications in the international environment.

International Efforts.

The global proliferation of UAVs as depicted in Figure 2 and discussed earlier applied to all forms of aviation. The Bard Center for Study of the Drone reports that by 2013, 87 countries are either developing or acquiring military drones.[88] Filtering this number down, a 2014 RAND Corporation report found 23 countries are potentially developing armed UAVs, of which eight countries are working on systems that would meet Category I criteria of the Missile Technology Control Regime (MTCR)—a range of at least 300 kilometers with a payload of at least 500 kilograms. Of these eight countries, three are MTCR members (Russia, Turkey, and the United States) and five are not members (China, India, Iran, Taiwan, and the United Arab Emirates).

Of note is that Israel, the largest exporter of UAVs (to over 42 countries), is not an MTCR member. Israel is assessed as developing MTCR Category II UAVs—the same range criteria as Category I, but with less payload.[89] Israel also exports ground systems like the Guardium unmanned ground vehicle (UGV), a semi-autonomous system designed primarily for routine patrols, but also able "to autonomously react to unscheduled events, in line with a set of guidelines specifically programmed for the site characteristics and security doctrine."[90] China is also an exporter of AWS, according to the DSB which noted that after their initial marketing at the Zhuhai air show in 2007, "now every major manufacturer for the Chinese military has a research center devoted to unmanned systems."[91] Other countries of interest for exporting AWS include Russia and Iran.[92]

Given the crowded international environment for military unmanned systems, how does the United States extend its force integration of AWS to include allies, coalition partners, and friends? *DoD Directive 3000.09* allows for the "international sales or transfers of autonomous and semi-autonomous weapon systems" in accordance with existing U.S. law.[93] Chapter 8 of the *Integrated Roadmap* identifies three primary methods of international cooperation for unmanned systems: international agreements for joint RDT&E; foreign military sales; and direct commercial sales. It also provides details regarding the rigorous control processes established by Congress to ensure proper arms export control, technology transfer, and foreign disclosure of sensitive information.[94]

An example of international cooperation is the North Atlantic Treaty Organization (NATO) Alliance Ground Surveillance (AGS), a system that uses the U.S. Global Hawk UAV to give NATO commanders comprehensive ground situational awareness. It was used successfully to help protect civilians in Libya during NATO operations there in 2011.[95] The DoD FY 2016 budget includes $198 million for RDT&E efforts for the AGS.[96]

Individual countries have benefited from U.S. partnerships with AWS as well. High-demand systems such as the RQ-1 Predator and MQ-1 Reaper UAVs built by General Atomics have been purchased by many countries, including NATO allies Canada, France, Germany, Italy, Spain, The Netherlands, and UK.[97] The Australian Army acknowledged the benefits of procuring "capabilities such as the Switchblade system (an armed, disposable micro-UAV)" to provide "opportunities for the [Australian] Army to enhance the individual lethality of its soldiers in an austere budget environment." [98]

How is NATO approaching the implementation of AWS into future operations? A series of workshops and seminars led by NATO Headquarters Supreme Allied Commander Transformation have focused on the objective "to improve awareness and understanding of autonomous systems, promote interoperability and provide guidance for the development of, use of, and defence against, autonomous systems."[99] Their work includes recommendations to adopt precise language when dealing with AWS, specifically the introduction of "autonomous functioning" as reference to "the ability of a system, platform, or software, to complete a task without human intervention, using behaviours resulting from the interaction of computer programming with the external environment."[100] Accordingly, the report recommendations include "rather than emphasising the fact that a system employs autonomous functions, focus should be placed on the level of human control and accountability and the type of decision being autonomised."[101] Such clarification appears to be in concert with the DoD policy guideline to ensure the exercise of appropriate levels of human judgment when using AWS.[102]

The challenges of integrating U.S. military unmanned systems into operations with other governmental entities are not limited to international military forces. There are also issues that DoD must consider related to military AWS operations in the continental United States and bordering countries. For example, a 2012 GAO report examined the use of UAVs by the Department of Homeland Security (DHS) to support national security operations along the U.S. southwest border. The Federal Aviation Administration (FAA) granted DHS authority to fly such missions, but were concerned about safety in the national airspace, since the UAVs had limited capabilities to avoid other aircraft.[103]

The January 2013 USD(AT&L) report to Congress on unmanned systems acknowledges that "current DoD UAS lack the same capabilities as manned aircraft to safely and efficiently integrate into the National Airspace System (NAS)."[104] The DoD UAS Task Force includes an integrated product team dedicated to address this problem:

> The Airspace Integration IPT (AI-IPT) seeks to improve airspace access for UAS operations and training requirements in support of homeland defense, homeland security, and defense support of civil authorities. The AI-IPT reviews and assesses operational requirements; identifies and develops acquisition solutions; assists in the development of UAS technical standards; and recommend straining and policy changes necessary to integrate UAS into necessary classes of airspace.[105]

The current process allows the FAA to issue a Certificate of Waiver or Authorization (COA) for government entities that desire to fly a UAS in civil airspace for purposes such as law enforcement, firefighting, border patrol, disaster relief, search and rescue, and military training. The FAA evaluates the COA request for safety and, if approved, defines the allowed airspace and any special provisions. The numbers of COAs granted has risen from 146 in 2009 to 609 in 2014.[106] To further complicate the situation, as of May 2014, 35 states have introduced legislation to restrict the use of drones by government; 12 state legislatures have actually some formal measures.[107] Returning full circle back to the international environment, it is important to note that the European Union (EU) is also considering airspace management restrictions for unmanned air systems.[108] Also, a March 2015 GAO report compares the evolution of airspace restrictions for UAS operation amongst the United States, Australia, Canada, France, and UK.[109]

Strategic Geopolitical Challenges.

What long-term strategic effects on American national security policy are likely to result from increased use of military AWS? When examining this question, one must ask if the AWS are simply an evolution of warfare, or whether they may represent a revolution in military affairs.[110] The 2014 report from NATO Allied Command Transformation recommends serious study regarding the impact of autonomous system to the character of war, specifically "the potential of autonomous technologies to impact the nature and conduct of war."[111] Consistent with this theme, the report concludes that one of the study's most important findings is the need to consider the proper balance of human control versus machine control. Toward this end, the report recommends this be done at policy levels and include the following factors:

- The type of decision being transferred to the machine;
- The command relationship between human and machine;
- The type of operating environment;
- The type of risk incurred if the machine makes the wrong decision; and,
- The particular military benefit of autonomization of certain functions (e.g. precision performance, faster decisionmaking, reduction of risk to personnel).[112]

In his study of the effectiveness of recent armed drone strikes, author James Walsh considers the long-term implications and asks "How will other countries and insurgent organizations respond to the use of drones as a U.S. tool of counterinsurgency?"[113] Use of drones can be seductive, since such operations require fewer "boots on the ground" and thus diminish the risk of U.S. casualties. However, a 2014 RAND Corporation report notes that this reduced fear of loss may "change the calculus for the employment of force" to lower the threshold of intervention and warns that "as armed UAVs spread, other countries may be more likely to intervene in similar circumstances."[114] A 2014 study of future warfare by the Australian Army echoed the need for carefully examining the potentially profound changes that autonomous technology may have in future wars. The report singles out armed AWS, stressing that "significant questions remain concerning the ethics and legality of arming autonomous platforms and empowering these systems to use lethal force."[115]

On the domestic political front, Walsh poses a question that would please Clausewitz: "How the reliance on drone strikes will influence perceptions on the part of the American public of the acceptability and desirability of the use of force."[116] Certainly, the administration of President Obama has greatly escalated the use of armed drones in the application of U.S. force, including use "over at least 475 decisions to carry out lethal force in nations beyond the ones where U.S. military forces are deployed on the ground."[117] An apparent side effect to this increased use is reduced operational and political costs at home, a trend that may make the decision to use force easier in the future. Many respected government experts have questioned if the authorities granted by such measures as the War Power Act have been interpreted too liberally in these operations. To address such concerns, let us examine the related legal issues.

LEGAL ISSUES RELATED TO USE OF AUTONOMOUS SYSTEMS

What are legally acceptable uses of autonomous weapon systems within the range of military operations? To examine this, we will first look at existing international legal conventions including the Law of Armed Conflict (LOAC). We will then review recent assessments by the UN LOAC. Next, we focus on the concept of human control and judgement as it applies to AWS. Finally, we shall review some current vignettes as well as consider some potential trends for the future.

International Law and LOAC.

Although the widespread use of AWS in warfare is still in its infancy, there have been serious concerns raised regarding the legality of their application. What forms the legal foundation for the use of AWS in warfare? *DoD Directive 3000.09* explicitly assigns responsibility to the General Counsel of DoD (GC, DoD) to "provide for guidance in and coordination of legal reviews of weapon systems submitted in accordance with" provisions of the directive.[118] This includes review of the Law of War (often called law of armed conflict, or LOAC) per the provisions of *DoD Directive 2311.01E, DoD Law of War Program*, which:

> encompasses all international law for the conduct of hostilities binding on the United States or its indi-

> vidual citizens, including treaties and international agreements to which the United States is a party, and applicable customary international law.[119]

To address the growing controversy regarding drone attacks, internationally recognized legal expert Michael Schmitt published a detailed legal analysis that examined both the *jus as bellum* (right to war) and *jus in bello* (international humanitarian law) principles. In general, he concluded "that there is little reason to treat drones as distinct from other weapons systems with regard to the legal consequences of their employment."[120] He also addressed the debate over U.S. drone attacks over countries whose government did not grant permission, such as Pakistan. Schmitt summarized the U.S. justification as one derived from Article 51 of the UN Charter (inherent right of self-defense), stating that "the victim state [the U.S.] may act militarily in self-defense, including the use of drones, to put an end to the unlawful activities" that the territorial state (Pakistan) fails to stop.[121] Schmitt's analysis included two other interesting concepts related to the use of drones. First, because of their capabilities for long duration loiter and precision strike, drones may in some cases be the most legally responsible choice of force application. Second, drone operators located in the United States remain legitimate targets of enemy attack.[122]

When considering the use of armed UAVs to target specific individuals or groups, the Bard College's Center for Study of the Drone assessment resonated with Schmitt's arguments. Specifically, the Center surmises that:

> under international humanitarian law, the United States may use lethal force against individuals outside

> of an active war zone, but only if these individuals are actively involved in hostilities that pose an imminent threat to the United States or its interests.[123]

Recent military doctrine of UK also echoed Schmitt's observation that AWS may in some cases be the most responsible choice. They offer the argument regarding the Counter-Rocket, Artillery and Mortar (C-RAM) employed in Afghanistan that "the potential damage caused by not using C-RAM in its automatic mode justifies the level of any anticipated collateral damage."[124]

Assessments by the United Nations.

Thus far, the discussion has focused on legal issues limited to AWS in the air domain; a more general discussion of armed AWS in all domains is necessary to properly assess the legal implications. Toward this objective, the UN has sponsored two meetings, in May 2014 and April 2015, under provisions of its Convention on Certain Conventional Weapons (CCW) focused on "questions related to emerging technologies in the area of lethal autonomous weapons [LAWS]."[125] The May 2014 Meeting of Experts on LAWS was attended by representatives from 87 countries as well as over 25 nongovernmental organizations (NGOs) and academe. In addition to discussing legal aspects of LAWS, the agenda included sessions on technical issues, ethics and sociology, and operational and military aspects. Since this was the inaugural UN meeting on LAWS, it generally focused on identifying the myriad issues and working toward a common lexicon to guide future discussion toward solutions.

The final report of the May 2014 meeting indicated that many of the delegates were trying to consider the balance between "the potential for rapid technological developments in autonomous weapons to radically transform the nature of warfare" and "the necessity of recognizing the significance of the peaceful uses of autonomous technologies in the civilian field."[126] While there was no agreement on any significant issue, several themes emerged in the technical sessions, to include "the notion of meaningful human control could be useful to address the question of autonomy" as well as "the concept of human involvement in design, testing, reviews, training and use" of LAWS.[127] The sessions on legal aspects revealed diverse views on the possibility for LAWS to comply with international humanitarian law as well as the adequacy of existing international law to address potential uses of LAWS. Another provocative issue regarded how responsibility for the use of LAWS would be determined and whether there may be an "accountability gap" that requires an examination of responsibilities for not only LAWS users, but also for those involved with the design and manufacturing.[128]

Based on the progress of their 2014 meeting, CCW leadership organized a second meeting to continue the dialogue on LAWS. In preparation for this meeting, the Center for a New American Security (CNAS) published a primer for delegates of the second meeting based in part on key issues raised in the first meeting. The primer encourages that "States should follow these [LAWS] discussions with a more focused examination of the **strategic stability** issues surrounding LAWS, perhaps in the form of a working group."[129] The issues listed by CNAS included: the current existence of LAWS; the legality, morality, and predictability of LAWS; how LAWS affect human dignity and ethics; and stabilizing and destabilizing nature of

LAWS in warfare. They also highlighted the concept of "meaning human control" as an important part of addressing the other challenge areas and proposed a working definition:

> There are three essential components of meaningful human control:
> 1. Human operators are making informed, conscious decisions about the use of weapons.
> 2. Human operators have sufficient information to ensure the lawfulness of the action they are taking, given what they know about the target, the weapon, and the context for action.
> 3. The weapon is designed and tested, and human operators are properly trained, to ensure effective control over the use of the weapon.

These standards help ensure accountability, moral responsibility, and the ability to safely control the weapon.[130]

The second Meeting of Experts on LAWS was held April 13-17, 2015, and included delegates from over 90 countries as well as from the EU and 15 NGOs. Observers at the proceedings noted that there was positive discussion, but still no true consensus on any significant issues. At the most fundamental level, there remains some disagreement as to what constitutes LAWS, especially with regard to existing systems, such as armed drones. There was also discussion of the dilemma surrounding the dual-use nature of autonomy and the concern that a universal ban on LAWS-related technologies may inadvertently outlaw some beneficial applications as well.[131]

While the formal report on the 2015 meeting is still being written and reviewed within UN channels, many of the written statements of contributing countries have posted on the CCW website. As one might expect, both meetings included representatives from the five permanent members of the UN Security Council (China, France, Russian, UK, and the United States), any of which could wield veto power over enactment of any eventual LAWS-related security resolutions. The opening statement by the UK clearly established their viewpoint: "From our perspective, to discuss LAWS is to discuss means and methods of warfare. As such, international humanitarian law provides the appropriate paradigm for discussion."[132]

The U.S. delegation clarified the U.S. position that the conference discussion should only involve future systems and "emerging technologies," and that for the purposes of the meeting, "we are not referring to remotely piloted aircraft, which as their name implies are not autonomous weapons, or other existing weapons systems."[133] The statement included "The United States has a process in place, applicable to all weapon systems, which is designed to ensure weapons operate safely, reliably and are understood by their human operators"[134] and further noted that *DoD Directive 3000.09* imposes additional scrutiny for any potential LAWS, but "neither encourages nor prohibits the development of such future systems."[135]

Human Control and Judgment.

In his closing remarks at the 2015 LAWS meetings, Paul Scharre of CNAS commented "There seems to be an emerging consensus that human control and judgment is needed. And most seem to agree that there should be a necessary quality to that control, just as there is with the use of weapons today."[136] Although one might dismiss this as a self-fulfilling prophecy facilitated by the CNAS primer, it is clear the issue of human control and judgment is an essential element to include in any deliberations of AWS. For example, the International Committee of the Red Cross (ICRC) held an Expert Meeting of Autonomous Weapon Systems in March 2014, the results of which informed the LAWS meetings.[137] The ICRC meeting included representatives from 21 countries and 13 NGOs and their findings included "recognition of the importance of maintaining human control over selecting and attacking targets, although there is less clarity on what would constitute 'meaningful human control'."[138] To help explore this conceptual ambiguity, presentations given at the meeting included topics on Human Supervisory Control; Distinction, Proportionality, and Precaution; and Accountability and Responsibility. Pointing to ethical considerations beyond legal factors, the report notes "it is argued that the manner in which people are killed matters, even if they are lawful targets."[139]

The 2014 NATO Allied Command Transformation report also addresses the importance of considering human control, and notes in general terms "the necessary level of human control depends on the particular situation, applicable legal constraints, and the level of tolerable risk."[140] For unarmed AWS, risk assessment may be based on the potential for collateral damage based on the size of the system and the possible kinetic energy if it crashed.[141] The report further notes the more severe restriction case of LAWS application and concludes, "The idea that autonomous systems could be autonomously deciding on the use of lethal force against humans, is perceived by some as being incompatible with the dictates of public conscience."[142]

Toward the Future.

Despite the insistence of the U.S. delegation to the recent UN meeting that armed drones are not associated with LAWS issues, it may be prudent to consider the opinions of the rest of the world. The first openly acknowledged successful use of an armed U.S. UAV was a Predator in Afghanistan on October 7, 2001.[143] The legal justification for the attack was based in large part on the "Authorization for Use of Military Force" passed as a joint resolution by Congress following the 9/11 attacks.[144] A report by the RAND Corporation found that since that first use, there have been eight other conflicts in which the United States used armed UAVs. Per the report's assessment of these conflicts, three did not occur in a recognized war zone (Pakistan, Yemen, and Somalia), and three did not have clear congressional authorization (Yemen, Libya, and Somalia). Also, the report posited that:

> the greatest concerns about U.S. use of armed UAVs appear to arise from operations outside active war zones, less-transparent operations, lack of clarity about congressional authorizations, and targeting of those not clearly identified as combatants or al Qaeda leaders.[145]

In a *Parameters* article, W. Andrew Terrill explored the use of drones over Yemen in further detail and noted that:

> despite their successes, the use of US drones is deeply unpopular with many Yemenis, and anger over their employment is one of the primary drawbacks to using these systems. One of the most important reasons for Yemeni anger is a concern about national sovereignty.[146]

Terrill noted the resulting reluctance of (former) President Ali Abdullah Saleh to publicly acknowledge Yemen cooperation with the United States for drone strikes. Even with the 2012 election of President Abed Rabbu Hadi and a more openly cooperative relationship with the United States, Terrill recommended that "US leadership correspondingly needs to avoid viewing its drone program as a panacea for Yemen's terrorism and insurgency problems."[147] In a rather prophetic conclusion, Terrill asserted:

> In sum, drones are on probation with the Yemeni public, and even a friendly Yemeni president can still be pressured to disallow drone strikes. Drones can help manage instability but they cannot, by themselves, create stability in Yemen.[148]

Since the publication of the *Parameters* article in 2013, the government of Yemen has devolved into civil war in March 2015 with rebel forces backed by Iran forcing President Hadi to flee to Saudi Arabia.[149] Granted, the dynamics in Yemen go far beyond a simple cause-and-effect equation with armed UAVs, and the eventual benefit, or detriment, of their use requires further study.

But even in a legitimate conflict with the support of local government, commanders and operators of AWS need to minimize collateral damage. The 2014 Australian Army Future Land Warfare Report notes that "the increasing difficulty of discriminating between combatants and noncombatants is likely to require more extensive targeting preparation and an increased need for target audience analysis."[150] Thus, governments need to be attuned to public awareness of battlespace operations and any implicit promise of war without casualties. Enabled by ubiquitous social media, the report suggests "the gap between perceptions of bloodless precision and the reality of close combat will be difficult to bridge."[151]

It will be even tougher to develop appropriate artificial intelligence for AWS to discriminate targets for application of lethal force. The challenge is so great and the implications so severe that the European Parliament has called on EU member states to consider to "ban the development, production, and use of fully autonomous weapons which enable strikes to be carried out without human intervention."[152] But even if these countries and the United States impose such restrictions, potential adversaries may not follow constraints. The 2014 Australian Army report sums this up well: "Legal, moral or ethical constraints, which are deemed to uphold the legitimacy and legality of Western military operations, are unlikely to restrict the actions of potential adversaries."[153]

The path forward for the United States will continue to be watched closely by the rest of the world. As a 2014 report for the Council for Foreign Relations cautions:

> Given that the United States is the lead actor and exemplar of drone use, its interpretation of international law, public articulation of its position, and future behavior will set a precedent on which other countries are like to base their own behavior.[154]

These strategic decisions will have implications for the future of all AWS, not just UAVs. Rather than focusing exclusively on the myriad tactic legal details involved with AWS and LAWS, perhaps the United States should also promulgate a broader vision of ethical behavior that can help promote a culture of responsible use of force. Rebecca Crootof of Yale Law

School studied international law for autonomous weapons in the context of LOAC and beyond. Her recommendation is straightforward: "Given that we do not yet fully understand the benefits and risks posed by autonomous weapons systems, developing flexible codes of conduct may be preferable to negotiating a treaty."[155] Indeed, developing such codes of conduct requires a dialogue that extends beyond the low bar of the interpretation of laws and considers the relevant ethical issues.

ETHICAL ISSUES RELATED TO USE OF AUTONOMOUS SYSTEMS

What should be the ethically acceptable and advisable uses of autonomous weapon systems within the range of military operations? What moral principles should form the foundation of AWS development and operation? We explore these questions by first reviewing the ongoing work for developing ethical frameworks for AWS. We then consider the varying cultural views that AWS applications may evoke. Next, we analyze the potential reduction or proliferation in warfare that widespread use of AWS may introduce. Finally, we look toward the future and contemplate potential long-term effects on national security.

Ethical Frameworks.

The report of the 2014 LAWS Expert Meeting included a section that summarized a session held to examine ethical and sociological aspects. Several noteworthy themes were identified for future discourse centered on the inherent deficiencies of inculcating ethics into machines. Many agreed that "the possibility for a robotic system to acquire capabilities of 'moral reasoning' and 'judgment' was highly questionable."[156] Some of the perceived difficulties in this endeavor would include the pragmatic task of writing software with appropriate values and ethics that could be exercised in complex and dynamic environments. The report also questioned how autonomous systems might respond to moral dilemmas. Finally, even if these challenges were surmounted, could humans fully trust such systems and would they be acceptable to society writ large?

Internationally recognized organizations that have dedicated efforts to examine the ethics involved with LAWS include the Human Rights Watch and the International Human Rights Clinic (IHRC), part of the Human Rights Program at Harvard Law School. Since November 2012, these groups joined to publish three reports on the dangers posed by "killer robots," which they define as fully autonomous weapons that "possess the ability to select and engage their targets without meaningful human control."[157] Their first report, *Losing Humanity: The Case against Killer Robots* (November 2012) builds a case for the possibility of killer robots becoming reality within 20 to 30 years as well as an urgency for their recommendation for appropriate national and international measures "to prohibit the development, production, and use of fully autonomous weapons."[158] The second report, *Shaking the Foundations, The Human Rights Implications of Killer Robots* (May 2014) emphasizes the ethical concepts of human dignity and right to life. Its conclusion includes:

> Finally, as machines, fully autonomous weapons could not comprehend or respect the inherent dignity of human beings. The inability to uphold this underlying

> principle of human rights raises serious moral questions about the prospect of allowing a robot to take a human life.[159]

The third and most recent report, *Mind the Gap: The Lack of Accountability for Killer Robots* (April 2015) focuses on a very direct premise: "Because these robots would be designed to kill, someone should be held legally and morally accountable for unlawful killings and other harms the weapons cause."[160] The report argues that existing immunity granted to military operators and contractors represent gaps in accountability and that such failure to uphold responsibility "add to the moral, legal, and technological case against fully autonomous weapons and bolster the call for a ban on their development, production, and use."[161]

Two of the positions endorsed by Human Rights Watch and IHRC complement earlier discussions in this Paper. First is their participation in the UN LAWS Meetings of Experts and specifically their recognition of the role of human control. In their opening statement at the 2014 meeting, their representative, Steve Goose, noted "The key to success this week will be the beginning of the emergence of a consensus that there should always be meaningful human control of the targeting and kill decisions in any individual attack on other humans."[162] Second is a recommendation from the first killer robot report that proposes a worthwhile initiative for those involved in the development of AWS:

> To Roboticists and Others Involved in the Development of Robotic Weapons
>
> - Establish a professional code of conduct governing the research and development of autonomous robotic weapons, especially those capable of becoming

> fully autonomous, in order to ensure that legal and ethical concerns about their use in armed conflict are adequately considered at all stages of technological development.[163]

The March 2014 ICRC Expert Meeting Report included summaries of three speakers focused specifically on ethical issues surrounding AWS. Professor Ronald Arkin of the Georgia Institute of Technology addressed the concept of ethical restraint of LAWS. He introduced several root causes of war crimes attributable to human motives (such as revenge, dehumanization, immaturity, frustration, and pleasure) that could be improved by the use of automated systems. However, he admitted that autonomous measures may also have negative impacts on squad cohesion as well as relations with local populations. In the end, he argued that noncombatants could benefit "though the judicious deployment of these robotic systems, if done carefully and thoughtfully, particularly in those combat situations where fighters have a greater tendency or opportunity to stray outside IHL."[164]

Dr. Peter Asaro of The New School, USA, provided an excellent overview of seminal works of ethics and philosophy that inform the dialogue on AWS. He noted the foundations set forth by the Martens Clause to evaluate not only a new weapon system's compliance with IHL but also its adherence to matters of humanity and public conscience. He also explained some of the moral frameworks that define this, such as the UN Declaration of Human Rights (1948) as well as Western philosophical tradition, such as rights-based (Kantian) theories and virtue ethics. Based on this, he posited that "in giving over the responsibility to make targeting decisions to machines, we fundamentally change the nature of the moral considerations involved in the use of violent force."[165] He concluded by pondering the implications of allowing AWS to take human lives, asking "As we give over the decisions of life and death to technological systems, are we diminishing the value of human life?"[166]

Finally, Dr. Peter Lee of the University of Portsmouth (UK) posited that "such a thing as a fully autonomous, cognisant, self-reasoning weapon system does not exist [yet]" and thus the current dialogue about future AWS "is necessarily shaped by two things: perceptions of the nearest equivalents (drones, currently remotely piloted), and the influence of science fiction and the Hollywood effect" and therefore "any ethical analysis is subject to contestation and lacking demonstrable 'facts'."[167] He also outlined "the moral calculus of oversight and accountability" by comparing the evolution of the "kill chain" from World War II bombings, to Reaper armed drones, and then to possible AWS operations. He concluded by arguing that the LAWS debate will need to continue for years since "ethical assessments of autonomous weapons are currently as limited as the technological, military and political assumptions they are based upon."[168] Dr. Lee noted the potential impact that popular science fiction may have on perceptions surrounding AWS ethical issues; what other cultural influences impact this discourse?

Cultural Views.

Greg Kennedy in a 2013 *Parameters* article examined some of the cultural views of other countries regarding war by proxy. He observes that, even though U.S. drone attacks may have military success, they may also increase animosity among the population that actually can increase attacks on a besieged government that the United States is attempting to bolster. Even though much of the resentment may be anti-American, unfortunately, "feelings of hostility are often visited on the most immediate structures of authority [of the local government]."[169] More troubling are the broader implications "regarding the legality, ethicality, and operational legitimacy of those [U.S.] acts to deter opponents."[170] Kennedy concludes that evolution from limited covert operations to widespread use of armed drones exacerbates "the apparent gap between stated core policies and values and the ability to practice targeted killings appears to be a starkly hypocritical and deceitful position internationally."[171]

Two additional articles from the same issue of *Parameters* delve into some of the nuances of Kennedy's article. Jacqueline L. Hazelton examined how the use of drone strikes compare to other tools of the state. She argues that strikes against assets that are planning an imminent attack on the U.S. homeland present different moral questions than strikes targeting individuals that may be acting suspiciously. Thus, she posits that leaders must consider the full political context when pondering the use of drone strikes, including "for example, theaters where the United States is at war, theaters in which it is not, theaters in which the United States has national or international permission to strike, theaters in which it does not, and so on."[172] In his article, Alan W. Dowd contends further that the current context for U.S. decisionmakers should take into account how "the brewing international backlash against the drone war reminds us that means and methods matter as much as ends."[173]

An example illustrating Dowd's observation regarding the means and methods can be found in

French author Grégoire Chamayou's book, *Théorie du drone* (*Drone Theory*) in the chapter titled "Ethos et psyche" ("Ethos and psyche"). There he mulls over the unit morale patch used by some U.S. Reaper UAV operators that depicts an image of the Grim Reaper holding a bloody scythe under a heading "USAF MQ-9 Reaper" and a tab with the motto "That Others May Die."[174] While the message behind the image may not win favor amongst international audiences, they may be even more dismayed to find out that the patch is a lampoon of the U.S. Air Force Pararescue force which uses a patch of the same design, but with an angel instead of the Grim Reaper and the motto, "That Others May Live."[175]

The 2014 NATO Allied Command Transformation report exploring policy guidance for use of autonomy also addressed ethical issues and recommended transparency for policymakers as they consider potential benefits and concerns related to AWS technology. However, the scope of their recommendation went beyond those of LAWS to include the review of "levels of responsibility for the intended and unintended consequences of tasks performed by autonomous systems," and it admonishes that considerations "should not neglect nonlethal tasks performed autonomously."[176]

Warfare: Reduction or Proliferation?

If AWS use becomes widespread, how will it affect the frequency and intensity of conflict and the application of force? Despite the anticipated improvements in lethality and precision in future AWS that may better deter aggression, many argue that the threshold for use of force may actually be lowered. Thomas Cowan explored the impact of robots on warfare using the

Clausewitz model of war—the trinity of primordial violence (depicted as the people), chance (depicted as the military), and reason (depicted as the government)—as the lens for his analysis. He posited that the use of "robots will significantly increase the potential for future conflicts" for three primary reasons. First, there will be fewer people directly involved as they are replaced by machines; second, friction will be reduced as the robots do not suffer from human physical or mental frailties; and third, the government may operate with less constraint since the probability of creating friendly casualties is reduced.[177]

In a 2002 *Parameters* article, D. Keith Shurtleff expounds on the notion of how increasing technology may diminish warfighters' humanity. He examines the concept of disengagement, often facilitated through video recordings such as "the luckiest man in Iraq"—a man in a video that drove a truck across a bridge just before a precision bomb destroyed the bridge. General Norman Schwarzkopf used this moniker as a punchline during an Operation DESERT STORM press conference as many others have done in a similar manner since. Shurtleff sums up the dilemma as:

> what we must deal with now is how to accept, even embrace, technologies that make war safer, and yet somehow counter the trend that such technologies have to disengage us, to make war more acceptable or potentially more ubiquitous.[178]

An interesting phenomenon that runs counter to Shurtleff's thesis that robots may reduce our basic humanity involves situations where soldiers in OEF/OIF personified "their" robots and wanted them fixed because of their "loyalty." This was the case of a badly damaged EOD PackBot named "Scooby-Doo" as told in Singer's *Wired for War*.[179]

In contrast, in his 2013 *Parameters* article, Dowd cautions against the possible development of a "Jupiter Complex" by national leaders—a condition coined during World War II to describe "the notion of the Allies as righteous gods raining retributive thunderbolts on their wicked enemies."[180] The promises of increased combat effectiveness at reduced costs can be seductive.

> UCAVs take the logic of the Jupiter Complex to its ultimate conclusion—maximum use of economic and technological resources with zero manpower losses and zero risks—all buffered by the virtual-reality nature of the delivery system.[181]

How can the U.S. leadership steer clear of such temptations?

Toward the Future.

A report on AWS under International Law by the Geneva Academy points to the need for leaders to consider the balance between advantages and disadvantages of using AWS for a given mission. Possible advantage include "the absence of emotions such as fear, vengeance, or self-interest [that] may lead to outcomes that overall are less harmful." But lack of feelings may be a disadvantage in certain situations since "autonomous weapon systems lack positive human emotions, such as compassion or mercy."[182] Dowd notes further that "they [UAS] remove the unique characteristics humans bring to the battlespace: deliberation, doubt, fear, gut instinct, and judgment." [183]

So then, how should leaders resolve the tension between these perspectives? Perhaps a good starting point is a group of questions sent to representatives of the 2015 UN LAWS Meeting as "Food-for-thought" to prepare for the dialogue.

Military rationale for autonomous functions in weapon systems.

(a) What is the military rationale for pursuing autonomy in specific functions of weapons systems? What would be the reasons for limiting the autonomous capabilities of weapon systems?

(b) In what situations are distinctively human traits, such as fear, hate, sense of honor and dignity, compassion, and love, desirable in combat? In what situations do machines that lack emotions offer distinct advantages over human combatants?

(c) International humanitarian law indicates how a party to a conflict should behave in relation to people at its mercy, how would machines comprehend such situations?

(d) Given the volume and complexity of available information, what advantages do autonomous processes offer? Do these make a machine more, or less reliable than a human decisionmaker?

(e) Are there scenarios in which autonomy might help to protect the lives of civilians and combatants? For example, more precise targeting, preventing collateral damage and lower response time to attacks?

(f) What are the specific opportunities and concerns for developing and deploying autonomous weapons in the context of land, sea, and air operations?[184]

Sources of recent studies and literature that support thoughtful deliberation of these questions can be found at the website of the CNAS Ethical Autonomy Project (this includes an extensive online bibliography as public education resource).[185] With such deliberate and continuous examination of the ethical issues in addition to those of mission effectiveness and legality, we can hopefully escape the fate offered in a final warning from Dowd: "It would be ironic if the promise of risk-free war presented by drones spawned a new era of danger for the United States and its allies."[186]

RECOMMENDATIONS

This Paper explores a diverse set of complex issues related to the developmental, operational, legal, and ethical aspects of AWS. Many of these issues are already on the agendas of competent government, nongovernment, and industry organizations, with mixed progress toward full understanding and resolution. The section offers recommendations to facilitate the best evolutionary path for the future of some of the key issues affecting the use of AWS to enhance U.S. national security.

Policy.

Current DoD policy appears to address the big issues being raised internationally in such venues as those sponsored by the UN and the ICRC. The next iteration of AWS policy in *DoD Directive 3000.09* should expand to include unarmed, unmanned platforms that are capable of causing damage to individuals or property if they malfunction or if their command and control link is lost.

DoD should abandon discrete definitions that pigeonhole systems into categories of autonomy and instead consider the recommendations of the DSB regarding the characterization of autonomy. Accordingly, DoD should develop a framework which considers the autonomous functions of a system and how they may change during the course of a given mission. Thus, it is more important to clearly identify when autonomous functioning of the unmanned system is planned to occur (intentionally autonomous) as well as how and when it can occur unintentionally (either through normal malfunction, interference, or attack by adversary on the system or its links). Existing frameworks to consider include ones proposed by CNAS (that examines human-machine command and control, complexity of machine, and type of decision)[187] and by the DSB (that examines cognitive echelon, mission timelines, and human-machine trade space).[188]

DoD and the Army need to evaluate the budget for unmanned ground vehicle development to assess the realism of its ability to achieve any serious evolution of capability and integration into the ground forces writ large. Any such review should attempt to justify resource allocation based on the operational merits of UGV systems and not emphasize dubious claims of cost savings.[189]

Maintaining Humanity.

DoD policy should continue to require measures that allow the exercise of human judgment and control in AWS operations. Further, this requirement should expand to include greater emphasis for commanders and planners to consider how the scope of such human control may vary during a given mission as well as the potential strategic implications of any fully autonomous mission segments. Also, the AWS development community should also emphasize how autonomy and human control may vary during operations and design fault-tolerate systems that incorporate "fail safe" modes for all mission segments, not just those designated to be intentionally autonomous. The development community should also establish and promulgate an ethical code of conduct for work on AWS similar in nature to that proposed by Human Rights Watch and IHRC.

All parties involved with the development and operation of AWS need to ensure the human dimension is explicitly emphasized and monitored in doctrine, organizations, and processes. Leaders and planners need to be vigilant to guard against any form of the "Jupiter Complex" that may emerge at the strategic level. Developers and operators need to guard against any unhealthy disengagement at the tactic and operational levels.[190]

Strategic Implications.

The mainstream discussions regarding military unmanned systems and AWS are dominated by issues related to the use of armed drones. Popular media focuses on the exploits of UAVs, from possible package delivery vehicles to platforms that invade privacy. Government and commercial investors are pursuing the development and integration of driverless cars into the nation's highway system. Many of these efforts involve regulations that cut across government departments, but there is no clear consideration for how these efforts are preceding writ large.

The long-term implications for current tactical and operational use of existing unmanned systems are setting de facto rules of engagement and expectations domestically and internationally. It is unlikely that any practical and authoritative strategy and governance will emerge that can embrace the full scope of current autonomous systems, let alone keep pace with future developments. With this in mind, the onus of considering the broader context and strategic implications is best practiced by individual stakeholders for the near future. Responsible stakeholders should act cooperatively and proactively as frameworks of compliance and best practices are formulated and formalized in the coming decades.

Additional Issues to Explore.

The scope of this Paper necessarily excludes many significant AWS issues, but two merit special attention for future studies. First, there needs to be serious dialogue regarding how AWS principles apply to systems that operate in the domains of space and cyberspace. Cyberspace systems are explicitly excluded from current DoD policy on AWS, but these systems not only facilitate the operation of AWS in other domains, but they may also act as autonomous software agents in operations limited to the cyberspace domain. Second, the use of autonomy and its anticipated proliferation need to be included in dialogues regarding hybrid warfare by state and nonstate actors.

CONCLUDING REMARKS

The evolution of autonomous weapon systems accelerated significantly after the 9/11 attacks on the U.S. homeland, and they will likely continue to grow in both capabilities and numbers. This growth of unmanned systems is not limited to the U.S. military or even the United States; it is an international phenomena that includes government and commercial applications in all domains—air, land, and sea. Currently, air-based systems dominate all aspects of AWS—budget, development, and operations. Unmanned ground systems receive much lower priority and are largely relegated to niche applications vice being seriously considered as part of an integrated future land force. Commercial endeavors for unmanned systems are at the forefront of many technologies and their proliferation will likely outnumber military use in the future.

As the U.S. military moves forward with the development of AWS doctrine that spans the full range of military operations, it may be well served to characterize autonomy not as a discrete property of a given system, but rather as a function that varies in its strategic, operational, and tactical context and mission application. When can the system be autonomous? When is it planned in a given mission to do so? When can it do so by accident or failure? Efforts that address such questions should be tempered with the purposeful consideration of human judgment and control as well as legal and ethical standards that foster international credibility. In many of the challenges related to autonomous weapon systems, the United States is setting both overt and tacit precedents for the world—will we be able to live up to them if they are applied to us?

ENDNOTES

1. Jenay M. Beer, Arthur D. Fisk, and Wendy A. Rogers, "Toward a Framework of Levels of Robot Autonomy in Human-Robot Interaction," *Journal of Human-Robot Interaction*, Vol. 3, No. 2, 2014, pp. 74-99.

2. Paul Scharre and Michael C. Horowitz, *An Introduction to Autonomy in Weapon Systems*, Working Paper, Washington, DC: Center for a New American Security, February 2015, available

from *www.cnas.org/sites/default/files/publications-pdf/Ethical%20Autonomy%20Working%20Paper_021015_v02.pdf*, accessed on June 2, 2015. This publication offers concise insight into three fundamental questions with regard to autonomous weapon systems: "What is autonomy"; "How is autonomy used in weapons today?"; and "What is an 'autonomous weapon'?"

3. *Report of the ICRC Expert Meeting on Autonomous weapon systems: technical, military, legal and humanitarian aspects*, *26-28 March, 2014, Meeting Highlights*, Geneva, Switzerland: ICRC, May 9, 2014, available from *https://www.icrc.org/eng/assets/files/2014/expert-meeting-autonomous-weapons-icrc-report-2014-05-09.pdf,* accessed June 10, 2015. This report states that only the United States and UK "are known to have developed national policy on autonomous weapon systems." (p. 10).

4. Under Secretary of Defense for Policy, *Department of Defense Directive* (DoDD) *3000.09*, *Autonomy in Weapon Systems*, Washington, DC: Department of Defense, November 21, 2012, p. 1. The Definitions section of this directive, p. 15, defines "unintended engagement" as:

> The use of force resulting in damage to persons or objects that human operators did not intend to be the targets of U.S. military operations, including unacceptable levels of collateral damage beyond those consistent with the law of war, ROE, and commander's intent.

5. *Ibid.* Definitions in Figure 1 are verbatim from the definitions in Part II (pp. 13-15) of this document.

6. James A. Winnefeld, Vice Chairman of the Joint Chiefs of Staff, and Frank Kendell, Under Secretary of Defense (Acquisition, Technology and Logistics), *Unmanned Systems Integrated Roadmap, FY2013-2038*, Reference Number 14-S-0553, Washington, DC: Department of Defense, 2013, p. 15.

7. Joint Chiefs of Staff, *Joint Publication* (JP) *1-02, Department of Defense Dictionary of Military and Associated Terms*, Washington, DC: U.S. Government Printing Office, November 8, 2010 (as amended through June 15, 2015), p. 254. This document contains the following definitions:

unmanned aircraft — An aircraft that does not carry a human operator and is capable of flight with or without human remote control. Also called UA. (JP 3-30)

unmanned aircraft system — That system whose components include the necessary equipment, network, and personnel to control an unmanned aircraft. Also called **UAS**. (JP 3-30)

8. *DoDD 3000.09,* pp. 1-2.

9. *Ibid.*, p. 2.

10. "Kettering Aerial Torpedo 'Bug'," Fact Sheet, National Museum of the U. S. Air Force website, April 7, 2015, available from *www.nationalmuseum.af.mil/Visit/MuseumExhibits/FactSheets/Display/tabid/509/Article/198095/kettering%ADaerial%ADtorpedo%ADbug.aspx*, accessed August 12, 2015. According to the fact sheet, the "Bug" was an early UAV with a 180-pound payload of explosives that used pneumatic and electrical controls to guide it to a target. Its range was 75 miles and, although 50 were built by the Dayton-Wright Airplane Company before World War I ended, none were ever used in combat.

11. Arthur Holland Michel and Dan Gettinger, "Out of the Shadows: The Strange World of Ground Drones," New York: Center for the Study of the Drone at Bard College, November 3, 2013, available from *dronecenter.bard.edu/shadows-strange-world-ground-drones/*, accessed June 2, 2015.

12. Richard Whittle, "Hellfire Meets Predator: How the drone was cleared to shoot," *AirSpaceMag.com*, March 2015, available from *www.airspacemag.com/flight-today/hellfire-meets-predator-180953940/?no-ist,* accessed July 30, 2015. The article noted on p. 2 that:

> By firing a Maverick from a modified Firebee on December 14, 1971, at Edwards Air Force Base in California, the Air Force's 6514th Test Squadron claimed a place in aviation history: the first launch of an air to ground missile from a remotely piloted aircraft. None was put into operation, though, and with the end of U.S. involvement in Vietnam, Air Force interest in drones evaporated.

13. Michel and Gettinger, "Out of the Shadows," p. 2.

14. Douglas W. Gage, "UGV History 101: A Brief History of Unmanned Ground Vehicle (UGV) Development Efforts," *Unmanned Systems Magazine*, Vol. 13, No. 3, Summer 1995, posted as DTIC Report ADA422845, available from *oai.dtic.mil/oai/oai?verb=getRecord&metadataPrefix=html&identifier=ADA422845*, accessed January 28, 2015.

15. Gage, "UGV History 101," pp. 2-4. Joint Army-Marine Corps projects included the Tactical Unmanned Ground Vehicle (TUGV) as well as other development vehicles such as the Surveillance and Reconnaissance Ground Equipment (SARGE), the Technology Test-Bed (TTB0, and the GECKO for semi-autonomous vehicle driving evaluation).

16. *Ibid.*, pp. 5-6. On p. 5, Gage points out the historical significance of the ROBART 1 robot:

> What is generally regarded as the world's first autonomous security robot, ROBART I, was developed in 1981 at the Naval Postgraduate School (Everett, 1982). While rich in collision avoidance sensors, this research platform had no sense of its absolute location within its indoor operating environment, and was thus strictly limited to navigating along reflexive patrol routes defined by the relative locations of individual rooms, while periodically returning to a recharging station by homing on an IR beacon.

17. *Unmanned Systems Integrated Roadmap, FY2013-2038*, p. 7.

18. Bryan J. McVeigh, "Robotics Portfolio Overview," briefing to the National Defense Industrial Association (NDIA) Robotics Division, Warren, MI: Program Manager Force Projection, December 4, 2014, slides 2-4, available from *www.ndia.org/Divisions/Divisions/Robotics/Documents/McVeigh.pdf*, accessed May 6, 2015.

19. *Unmanned Systems Integrated Roadmap, FY2013-2038,* pp. iii-xiv.

20. JP *1-02.*

21. *Unmanned Systems Integrated Roadmap, FY2013-2038*, pp. 4-8. The definitions presented in Table 1 are taken verbatim from this source.

22. For a list of GAO reports related to unmanned aerial systems (drones), see *www.gao.gov/key_issues/unmanned_aerial_systems/issue_summary*, accessed May 29, 2015.

23."Agencies Could Improve Information Sharing and End-Use Monitoring on Unmanned Aerial Vehicle Exports," Report GAO-12-536, Washington, DC: U.S. Government Accountability Office, July 2012, p. 1.

24. "Information Sharing and End-Use Monitoring on Unmanned Aerial Vehicle Exports," Report GAO-12-536, p. 10. Figure 10 of this report lists the 76 countries that had acquired UAVs by December 2011 as follows: Algeria, Angola, Argentina, Australia, Austria, Azerbaijan, Belarus, Belgium, Botswana, Brazil, Bulgaria, Burundi, Canada, Chile, China, Colombia, Croatia, Czech Republic, Denmark, Egypt, Estonia, Ethiopia, Finland, France, Georgia, Germany, Greece, Hungary, India, Indonesia, Iran, Israel, Italy, Ivory Coast, Japan, Jordan, Kazakhstan, Latvia, Lebanon, Libya, Lithuania, Malaysia, Mexico, Morocco, Netherlands, New Zealand, Nigeria, Norway, Pakistan, Panama, Peru, Philippines, Poland, Republic of Korea, Romania, Russia, Serbia, Singapore, Slovakia, Slovenia, South Africa, Spain, Sri Lanka, Sweden, Switzerland, Syria, Taiwan, Thailand, Trinidad and Tobago, Tunisia, Turkey, Uganda, Ukraine, United Arab Emirates, UK, and United States.

25. "Unmanned Systems and Robotics Directory," Association for Unmanned Vehicle Systems International (AUVSI) website, available from *roboticsdatabase.auvsi.org/home*, accessed July 30, 2015.

26. Darryl Jenkins and Bijan Vasigh, *The Economic Impact of Unmanned Aircraft Systems Integration in the United States*, Arlington, VA: AUVSI, March 2013, available from *https://higherlogicdownload.s3.amazonaws.com/AUVSI/958c920a-7f9b-4ad2-9807-f9a4e95d1ef1/UploadedImages/New_Economic%20Report%202013%20Full.pdf,* accessed July 30, 2015.

27. *DoDD 3000.09*, pp. 7-8.

28. *Unmanned Systems Integrated Roadmap, FY2013-2038*, p. 14.

29. *Ibid.,* p. v.

30. *Ibid.,* p. 1. DoD's vision is for unmanned capabilities that will:

- Prevail in the full range of contingencies and in all operating domains, including cyberspace (Defense Strategic Guidance 2012);
- Enable decisive force effectiveness in Joint and coalition operations;
- Be critical to future success;
- Emphasize missions according to strategic guidance from intelligence, surveillance, and reconnaissance (ISR); counterterrorism; counter-weapons of mass destruction (WMD); and operations required to operate across all environments, including anti-access and area denial (A2/AD);
- Protect the homeland; and,
- Be able to surge and regenerate forces and capabilities.

31. Defense Science Board (DSB), *Task Force Report: The Role of Autonomy in DoD Systems*, Washington, DC: Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics, July 2012, p. i.

32. *Ibid.,* pp. 56-57. The report finds both evolutionary and revolutionary aspects in the recent use of unmanned systems:

> The conflicts in Iraq and Afghanistan provided an operational pull for unmanned systems—particularly air and ground vehicles—that resulted in the deployment of many prototype or developmental systems. Once in theater, the demands of combat, combined with the ingenuity of the troops that operated the systems, resulted in unmanned systems being used extensively. This operational experimentation led to the employment of the systems in unanticipated ways with great benefits. The key missions that drove the evolution of unmanned systems were ISR, the defeat of improvised explosive devices and the pursuit and elimination of high value targets (HVTs). (p. 56)

> The most important development for the HVT mission was arming UAVs, combining ISR and strike on the same platform to reduce the reaction time and shorten the kill chain. The fleeting, often without warning, window of opportunity against an HVT required both the long-term persistent observation provided by an ISR UAV enabling target confirmation and rapid strike without hand-off delays. This functionality was enabled by arming the platform. The operational concepts for most manned systems separated the ISR and strike functions. Consequently, the combination of strike and ISR on a single platform was essentially a revolutionary new capability. (p. 57)

33. Glenn Baca, "An Analysis of U.S. Army Unmanned Ground Vehicle Strategy," Civilian Research Project, Carlisle Barracks, PA: U.S. Army War College, July 2012, pp. 3-4.

34. McVeigh, "Robotics Portfolio Overview," slide 4.

35. *Ibid.,* slide 4.

36. Christopher G. Pernin *et. al.*, *Lessons from the Army's Future Combat Systems Program*, Santa Monica, CA: Arroyo Center, The RAND Corporation, 2012, pp. 1-4, 197, available from *www.rand.org/content/dam/rand/pubs/monographs/2012/RAND_MG1206.pdf*, accessed on August 3, 2015.

37. Jeffrey Jaczkowski, "Unmanned Ground Vehicle Update," Warren, MI: Robotics Systems Joint Program Office, June 2012, slide 3, available from *www.ndia.org/Divisions/Divisions/Robotics/Documents/Quarterly%20Meetings/14%20June%202012/Mr.%20Jeff%20Jaczkowski.pdf*, accessed May 6, 2015.

38. McVeigh, "Robotics Portfolio Overview," slide 5. See also Jeff Child, "Upgrades and Autonomy Improvement Lead UGV Technology Advance," COTS Journal Online, April 2013, available from *www.cotsjournalonline.com/articles/view/103307*, accessed June 25, 2015.

39. *Unmanned Systems Integrated Roadmap, FY2013-2038,* p. 10. The expanded description of the unmanned technologies bullet is:

- Unmanned technologies will continue to improve in many different capability areas.

- Competitors are catching up in unmanned technology.
- Increasingly data-intensive multisensor/multi-mission capabilities are evolving.
- Unmanned technology innovations are rapidly increasing.

40. *Ibid.,* p. 10.

41. *Ibid.,* p. 23-25.

42. *Ibid.,* pp. 26-79. In essence, Table 2 provides a concise outline of Chapter 4 of the Roadmap; the objectives and activities in the table were derived from the text. Specific goals for each area of technology are explicitly presented in three time frames: near-term (2013-17); mid-term (2018-21); and long-term (2022-2030+). See figures 11, 12, 18, 19-23, and 30 of the Roadmap for details.

43. *Ibid.,* pp. 73-76.

44. *Ibid.,* p. 66.

45. *Ibid.,* p. 67.

46. Bobby Junker, "ONR 101 & Navy Autonomy Issues and Needs," NDIA Ground Division Quarterly Meeting, Arlington, VA: Office of Naval Research, June 16, 2011, available from *www.ndia.org/Divisions/Divisions/Robotics/Documents/ONR%20101%20and%20Autonomy%20to%20NDIA%20robotics%20conference%206-16-2011-Bobby%20Junker.pdf*, accessed May 6, 2015, slide 8.

47. DSB, *The Role of Autonomy in DoD Systems,* p. 31.

48. *Ibid.,* pp. 31-55.

49. *DoDD 3000.09*, pp. 6, 10.

50. *Unmanned Systems Integrated Roadmap, FY2013-2038*, p. 87.

51. *Ibid.,* p. 69.

52. Robotics Collaborative Technology Alliance (RCTA), *FY 2012 Annual Program Plan*, Adelphi, MD: Army Research Laboratory, March 2012. In addition to the Army Research Laboratory,

member of the RCTA are Boston Dynamics, Carnegie Mellon University, Florida State University, General Dynamics Robotic Systems, NASA Jet Propulsion Laboratory, QinetiQ North America, University of Central Florida, and University of Pennsylvania. The program announcement (February 2, 2009), which solicited proposals from perspective team members, "identified four key technology areas expected to be critical to the development of future autonomous systems, namely: Perception, Intelligence, Human-Robot Interaction (HRI), and Dexterous Manipulation and Unique Mobility (DMUM)." (p. 1)

53. *Ibid.,* p. 5. The five cross-cutting technical barriers are:

> **Simplistic/Shallow World Model**. Existing autonomous systems fall into two categories: either they have a world model that is at only a metric level, thus precluding any cognitive reasoning, or they have a model that exists at only a cognitive level without physical grounding in the metric world. Neither approach is sufficient for our vision where robots must behave cognitively while interacting in the physical world.
> **Lack of Semantic Understanding.** In existing systems, objects in the world are perceived primarily or only as mobility regions, not as discrete objects of semantic and cognitive importance. Thus, one cannot tell a robot, "Go block the back door of this building" and expect it to do anything useful.
> **Scripted and Brittle Planning.** Robots are almost always tele-operated or, at best, only perform simple scripted behaviors. Scripting all needed behaviors is not tractable and does not allow for learning new or alternative behaviors. Planning algorithms in robots work well only when the planning space is both small and certain enough, but the real world is fraught with uncertainty and high dimensionality. The inability to reason in complex and uncertain environments means that users must intervene frequently in robot operations and are trapped at a close level of "supervised autonomy."
> **No Shared Understanding of Missions and Roles**. Robots now are opaque and distrusted and cannot explain what they are doing. Not only do they not know what they are doing, but also they do not understand what their teammates are doing or what the expectations for roles and communication are. Consequently, current systems must use tedious

> OCUs to bridge the enormous cognitive gap between humans and robots.
> **Missing or Shallow Learning Capability.** Robots now must be explicitly programmed to do tasks, so producing the needed scope of behavior is intractable. Existing learning capability is shallow and lacks generalization. Thus, we cannot retrain robots without bringing engineers to the field or sending the robots back to the developer.

54. *Ibid.*, pp. 2-4.

55. *Unmanned Systems Integrated Roadmap, FY2013-2038*, p. 3. For the chart's abbreviations: RDTE = Research, Development, Test and Evaluation; Proc = Procurement; and OM = Operations and Maintenance.

56. Office of the Under Secretary of Defense (Comptroller)/CFO, *Program Acquisition Cost by Weapon System, Fiscal Year 2016 Budget Request,* Washington, DC: Department of Defense, February 2015, pp. 1-1 through 1-5.

57. *DoD FY 2016 President's Budget Submission: Army Justification Book of Aircraft Procurement, Army*, Washington, DC: Department of the U.S. Army, February 2015, p. 25. The full description for P-1 Line Number A00005, p. 25, MQ-1 UAV is:

> Gray Eagle provides Reconnaissance, Surveillance, Target Acquisition (RSTA), command and control, communications relay, Signals Intelligence (SIGINIT), battle damage assessment, and manned-unmanned teaming capability. Gray Eagle is a dedicated, assured, multi-mission Unmanned Aircraft System (UAS) fielded to all ten Army Divisions to support the commander's combat operations. The Army Special Operations Aviation Command (ARSOAC) Gray Eagle units and Aerial Exploitation Battalions (AEB) Gray Eagle units are self-contained Intelligence, Surveillance and Reconnaissance capabilities teamed with organic Processing, Exploitation and Dissemination that are a global rapidly deployable force and contribute to the Department of Defense Global ISR mission. A Gray Eagle unit consists of either 9 or 12 Aircraft, Universal Ground Control equipment, Standard Equipment Package and Payloads to include: Electro-Optical/Infrared Laser Range Finder/Laser Designator,

synthetic aperture radar/ground moving target indicator, communication relay, and up to 4 HELLFIRE Missiles.

58. *DoD FY 2016 President's Budget Submission: Army Justification Book of Research, Development, Test & Evaluation, Army RDT&E – Volume II, Budget Activity 5a,* Washington, DC: Department of the U.S. Army, February 2015, p. 214. The mission description for the Tactical Unmanned Ground Vehicle includes:

> CRS-(I) is a man-packable, miniature (<25lbs), highly mobile, unmanned robotic system with advanced sensors/mission modules for dismounted Soldiers. The program is the result of collaboration between Director, Army Capabilities Integration Center (DIR ARCIC), United States Army Training and Doctrine Command (TRADOC) and Deputy Commandant for Combat Development and Integration (DC CD&I), Headquarters Marine Corps (HQMC) dated 19 Sep 2012. Thus the CRS-(I) program has been jointly developed by the Army and USMC incorporating Army capability requirements, USMC Engineering Squad Robot (ESR) and USMC Tactical Robotic Controller (TRC) capabilities into one program.
>
> The CRS-(I) capability contributes to the essential Joint Operational Concepts (JOC) of: Major Combat Operations (MCO); Military Support to Stabilization, Security, Transition, and Reconstruction (SSTR); Homeland Support and Civil Defense and Joint Functional Concepts (JFC) of: Force Application and Protection. The CRS-(I) contributes directly to Situational Awareness, Detect, Protect and Neutralize by providing a standoff hazards interrogation, detection, confirmation and neutralization capability employed to support a wide spectrum of mobility missions for current and future forces by providing required standoff capability across the Warfighting Functions. This capability allows commanders to make more informed decisions and plans, to use their forces more effectively and efficiently to produce desired outcomes, and to conduct focused operations for high-risk missions or selected missions that best satisfy the requirement without the limitations and vulnerabilities of manned systems. The CRS-(I) capability provides commanders the ability to persistently monitor the operational environment (OE) while protecting and sustaining the force at standoff distances from the threat. The CRS-(I) complements the

> Joint Integrated Warfighting Force by providing standoff to the Warfighter during Major Combat Operations, stability operations, and homeland security. The CRS-(I) provides Warfighters the capability to find and identify targets of interest in the operational environment.

59. *Ibid.,* p. 214, includes further details on the use of COTS and other similar resources:

> In support of emerging requirements, the Robot Enhancement Program (REP) uses a 'buy, try and inform' methodology to evaluate Commercial Off The Shelf (COTS), Government Off The Shelf (GOTS) and Non-Developmental Items (NDI) products that have the potential to enhance Soldier combat effectiveness. Hardware quantities will be limited to available REP funds. Evaluation results obtained will be used to inform emerging requirements documents and Cost-Benefit Analyses to support future Army decisionmaking actual operational user feedback.

60. Department of Defense, *Fiscal Year (FY) 2016 President's Budget Submission*: *Army Justification Book of Research, Development, Test & Evaluation, Army RDT&E−Volume II, Budget Activity 4*, Washington, DC: Department of Defense, February 2015, p. 324.

61. Jon Bronstein and Bob Mitchell, "Robotics Collaborative Technology Alliance—Foundations of Autonomy for Ground Robotics," program overview briefing, Adelphi, MD: Army Research Laboratory, April 26, 2012, slide 2, available from *www.arl.army.mil/www/pages/392/OverviewBriefingRoboticsCTA.pdf*, accessed on May 6, 2015.

62. *Unmanned Systems Integrated Roadmap, FY2013-2038*, pp. 23-25.

63. DSB, *The Role of Autonomy in DoD Systems,* p. 92.

64. *Ibid.,* p. 19.

65. *DoDD 3000.09*, p. 12.

66. *Unmanned Systems Integrated Roadmap, FY2013-2038*, p. 18. The benefits of integrating unmanned systems into existing force structure include:

> Unmanned systems open up new avenues for pursuing systems that are smaller, lighter, faster, and more maneuverable and that take more risk than equivalent manned platforms. In particular, the ability of unmanned assets to take risks that would not be taken with manned assets opens up new CONOPS, such as low-cost, expendable systems that trade armor and stealth for quantity. In other words, a fleet of low-cost, disposable platforms could survive through attrition rather than through expensive, exquisite capabilities.

67. Pernin *et. al.*, *Lessons from the Army's Future Combat Systems Program*, pp. 236-238.

68. *Ibid.,* p. 43.

69. Robotics Systems JPO, *Unmanned Ground Systems Roadmap*, pp. 41-43.

70. *Ibid.,* p. 43.

71. *Ibid.,* p. 44.

72. DSB, *The Role of Autonomy in DoD Systems,* p. 16. The report provides further details on the challenge of creating an autonomous system that can follow complex instructions in a dynamic environment:

> Terrain negotiation and obstacle avoidance are driven by mechanical capabilities coupled with pattern recognition and problem solving skills. Operations within the ROE, however, represent a higher order, biomimetic cognitive skill that must fall within the commander's intent. Going forward, development efforts should aim to advance technologies to better overcome these challenges. Particularly in the latter case, the development of autonomous systems that allow the operator/commander to delegate specific cognitive functions, that may or may not change during the course of a mission or engagement, would appear to be an important milestone in evolution from remotely controlled robotics to autonomous systems.

73. Robotics Systems Joint Project Office, *Unmanned Ground Systems Roadmap*, Washington, DC: Department of the Army, July

2011, p. 41-43. Appendix A (pp. 56-71) of this roadmap provides descriptions and specifications for the systems and programs overseen by the Robotics Systems Joint Program Office at that time. They were:

Anti-Personnel Mine Clearing System, Remote Control (M160)
PackBot Family of Systems
Mini-EOD [explosive ordnance disposal]
TALON Family of Systems
MARCbot
Common Mobility Platform (CMP)
XM1216 Small Unmanned Ground Vehicle (SUGV)
XM155 Autonomous Navigation System (ANS)

74. *Unmanned Systems Integrated Roadmap, FY2013-2038*, p. 19. A more detailed description of the MUM-T concept is included in Appendix E:

> The concept of MUM-T is to combine the inherent strengths of manned platforms with the strengths of UAS, with product synergy not seen in single platforms. MUM-T combines robotics, sensors, manned/unmanned vehicles, and dismounted soldiers to achieve enhanced situational awareness, greater lethality, improved survivability, and sustainment. Properly designed, MUM-T extends sensor coverage in time and space and provides additional capability to acquire and engage targets.
>
> The pilot can use the sensor on the UAS, just as a sensor would be used aboard an aircraft, except that the position of the UAS sensor can be up to 80 km ahead from the aircraft. The MUM-T capability provides an unprecedented standoff range from threat weapons and acquisition systems. MUM systems largely depend on mission, enemy, terrain, troops, time, and civil considerations. The transfer of sensor data between the UAS and the manned system reduces risk to both platforms and increases the mission effectiveness and survivability rates of friendly forces. Environmental conditions affect the efficiency of MUM-T employment. (p. 139)

75. *Ibid.,* p. 139-141.

> The MUSIC exercises showcase to the soldier and Army community the progress being made in unmanned interop-

erability and emerging technologies through common interfaces. Exercises also act as a strategic planning tool by driving integration and test of the various platforms to a common hardware and software baseline.

Overview. The objective for the MUSIC I Exercise was to showcase interoperability progress and emerging technologies in accordance with the 2.x series of the Army UAS IOPs. The exercise took place in Dugway Proving Grounds, Utah, at the UAS Rapid Integration & Acceptance Center on 16 September 2011. Weeks of pre-ground and -flight checks culminated into a live two-hour demonstration to a group of media, contractors, and Army officials. The audience witnessed real-time video feeds from the unmanned and manned payloads, screen captures from the GCSs, video feeds from within the shelter, and visual aids through an operational scenario to help demonstrate the capabilities and achieve a better understanding of how they benefit the soldier. Successful execution of the MUSIC exercise provided the product office with a wide range of lessons learned across multiple areas, including system usability, reliability, integration, and configuration control. (p. 139)

76. Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics, *Report to Congress on Addressing Challenges for Unmanned Aircraft Systems*, Washington, DC: Department of Defense, September 2010, p. 3. The UAS TF Charter identified goals for the organization as:

1. Coordinate and evaluate DoD UAS requirements, remaining constantly conscious of technology, cost, schedule, jointness, and interoperability imperatives;
2. In coordination with key UAS stakeholders, increase the operational effectiveness of DoD UAS by promoting the development and fielding of interoperable systems and networks;
3. Shape DoD UAS acquisition programs to prioritize joint solutions which guarantee interoperability, efficient production, lower unit costs, decreased support costs, and increased capability;
4. Serve as the DoD's advocate for shaping the regulatory policies, procedures, certification standards, and technology development activities that are critical to the integration of Department UAS into the national airspace system to fulfill future operational and training requirements; and

> 5. Serve as the Department's lead activity for the development and promulgation of the Unmanned Systems Roadmap. (pp. 3-4)

77. Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics, *Report to Congress on Addressing Challenges for Unmanned Aircraft Systems*, Washington, DC: Department of Defense, January 2013, p. 2. The goals for UAS TF integrated product teams are:

> The [Interoperability] I-IPT continues to lead the DoD effort championing more efficient acquisition policies and practices, promoting Joint standards and architectures, and influencing common practices that enhance manned and unmanned interoperability across the Joint, Interagency, Intergovernmental, and Multinational (JIIM) domains. (p. 1)

> The Frequency and Bandwidth IPT (FB-IPT) is tasked to develop DoD spectrum and bandwidth guidance for improving UAS operational effectiveness and mission capability for large, medium, and small platforms via new technical capabilities; operational TTPs; and regulatory actions. The FB-IPT represents DoD and upholds the U.S. frequency and bandwidth policies and guidance associated with UAS around the world. (p. 12)

> The goal of Logistics and Sustainment IPT (LS-IPT) is development of affordable DoD-wide approaches for long-term sustainment of UAS capabilities that support systems' readiness objectives. The LS-IPT provides a forum to discuss common issues and opportunities for synergies between programs aimed at assisting UAS programs and the Military Departments in the development of UAS sustainment strategies by leveraging experience from existing programs, organizations, disciplines, and processes to identify best practices and lessons learned. (p. 15)

78. Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics, *Report to Congress on Addressing Challenges for Unmanned Aircraft Systems*, Washington, DC: Department of Defense, December 2013, p. 1.

79. *DoDD 3000.09*, pp. 7-8. Enclosure 3, paragraph 1.b. includes: b. Before fielding, the USD(P), USD(AT&L), and CJCS shall ensure:

(1) System capabilities, human-machine interfaces, doctrine, TTPs, and training have demonstrated the capability to allow commanders and operators to exercise appropriate levels of human judgment in the use of force and to employ systems with appropriate care and in accordance with the law of war, applicable treaties, weapon system safety rules, and applicable ROE.
(4) Adequate training, TTPs, and doctrine are available, periodically reviewed, and used by system operators and commanders to understand the functioning, capabilities, and limitations of the system's autonomy in realistic operational conditions.
(5) System design and human-machine interfaces are readily understandable to trained operators, provide traceable feedback on system status, and provide clear procedures for trained operators to activate and deactivate system functions.

80. P. W. Singer, *Wired for War: The Robotics Revolution and Conflict in the Twenty-first Century*, New York, NY: The Penguin Press, 2009, p. 210.

81. Junker, "ONR 101 & Navy Autonomy Issues and Needs," slide 10.

82. DSB, *The Role of Autonomy in DoD Systems,* p. 45.

83. Junker, "ONR 101 & Navy Autonomy Issues and Needs," slide 3.

84. Brian P. Bedell, "Small Ground Robot's Effectiveness and Acquisition Strategy," Civilian Research Project, Carlisle Barracks, PA: U.S. Army War College, June 2010, p. 84.

85. DSB, *The Role of Autonomy in DoD Systems,* p. 50. The report provides more detail on the concepts of cooperation and collaboration:

> Synchronization is often, but not universally, referred to as cooperation by multi-agent systems researchers, with cooperation being either active (such as in robot soccer) or non-active (such as the foraging behavior seen in ants). Collaboration is related to cooperation but is treated as a

distinct topic as it assumes that the agents have a cognitive understanding of each other's capabilities, can monitor progress towards the goal, and engage in more human-like teamwork. Multi-agent coordination and human-robot interaction are related fields of inquiry, but in general, multi-agent coordination research focuses more on cooperation schemes for different types of configurations of distributed agents and human-robot interaction focuses more on cognition in collaboration.

86. Robert O. Work and Shawn Brimley, *20YY: Preparing for War in the Robotic Age*, Washington, DC: Center for a New American Security, January 2014, p. 29. A follow-up to this report provides greater detail on possible methods to use swarms of unmanned systems to provide advantages in mass, speed, coordination, and effectiveness on the future battlefield. See Paul Scharre, *Robotics on the Battlefield Part II: The Coming Swarm*, Washington, DC: Center for a New American Security, October 2014. In the report, the author asserts the benefits of swarms in future combat:

> The power of swarming lies in more than just greater numbers, however. Today's modern military forces fight as a network, with interconnected human-inhabited platforms passing surveillance and targeting data across great distances. Future military forces will fight as a swarm, with greater coordination, intelligence and speed. Autonomous and uninhabited systems will be networked and cooperative with the ability to autonomously coordinate their actions in response to events on the ground. Swarming, coordinated action can enable synchronized attack or defense, more efficient allocation of assets over an area, self-healing networks that respond to enemy actions or widely distributed assets that cooperate for sensing, deception and attack. Harnessing the power of swarming will require new command-and-control models for human supervision of large swarms. This will mean moving beyond existing paradigms where humans directly control a vehicle's movements to one where human controllers supervise the mission at the command level and uninhabited systems maneuver and perform various tasks on their own. (p. 6)

> Networked, cooperative swarms of unmanned systems that can maneuver and engage targets collectively also have the potential to achieve reaction times much faster

> than that of human operators. Intelligent swarms can overwhelm adversary defenses, autonomously jamming, spoofing and employing non-lethal disruptive weapons such as high-powered microwaves, while relaying the position of enemy targets to human controllers who can authorize lethal engagements. Human controllers, safely removed from harm's way, would provide mission-level control over the swarm, but the leading edge of the battlefront across all domains would be unmanned, networked, intelligent and autonomous. The resulting *reconnaissance-strike swarm* could achieve speed, synchronization and coordination of maneuver far surpassing that possible with manned platforms, rendering previous methods of warfare obsolete. (p. 29)

87. Bedell,"Small Ground Robot's Effectiveness and Acquisition Strategy," p. 11. The author contrasts the unique challenges facing unmanned grounds systems:

> The main question on policy is how to apply self-protection or anti-handling capability to small ground robots. The ground battlespace is much more complex than the air domain and one of the critical complications ground robots will face is the direct contact with the enemy and the enemy's use of —innocents as surrogates to impede the operational use of the ground robots.

88. Dan Gettinger *et. al.*, *The Drone Primer: A Compendium of the Key Issues*, Annandale-on-Hudson, NY: Center for Study of the Drone, Bard College, 2014, p. 8.

89. Lynn E. Davis *et. al*, *Armed and Dangerous? UAVs and U.S. Security*, Santa Monica, CA: The RAND Corporation, 2014, pp. 8-10. The 23 countries listed as potentially developing armed drones are: MTCR Category I-capable (8): China, India, Iran, Russia, Taiwan, Turkey, UAE and U.S.; MTCR Category II-capable (3): Israel, Pakistan, and South Africa; not MTCR capable (12): France, Germany, Greece, Italy, Lebanon, North Korea, South Korea, Spain, Sweden, Switzerland, Tunisia, and UK. Eleven of these 23 countries are currently not members of the MTCR: China, India, Iran, Israel, Lebanon, North Korea, Pakistan, Switzerland, Taiwan, Tunisia, and UAE. The report defines "armed drone" as:

> UAVs designated in the (open source) databases as attack systems, precision strike systems, 'hunter-killer' systems,

> unmanned combat aerial vehicles (UCAVs), UCAV demonstrators, and/or systems described as a 'suicide UAV,' or for use as a cruise missile. (p. 9)

90. Guardium UGVTM Fact Sheet, Yokneam, Israel: G-NIUS Unmanned Ground Systems, available from *g-nius.co.il/pdf/brochures/GuardiumUGV.pdf*, accessed on June 2, 2015.

91. DSB, *The Role of Autonomy in DoD Systems*, p. 69. The report characterizes Chinese efforts in the development of unmanned systems as aggressive:

> The latest pictures and models of unmanned systems from China show a reconnaissance truck with a joined wing and tail that could considerably increase range and payload and produce better handling at high altitudes. Roughly the same size as the General Atomics Avenger, and powered by a single turbofan engine, this new UAV is the most advanced Chinese design seen to date and is the largest joined wing aircraft known to have been built. Much of China's efforts remain secret, but the large number of unmanned systems displayed at recent exhibitions, and very recent revelations on development and operational efforts underscore not only China's determination to catch up in this sector, but also its desire to sell this technology abroad. (pp. 69-70)

> After many years of displaying unmanned systems models at international air shows, and recent evidence of prototype and operational systems, it is clear that China is moving rapidly to catch up—and perhaps ultimately overtake—the West in this rapidly growing and increasingly important sector of aerospace and defense. In this defense-dominated field, China cannot look (openly) to the West for technical expertise and experienced suppliers, as it has done in the commercial airliner sector, and therefore it is evident the Chinese are copying other successful designs to speed their development of unmanned systems and rapidly apply lessons learned. (p. 71)

92. For information with examples regarding Russian and Iranian unmanned system programs, see the following: David Hambling, "Russia Wants Autonomous Fighting Robots, and Lots of Them," *Popular Mechanics* online, May 12, 2014, available from *www.popularmechanics.com/military/a10511/russia-wants-*

autonomous-fighting-robots-and-lots-of-them-16787165/warsonline.info/bronetechnika/boevoyrobotizirovanniykompleksargo.html, accessed June 2, 2015. Also see, Dan Gettinger, "Drones Are Not Toys: The Russian Program," New York: Center for the Study of the Drone at Bard College, March 5, 2014, available from *dronecenter.bard.edu/drones-toys-russian/* accessed June 2, 2015; and Arthur Holland Michel, "Iran's Many Drones," New York: Center for the Study of the Drone at Bard College, November 25, 2013, available from *dronecenter.bard.edu/irans-drones/*, accessed June 2, 2015.

93. *DoDD 3000.09*, p. 9. Enclosure 4, paragraph 1.d. states the USD(P)'s role in foreign military sales of AWS: "Approve the DoD position on international sales or transfers of autonomous and semi-autonomous weapon systems in accordance with existing technology security and foreign disclosure requirements and processes."

94. *Unmanned Systems Integrated Roadmap, FY2013-2038*, pp. 113-119.

95. Alliance Ground Surveillance (AGS), NATO Fact Sheet, September 2014, available from *www.nato.int/nato_static_fl2014/assets/pdf/pdf_2014_09/20140901_140901-Factsheet-AGS_en.pdf*, accessed July 30, 2015. A more complete description of AGS:

> NATO is acquiring the Alliance Ground Surveillance (AGS) system that will give commanders a comprehensive picture of the situation on the ground. NATO's operation to protect civilians in Libya in 2011 showed how important such a capability is. A group of Allies is acquiring five Global Hawk remotely piloted aircraft (RPA) and the associated command and control base stations that make up the AGS system. NATO will then operate and maintain them on behalf of all 28 Allies.
>
> The AGS system is being acquired by 15 Allies (Bulgaria, Czech Republic, Denmark, Estonia, Germany, Italy, Latvia, Lithuania, Luxembourg, Norway, Poland, Romania, Slovakia, Slovenia, and the United States), and will be made available to the Alliance in the 2017-2018 time frame. All Allies will contribute to the development of the AGS capability through financial contributions covering the establishment of the AGS main operating base, as well as to communications and life-cycle support of the AGS fleet. Some Allies

> will replace part of their financial contribution through 'contributions in kind' (national surveillance systems that will be made available to NATO).

96. *Program Acquisition Cost by Weapon System, FY 2016 Budget Request,* p. 1-4.

97. Predator RQ-1/MQ-1/MQ-9 Reaper UAV, United States of America," Fact Sheet on *airforce-technology.com*, available from *www.airforce-technology.com/projects/predator-uav/*, accessed August 14, 2015.

98. Australian Army Headquarters, *Future Land Warfare Report 2014*, Canberra, Australia: Directorate of Future Land Warfare, April 2014, available from *www.army.gov.au/~/media/Army/Our%20future/Publications/Key/FLWR_Web_B5_Final.pdf,* accessed May 6, 2015. The report envisions a future operating environment characterized by five meta-trends: (1) a crowded environment; (2) a connected environment; (3) a lethal environment; (4) a collective environment; and (5) a constrained environment (pp. 7-21). "The environment in which the land force will operate will most likely be the urban littoral, characterised by the meta-trends identified in this report." (p. 23).The report noted that:

> The changing global environment continues to challenge our common assumptions, accelerating technologies in which information and precision dominate, and making it increasingly difficult for the Army to marry this technology with its core tasks in what is an increasingly cost-conscious Australian Defence Force. (p. 3)

Like U.S. goals, the Australian report offers use of AWS as part of a solution to budget limits (p. 15):

> Capabilities such as the Switchblade system (an armed, disposable micro-UAV), recently deployed operationally by the United States Marine Corps, offer cheap, precise lethality and similar systems will potentially populate the inventories of many nations. These types of low-cost capabilities also offer opportunities for the Army to enhance the individual lethality of its soldiers in an austere budget environment.

99. Artur Kuptel and Andrew Williams, *Policy Guidance: Autonomy in Defence Systems*, Multinational Capability Development Campaign (MCDC) 2013-2014, Focus Area "Role of Autonomous System in Gaining Operational Access," Norfolk, VA: Supreme Allied Commander Transformation HQ, October 29, 2014, p. 5, available from *https://innovationhub-act.org/sites/default/files/u4/Policy%2520Guidance%2520Autonomy%2520in%2520Defence%2520Systems%2520MCDC%25202013-2014%2520final.pdf*, accessed June 9, 2015. Details on the membership and organization of the study are:

> This document is a final product from the Autonomous Systems focus area, led by NATO Headquarters Supreme Allied Commander Transformation (HQ SACT), and conducted under the auspices of the Multinational Capability Development Campaign (MCDC) 2013-14—a collaborative programme between 19 nations, NATO and the European Union. The Autonomous Systems project team adopted a guiding problem statement for the project: 'Coalitions need to improve awareness and understanding of autonomous systems, promote interoperability and provide guidance for the development of, use of, and defence against, autonomous systems.'
>
> The project conducted five studies: a definitional study led by HQ SACT focusing on the meaning of autonomy; a legal study led by Switzerland, which examined legal issues mainly concerning weapon systems with autonomous capability; a human factors and ethical study co–led by the United States and HQ SACT, which explored future ethical, organisational and psychological implications; a military operations study led by HQ SACT, describing operational benefits and challenges, and lastly; a technology study led by the Czech Republic, which summarised key technological developments and challenges. These study findings and records from the various workshops and seminars are published separately in an MCDC Autonomous Systems Proceedings report, available from the MCDC Secretariat [email address:] MCDC_Secretariat@apan.org.

100. *Ibid.,* p. 11. The report expands and clarifies their proposed definition of "autonomous functioning" as follows:

Tasks or functions executed either by a platform, or distributed between a platform and other parts of the system, may be performed using a variety of behaviours, which may include reasoning and problem solving, adaptation to unexpected situations, self-direction, and learning.

Which functions are autonomous, and the extent to which human operators can direct, control or cancel functions, is determined by system design tradeoffs, mission complexity, external operating environment conditions, and legal or policy constraints.

This can be contrasted against automated functions, which although require no human intervention, operate using a fixed set of inputs, rules, and outputs, whose behaviour is deterministic and largely predictable. Automatic functions do not permit dynamic adaptation of inputs, rules, or outputs.

101. *Ibid.,* p. 12.

102. *DoDD 3000.09*, p. 7.

103. "Observations on Costs, Benefits, and Challenges of a Department of Defense Role in Helping to Secure the Southwest Land Border," Report GAO-12-657T, Washington, DC: U.S. Government Accountability Office, April 2012, p. 10.

104. Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics, *Report to Congress on Addressing Challenges for Unmanned Aircraft Systems*, Washington, DC: Department of Defense, December 2013, p. 9.

105. USD(AT&L), *Report to Congress for Unmanned Aircraft Systems*, p. 9.

106. Unmanned Aircraft Systems (UAS) Fact Sheet, Washington, DC: Federal Aviation Administration, February 15, 2015, available from *www.faa.gov/news/fact_sheets/news_story cfm?newsId=18297*, accessed August 1, 2015.

107. Gettinger *et. al.*, *The Drone Primer*, p. 29.

108. Kuptel and Williams, *Policy Guidance: Autonomy in Defence Systems*, p. 9.

109. "Unmanned Aerial Systems: Status of Test Sites and International Developments," Report GAO-15-486T, Washington, DC: U.S. Government Accountability Office, March 2015.

110. See Steven Metz, "The Next Twist of the RMA," *Parameters*, Vol. XXX, No. 3, Autumn 2000, pp. 40-53.

111. Kuptel and Williams, *Policy Guidance: Autonomy in Defence Systems*, p. 30. The report recommends that "Strategic-level research should be encouraged on the potential of autonomous technologies to impact the nature and conduct of war. In addition, study is required on the likely change in military tactics that new concepts such as swarm operations and joint human-machine teaming will bring."

112. *Ibid.*, p. 14.

113. James Igoe Walsh, *The Effectiveness of Drone Strikes in Counterinsurgency and Counterterrorism Campaigns*, Carlisle, PA: Strategic Studies Institute, U.S. Army War College, September 2013, p. 51.

114. Davis *et. al.*, p. 15.

115. Australian Army Headquarters, *Future Land Warfare Report 2014*, p. 21. The full text from the report reads:

> Restrictions based on ethical or evolving legal norms are different to the predominately technical limitations discussed earlier. At present, autonomous technology is in its infancy; in time the effect of these systems on the conduct of future war is likely to be profound. Significant questions remain concerning the ethics and legality of arming autonomous platforms and empowering these systems to use lethal force. The land force will require a detailed understanding of these issues before any decision to acquire such systems is made.

116. Walsh, *The Effectiveness of Drone Strikes*, pp. 42, 53.

117. Laura A. Dickinson and Peter W. Singer, "Ask Your 2016 Candidate These Questions on Drone Warfare," *Defense One* online, May 18, 2015, available from *www.defenseone.com/ideas/2015/05/ask-your-2016-candidate-these-questions-drone-warfare/113098/*, accessed June 18, 2015.

118. *DoDD 3000.09*, pp. 7, 10.

119. General Counsel for the Department of Defense, *DoDD 2311.01E*, *DoD Law of War Program*, Washington, DC: Department of Defense, May 9, 2006 with Change 1, November 15, 2010, p. 2.

120. Michael N. Schmitt, "Drone Attacks under the *Jus ad Bellum* and *Jus in Bello*: Clearing the 'Fog of Law'," Chapter 9, *Yearbook of International Humanitarian Law–2010*, M. N. Schmitt, L. Arimatu, and T. McCormack, eds., The Hague, The Netherlands: T. M. C. Asser Press, p. 313.

121. *Ibid.,* p. 316.

122. *Ibid.,* pp. 323-324. Schmitt explains the potential mandate to use drones in some cases as follows:

> If use of a drone, because it is a relatively precise weapon system and its loiter capability often affords a longer window of opportunity within which to strike, would likely result in less collateral damage than use of other systems (such as a manned aircraft, artillery or ground attack), and if such drone use is militarily feasible, the drone must be employed as a matter of law. Conversely, other systems must be used in lieu of a drone when doing so is feasible and their use will lessen collateral damage without forfeiting military advantage. Since the use of a drone presents no risk to the operator and in light of its unique capabilities, such circumstances will be rare.

123. Gettinger *et al.*, *The Drone Primer*, p. 10. The report further noted that there were cases of application of force similar to that of the U.S. armed drone attacks:

> The term 'targeted killing' was first used to describe Israel's campaign against the leaders of Hamas in the early-2000s. The Israeli Defense Forces–and, in 2006, the High Court of

> Israel—defended the practice, arguing that Israel was engaged in a state of war with Hamas and that the Palestinian Authority had failed to apprehend terrorists who posed a direct threat to Israel.

124. United Kingdom Ministry of Defence, Joint Doctrine Note 2/11, *The UK Approach to Unmanned Aircraft Systems*, Swindon, Wiltshire, UK: The Development, Concepts and Doctrine Centre, March 30, 2011, available from *www.gov.uk/government/uploads/system/uploads/attachment_data/file/33711/20110505JDN_211_UAS_v2U.pdf*, accessed July 29, 2015. This report includes the following definition for "Autonomous System:"

> An autonomous system is capable of understanding higher level intent and direction. From this understanding and its perception of its environment, such a system is able to take appropriate action to bring about a desired state. It is capable of deciding a course of action, from a number of alternatives, without depending on human oversight and control, although these may still be present. Although the overall activity of an autonomous unmanned aircraft will be predictable, individual actions may not be.

125. UNOG-The United Nations Office at Geneva, "2015 Meeting of Experts on LAWS," website available from *www.unog.ch/80256EE600585943/(httpPages)/6CE049BE22EC75A2C1257C8D00513E26?OpenDocument*, accessed June 2, 2015.

126. Jean-Hugues Simon-Michel, *Report of the 2014 informal Meeting of Experts on Lethal Autonomous Weapons Systems (LAWS)*, document CCW/MSP/2014/3, Geneva, Switzerland: United Nations Convention on Certain Conventional Weapons (CCW), June 11, 2014, p. 3, available from *daccess-dds-ny.un.org/doc/UNDOC/GEN/G14/048/96/PDF/G1404896.pdf?OpenElement*, accessed August 4, 2015.

127. *Ibid.,* p. 4.

128. *Ibid.,* pp. 4-5. The summary paragraphs of the sessions on legal aspects were:

26. The session examined the question of compatibility and compliance of LAWS with existing international law, in particular the principles of international humanitarian law (distinction, proportionality and precautions in attack), as well as with the 1949 Geneva Conventions, the Martens Clause, and customary law.

27. Delegations and experts reaffirmed the necessity for any development and use of LAWS to be in compliance with international humanitarian law. There were various views on the possibility of LAWS being able to comply with such rules.

28. The adequacy of existing international law was also discussed with different views expressed. Some interventions noted that a potential definition of LAWS, and especially the definition of autonomy and the level of predictability of such systems, could have a significant impact in this area.

29. The necessity for legal reviews was stressed, especially when developing new weapons technologies. The question of transparency and information exchange on best practices in reviews was raised. The implementation of weapons reviews, including Article 36 of Additional Protocol I (1977) to the 1949 Geneva Conventions was suggested as an area where more discussions could be valuable.

30. A number of interventions questioned whether an accountability gap was created by the possible use of LAWS. In particular, the issue of responsibility was mentioned as an area to be further explored, including the possibility of engaging responsibility at the State level or at an individual level.

31. The discussions focused on whether one could establish responsibility for violations of international law and whether such cases incurred the responsibility of subordinates, programmers or manufacturers. The notion of negligence was also mentioned as an area which could be further explored.

32. Issues related to human rights law by the possible development and use of LAWS were also deliberated on, in particular the right to life, human dignity, the right to be

protected against inhuman treatment and the right to a fair trial.

33. Regarding the possible impact of the development and use of LAWS on jus ad bellum, the question as to whether LAWS could change the threshold of use of force was raised.

129. Paul Scharre, Michael C. Horowitz, and Kelley Sayler, *Autonomous Weapons at the UN: A Primer for delegates*, Washington, D.C: Center for a New American Security, April 2015, p. 4, available from *www.cnas.org/sites/default/files/publications-pdf/Autonomous%20Weapons%20at%20the%20UN_040615_FINAL.pdf*, accessed June 2, 2015.

130. *Ibid.,* p. 3.

131. Kelley Sayler, "Postgame: the U.N. Debate on Lethal Robots," New York: Center for the Study of the Drone at Bard College, April 24, 2015, available from *dronecenter.bard.edu/postgame-debate-on-lethal-robots/,* accessed on June 2, 2015.

132. "Statement to the Informal Meeting of Experts on Lethal Autonomous Weapons Systems," Representative of United Kingdom of Great Britain and Northern Ireland, Geneva, Switzerland: United Nations Convention on Certain Conventional Weapons (CCW), April 13, 2015, available from *www.unog.ch/80256EDD006B8954/(httpAssets)/1CBF996AF7AD10E2C1257E260060318A/$file/2015_LAWS_MX_United+Kingdom.pdf,* accessed August 16, 2015.

133. Michael W. Meier, "U.S. Delegation Opening Statement, The Convention on Certain Conventional Weapons (CCW) Informal Meeting of Experts on Lethal Autonomous Weapons Systems," Geneva, Switzerland: United Nations Convention on Certain Conventional Weapons (CCW), April 13, 2015, p. 1, available from *www.unog.ch/80256EDD006B8954/(httpAssets)/8B33A1CDBE80EC60C1257E2800275E56/$file/2015_LAWS_MX_USA+bis.pdf*, accessed August 16, 2015.

134. *Ibid.,* p. 1.

135. *Ibid.,* p. 2.

136. Paul Scharre, "CNAS Statement on Way Ahead," comments to 2015 Meeting of Experts on Lethal Autonomous Weapons Systems, Geneva, Switzerland: United Nations Convention on Certain Conventional Weapons (CCW), April 17, 2015, p. 2, available from *www.unog.ch/80256EDD006B8954/(httpAssets)/1214FD2D92C405ADC1257E2F0056BCC8/$file/CNAS+closing+statement+17+Apr+2015.pdf*, accessed June 2, 2015.

137. International Committee of the Red Cross (ICRC), "Autonomous weapons: ICRC addresses meeting of experts," Geneva, Switzerland: ICRC, May 13, 2014, pp. 1-2, available from *https://www.icrc.org/eng/resources/documents/statement/2014/05-13-autonomous-weapons-statement.htm,* accessed August 5, 2014. This ICRC meeting informed the first UN LAWS meeting, and posed six key questions for the UN meeting:

1. What should be the scope of the discussions about autonomous weapon systems?
2. What is 'meaningful human control'?
3. What lessons can be drawn from autonomy in existing weapon systems?
4. What are the implications, for compliance with IHL, of increasing autonomy?
5. Are autonomous weapons systems necessary?
6. Are autonomous weapon systems ethically and morally acceptable?

138. ICRC, *Autonomous Weapon Systems: Technical, Military, Legal and Humanitarian Aspects, Expert Meeting*, *26-28 March, 2014*, Geneva, Switzerland: ICRC, November, 2014, p. 8, available from *https://www.icrc.org/en/document/report-icrc-meeting-autonomous-weapon-systems-26-28-march-2014*, accessed June 10, 2015.

139. *Ibid.,* p. 9.

140. Kuptel and Williams, *Policy Guidance: Autonomy in Defence Systems*, p. 14.

141. William Rauch, "A Risk-Based Approach for the Classification of UAS," Knowledge at AUVSI blog article, June 30, 2014, available from *knowledge.auvsi.org/blogs/william-rauch/2014/06/30/a-risk-based-approach-for-the-classification-of-uas*, accessed on August 17, 2015.

142. Kuptel and Williams, *Policy Guidance: Autonomy in Defence Systems*, p. 19.

143. Davis *et al.*, pp. 18, 19. This RAND reports argues that:

> The greatest concerns about U.S. use of armed UAVs appear to arise from operations outside active war zones, less-transparent operations, lack of clarity about congressional authorizations, and targeting of those not clearly identified as combatants or al Qaeda leaders. (p. 19)

144. 107th Congress, "Joint Resolution to authorize the use of United States Armed Forces against those responsible for the recent attacks launched against the United States." Public Law 107-40, Washington, DC: U.S. Government Printing Office, September 18, 2001, available from *www.gpo.gov/fdsys/pkg/PLAW-107publ40/pdf/PLAW-107publ40.pdf*, accessed August 1, 2015. The text of this very short piece of legislation includes:

> SEC. 2. AUTHORIZATION FOR USE OF UNITED STATES ARMED FORCES.
> (a) IN GENERAL.—That the President is authorized to use all necessary and appropriate force against those nations, organizations, or persons he determines planned, authorized, committed, or aided the terrorist attacks that occurred on September 11, 2001, or harbored such organizations or persons, in order to prevent any future acts of international terrorism against the United States by such nations, organizations or persons.
>
> (b) WAR POWERS RESOLUTION REQUIREMENTS.—
> (1) SPECIFIC STATUTORY AUTHORIZATION.—Consistent with section 8(a)(1) of the War Powers Resolution, the Congress declares that this section is intended to constitute specific statutory authorization within the meaning of section 5(b) of the War Powers Resolution.
>
> (2) APPLICABILITY OF OTHER REQUIREMENTS.—Nothing in this resolution supercedes any requirement of the War Powers Resolution.

145. Davis *et al.*, pp. 17-19. The eight conflicts identified by RAND are: (1) Afghanistan (2001-present); (2) Pakistan (2004-present); (3) Iraq No-Fly (2002-2003); (4) Iraq Combat (2003); (5) Iraq

COIN (2004-2011); (6) Yemen (2002 and 2010); (7) Libya (2011); and (8) Somalia (2011-present).

146. W. Andrew Terrill, "Drones over Yemen: Weighing Military Benefits and Political Costs," *Parameters*, Vol. XXXXIII, No. 1, Spring 2013, pp. 21.

147. *Ibid.,* p. 23. Terrill also notes that: "Moreover, engaging in such strikes without Yemeni government permission is not an option since the United States is attempting to support the Hadi government and not undermine it."

148. *Ibid.,* p. 23.

149. Stephanie Nebehay, "Yemen 'crumbling' from war, sieges causing starvation: aid groups," Reuters, August 11, 2015, available from *www.reuters.com/article/2015/08/11/us-yemen-security-redcross-idUSKCN0QG0OY20150811*, accessed on August 17, 2015.

150. Australian Army Headquarters, Future Land Warfare Report 2014, p. 20.

151. *Ibid.,* p. 21.

152. Geneva Academy of International Humanitarian Law and Human Rights, *Academy Briefing No. 8: Autonomous Weapon Systems under International Law*, Geneva, Switzerland: Geneva Academy, November 2014, p. 5.

153. Australian Army Headquarters, *Future Land Warfare Report 2014*, p. 21.

154. Micah Zenko and Sarah Kreps, *Limiting Armed Drone Proliferation*, Council Special Report No. 69, New York, NY: Council on Foreign Affairs Center for Preventative Action, June 2014.

155. Rebecca Crootof, "The Varied Law of Autonomous Weapon Systems," in *Autonomous Systems: Issues for Defence Policy Maker*, Andrew Williams and Paul Scharre, eds., Norfolk, VA: NATO Allied Command Transformation, Fall 2015, available from *papers.ssrn.com/sol3/papers.cfm?abstract_id=2569322*, accessed June 9, 2015.

156. Simon-Michel, *Report of the 2014 Meeting of Experts on LAWS*, p. 4.

157. Human Rights Watch and the International Human Rights Clinic (IHRC), *Mind the Gap: The Lack of Accountability for Killer Robots*, New York, NY: Human Rights Watch, April 2015, p. 1.

158. Human Rights Watch and the International Human Rights Clinic (IHRC), *Losing Humanity: The Case against Killer Robots*, New York, NY: Human Rights Watch, November 2012, p. 5.

159. Human Rights Watch and the International Human Rights Clinic (IHRC), *Shaking the Foundations, The Human Rights Implications of Killer Robots*, New York, NY: Human Rights Watch, May 2014, p. 25.

160. Human Rights Watch and IHRC, *Mind the Gap,* p. 37.

161. *Ibid.,* p. 37.

162. Steve Goose, "Statement by Human Rights Watch To the Convention on Conventional Weapons Informal Meeting of Experts on Lethal Autonomous Weapons Systems," Geneva, Switzerland: United Nations Convention on Certain Conventional Weapons (CCW), May 13, 2014, p. 2, available from *www.unog.ch/80256EDD006B8954/(httpAssets)/6CF465B62841F177C1257CE8004F9E6B/$file/NGOHRW_LAWS_GenStatement_2014.pdf*, accessed August 17, 2015.

163. Human Rights Watch and IHRC, *Losing Humanity,* p. 5.

164. ICRC, *Autonomous Weapon Systems Expert Meeting,* p. 37. Professor Arkin offers interesting insights into the causes of war crimes that the use of autonomy might mitigate:

> Potential explanations for the persistence of war crimes include: high friendly losses leading to a tendency to seek revenge; high turnover in the chain of command leading to weakened leadership; dehumanization of the enemy through the use of derogatory names and epithets; poorly trained or inexperienced troops; no clearly defined enemy;

> unclear orders where intent of the order may be interpreted incorrectly as unlawful; youth and immaturity of troops; external pressure, e.g. for a need to produce a high body count of the enemy; and pleasure from the power of killing or an overwhelming sense of frustration. There is clearly room for improvement and autonomous systems may help address some of these problems. (p. 33)

165. *Ibid.,* p. 50.

166. *Ibid.,* p. 52.

167. *Ibid.,* p. 53.

168. *Ibid.,* p. 55.

169. Greg Kennedy, "Drones: Legitimacy and Anti-Americanism," *Parameters*, Vol. XXXXIII, No. 1, Spring 2013, pp. 25-28.

170. *Ibid.,* p. 27.

171. *Ibid.,* p. 28.

172. Jacqueline L. Hazelton, "Drones: What are They Good For?" *Parameters*, Vol. XXXXIII, No. 1, Spring 2013, p. 32.

173. Alan W. Dowd, "Drone Wars: Risks and Warnings," *Parameters*, Vol. XXXXIII, No. 1, Spring 2013, p. 15.

174. Grégoire Chamayou, *Théorie du drone* (*Drone Theory*), Paris, France: La Fabrique éditions, 2013, pp. 132-133. The original description in French of the Reaper unit patch and a translation by the monograph author follows:

> Original:
> Au 21e siècle, le livre des images de la mort représentait un guerrier en armes luttant contre un squelette — la mort elle-même. allégorie d'une lutte dérisoire, vanité d'en combat perdu d'avance, car la mort, elle, ne meurt jamais. Elle a le temps pour elle, et les yeux du soldat qui l'affronte semblent déjà vides.

Les opérateurs de drones reprennent aujourd'hui volontiers à leur compte cette imagerie classique. L'écusson du drone <<MQ 9 Reaper>> figure la faucheuse, rictus inquiétant et perles de sang sur sa lame, avec sa devise: <<Que les autres meurent>>.

Translation:
In the 21st century, the books with images of death may show an armored warrior fighting against a skeleton — death itself. An allegory of a ridiculous fight; a fight for vanity; a losing battle, because death, she never dies. She keeps her own time, and the eyes of the soldier who confronts her already seem empty.

UAV operators today willingly propagate this classic imagery. The crest of the MQ 9 Reaper drone shows the Grim Reaper figure, with a disturbing grin and blood beads on his blade, and with its motto "That Others May Die."

175. See *www.pararescue.com*.

176. Kuptel and Williams, *Policy Guidance: Autonomy in Defence Systems*, p. 25.

177. Thomas H. Cowan, Jr., "A Theoretical, Legal and Ethical Impact of Robots on Warfare," USAWC Strategy Research Project, Carlisle Barracks, PA: U.S. Army War College, March 30, 2007.

178. D. Keith Shurtleff, "The Effects of Technology on Our Humanity," *Parameters*, Vol. XXXII, No. 2, Summer 2002, pp. 106.

179. Singer, *Wired for War*, pp. 337-338. See also Meghan Neal, "Are Soldiers Getting Too Emotionally Attached to War Robots?" Motherboard, September 18, 2013, available from *motherboard.vice.com/blog/are-soldiers-getting-too-emotionally-attached-to-war-robots*, accessed August 20, 2015.

180. Dowd, "Drone Wars: Risks and Warnings," p. 13.

181. *Ibid.,* p. 13.

182. Geneva Academy, *Autonomous Weapon Systems under International Law*, pp. 4-5.

183. Dowd, "Drone Wars: Risks and Warnings," p. 11.

184. "Lethal autonomous weapons systems Food-for-thought for the informal meeting of experts on lethal autonomous weapons systems Geneva, April 13-17, 2015," document CCW/MSP/2015/WP.2, submitted by Germany (Ambassador Michael Biontino), Geneva, Switzerland: United Nations Convention on Certain Conventional Weapons (CCW), March 20, 2015, pp.1-2, available from *daccess-dds-ny.un.org/doc/UNDOC/GEN/G15/061/30/PDF/G1506130.pdf?OpenElement*, accessed on July 18, 2015.

185. The CNAS Autonomy Project website is available from *www.cnas.org/ethicalautonomy*. The CNAS Ethical Autonomy Project Bibliography is available from *www.cnas.org/research/defense-strategies-and-assessments/20YY-Warfare-Initiative/Ethical-Autonomy/bibliography*.

186. Dowd, "Drone Wars: Risks and Warnings," p. 16.

187. Scharre and Horowitz, *An Introduction to Autonomy in Weapon Systems*, pp. 5-6.

188. DSB, *The Role of Autonomy in DoD Systems*.

189. Kuptel and Williams, *Policy Guidance: Autonomy in Defence Systems*, p. 12. This report refutes the claims of that unmanned systems will significantly lower operational costs: "While cost savings are often claimed as a benefit of increasing autonomy, or of unmanned systems more generally, there is currently very little rigorous cost-benefit analyses on which to draw robust conclusions about potential savings."

190. Thomas K. Adams, "Future Warfare and the Decline of Human Decisionmaking," *Parameters*, Vol. XXXV, No. 4, Winter 2001-2002, pp. 57-71. In his article, Adams raises cautions about certain aspects of disengagement facilitated by technology:

> Automated systems can certainly reduce the pressure of information saturation and eliminate conflicts, but at a price. Essentially, they do so by creating a series of information 'filters' that establish priorities and eliminate marginal data, reconcile the remaining information conflicts, and present

a consensus picture of the situation. All of this is invisible to the ultimate consumer, out of his or her control and very likely not well understood. This means that the commander is receiving a picture of the battlefield that is designed to emphasize certain things while de-emphasizing others. Still other factors are omitted entirely. (p. 62)

In sum, this approach results in the development of systems that take the operator 'out of the loop,' shifting the role of the human operator from that of an active controller to that of a supervisor who serves in a fail-safe capacity in the event of system malfunction. Unfortunately, the role of passive monitor seems to be a task for which humans are poorly suited. (p. 64)

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