AUTONOMY, UNMANNED GROUND VEHICLES, AND THE US ARMY: PREPARING FOR THE FUTURE BY EXAMINING THE PAST

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14. ABSTRACT
As a result of technological maturation, Congressional mandate, and battlefield use, the U.S. Army is currently involved in a tremendous amount of activity surrounding the development of unmanned systems (UMS). While current systems require near constant supervision, the research and development community is developing capabilities that will greatly increase the autonomy of future UMS. The payoff of employing highly autonomous unmanned ground vehicles (UGV) for the Army is potentially high in a number of areas. However, the second or third order effects could have negative consequences. This monograph analyzes current U.S. Army activities surrounding the development of autonomous UGVs in order to provide ideas for developers to better attain success and help prevent unintended consequences. Using lessons from the past and theories for innovation, leaders can gain insight for the conduct of current development. The progress of technology has often been faster than our doctrine and policy development. As challenging as the time, money, and manpower might be to focus on autonomous UGV issues, the potential benefits of autonomy to our Soldiers are too great not to make the investment.

Unmanned ground vehilces, UGV, unmanned systems, robot, UMS, autonomy, innovation, combat development

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Abstract

AUTONOMY, UNMANNED GROUND VEHICLES, AND THE U.S. ARMY: PREPARING FOR THE FUTURE BY EXAMINING THE PAST, by MAJ Gregory J. Nardi, US Army, 57 pp.

As a result of technological maturation, Congressional mandate, and use on the battlefield, the U.S. Army is currently involved in a tremendous amount of activity surrounding the development of unmanned systems. While current systems require constant or near constant supervision, the research and development community is developing capabilities that will greatly increase the autonomy of future unmanned systems. The payoff of employing highly autonomous unmanned ground vehicles (UGV) for the Army is potentially great in a number of areas. However, the second or third order effects of autonomous UGVs could have negative consequences if the challenges are not anticipated and overcome. Catastrophic failure during the initial introduction of autonomous UGVs will likely set back the re-introduction of autonomous UGVs back years while leaders regain trust in a system that produced unintended and unanticipated consequences in lost time, money, or lives. This monograph analyzes current U.S. Army activities surrounding the development of highly autonomous UGVs in order to provide ideas to developers to better attain success and help prevent unintended consequences. Using lessons from the past and theories for military innovation, Army leadership can gain insight for the conduct of current innovative development. The progress of technology has often been faster than our doctrine and policy development. As challenging as the time, money, and manpower might be to focus on autonomous UGV issues, the potential benefits of autonomy to the nation's Soldiers are too great not to make the investment.

TABLE OF CONTENTS

Introduction

The saddest aspect of life right now is that science gathers knowledge faster than society gathers wisdom. – Isaac Asimov

As a result of the National Defense Authorization Act (NDAA) of 2001, Congress signed into law a mandate for the Department of Defense to enact a plan to develop and field unmanned systems. The largest impact for the U.S. Army came with the directive to field "unmanned, remotely controlled technology such that by 2015, one third of the operational ground combat vehicles are unmanned."[1] Ideas surrounding unmanned ground vehicles suggest images ranging from relatively simple systems such as small, remote controlled vehicles controlled by short range radios to large, highly independent systems akin to images from the movies "Star Wars," "Terminator," and "RoboCop." The absence of a human on board the vehicle and the displacement of the operator (or supervisor) by some distance suggest capabilities that present new and unique opportunities in which Army forces can operate. While tele-operated (or remote control) unmanned ground vehicles (UGVs) have seen use in the Army for over two decades, large, independently moving and operating UGVs have much less precedent. The mental images of an armed autonomous UGV firing at a perceived hostile target or of an unarmed autonomous UGV running over a person on the side of the road bring forth the moral, legal, and ethical hurdles that confront Army leadership. The perceived benefits of autonomous UGVs to enhance the capabilities of the Soldier doing the dull, dangerous, and dirty missions are also easy to recognize. The challenge lies in the relative newness and lack of precedent surrounding autonomous UGVs to help guide and inform development and anticipate second and third order effects.

[1] National Defense Authorization Act for Fiscal Year 2001, Public Law 106-398, Section 220, U.S. Statutes at Large 114 (2001).

The purpose of this monograph is to analyze current U.S. Army activities surrounding the development of highly autonomous Unmanned Ground Vehicles (UGV). The monograph seeks to explore historical and social science theories of innovation in order to add to the body of literature that informs the professional debate as to what the U.S. Army may need to consider or change in order to successfully develop and utilize autonomous UGVs. History shows that militaries can be prone to misinterpreting strategic, operational, and tactical impacts when developing systems that have little precedent. Lack of critical evaluation of developmental activities can lead to making invalid conclusions and ultimately result in wasted time, money, and materiel, decreased effectiveness, and potentially needless loss of life.

This monograph seeks to further inform the professional discussion on the meaning and implications of autonomy and autonomous ground systems on the battlefield. It will not provide a definitive solution on how the Army should or should not develop autonomous UGVs but rather explore various models that suggest ideas for the warfighting community to be thorough in study and objective in analysis of these new systems that have the potential to significantly alter tactics, operations, or even strategy. These ideas come from the study of past events and while history "does not and cannot offer clear answers," it can "suggest possible paths for the future."[2] These insights help determine if leaders in the Army are asking all the questions that could or should be explored such as:

What changes strategically, operationally, tactically?

What internal cultural barriers may prevent the Army or a subordinate organization or branch from seeking/seeing the best answer?

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[2] Williamson Murray and Allan R. Millett. *Military Innovation in the Interwar Period* (New York: Cambridge University Press, 1996), 3-4.

What external cultural aspects/responses (from DoD, Congress, current and future allies) need the Army consider?

Is the Army using all the tools that support thorough analysis and prediction?

Does the Army have the organization in place to successfully monitor and guide the discussion and develop the policy and doctrine (part of which is education) for successful UGV introduction and use?

Previous instances of innovation suggest that the development of a new weapon system is not a simple matter. "The process of innovation within military institutions and cultures, which involves numerous actors, complex technologies, the uncertainties of conflict and human relations, forms a part of this world and is no more open to reductionist solutions than any other aspects of human affairs."[3]

The U.S. Army is currently involved in a tremendous amount of developmental activity surrounding the development of unmanned systems. The positive impact of this work is seen in the significant increase in demand for UGV capability in Iraq and Afghanistan as military leaders see and experience their value. While UGVs have been used extensively over the past decade, the addition of sophisticated autonomy and the resulting dynamics that will result on the battlefield require careful consideration. While autonomous UGVs will not likely eliminate the need for the human dimension of warfare, there will likely be some significant impacts on the ability and manner in which forces are able to operate across the spectrum of conflict. For example, the use of autonomous UGVs in some of the more dangerous missions could dramatically decrease casualties. Like the long term loitering capabilities of today's Unmanned Air Systems (UAS), autonomous UGVs potentially provide a capability to penetrate areas

[3] Williamson Murray, "Innovation: Past and Future." in *Military Innovation in the Interwar Period*, ed. Williamson Murray and Allan R. Millett (New York: Cambridge University Press, 1996), 303.

previously thought inaccessible, monitor areas of interest for long periods of time, and deliver effects with precision. Autonomous UGVs will not fall asleep, get scared, or react emotionally. In a political environment that desires to reduce casualties to an absolute minimum, the perception, right or wrong, of significantly displacing (some have said removing) the human from the battlefield might have strategic implications. Depending on their opinion, the American public, elected officials, and military leaders might advocate the use of violence or crossing of international boundaries more easily if U.S. lives are not directly at stake. Perhaps present day UAS operations in the Afghanistan and Pakistan border regions provide the first glimpses of this idea.

In light of this potential, there are some areas the Army should consider for improvement in order to successfully understand the strengths, weaknesses, and second and third order effects of autonomous UGVs. Primary among these considerations should be the establishment of a centralized proponent within the U.S. Army's Training and Doctrine Command (TRADOC), such as a TRADOC System Manager, to coordinate development issues with respect to UGVs. This central agency would provide oversight into overarching 'warfighter' issues pertaining to UGV programs in the Army and provide a counterpart to the centralized UGV development offices in the acquisition and research and development communities. This proponent would also further enable the establishment of clear language in order to ensure UGV issues are clearly articulated and understood in and out of the Army. Also critical to the overall UGV development strategy is the improvement of simulations that realistically model Soldier-operator task load and UGV projected capabilities of autonomous UGVs. In the absence of significant numbers of prototypes to use in field exercises, simulations are the next best tool to help predict the best use of these future capabilities and determine potential operational and strategic implications.

The price of getting it wrong will be the unnecessary and tragic loss of life in addition to lost time and money. The time lost to ineffective fielding is not just related to fixing whatever capability or organizational issues arise but also in the loss of trust. Catastrophic failure during the initial introduction of autonomous UGVs will likely set back the re-introduction of autonomous UGVs back years while leaders at all levels in the Army, DoD, and U.S. government regain trust in a system that produced unintended and unanticipated consequences in lost time, money, or lives. While not as likely, there could also be increased chances for loss of comparative advantage. Unsuccessful testing and fielding of autonomous UGVs could give more time to a potential adversary to produce a similar or counter capability to U.S. Army UGVs.

Section 2 of the monograph, Key Terms and Ideas Surrounding Autonomy and UGVs, defines the terminology and major thoughts surrounding UGVs and autonomy. One of the first challenges any community of practice must face is establishing clear language to enable effective communication. The terminology surrounding unmanned systems is not always clear. At times, military programmatic documentation refers to terms such as robotic, automated, autonomous, and unmanned. These terms are not necessarily interchangeable. Writers such as Dr. Robert Finkelstein, acknowledged robotics expert, university professor, and founder and President of Robotic Technology Inc. (RTI), and Steven Shaker, former CIA Operations Officer, technology forecaster and futurist, and author of several books, provide overviews of the various meanings in their book *Unmanned Vehicle Systems: Military and Civil Robots for the 21st Century and Beyond*. Army Future Combat Systems (FCS) programmatic documentation provides insight as to how the Army views the terms. Perhaps the most authoritative definitions come out of the National Institute of Standards and Technology (NIST). The Autonomy Levels For Unmanned Systems (ALFUS) working group is an open, intergovernmental agency effort sponsored by NIST taking efforts to develop a "framework to facilitate characterizing and articulating autonomy for unmanned systems" part of which entails developing standard terms and definitions for requirements specification.[4] Members of the U.S. Army TRADOC's FCS development community continue to participate in and support this effort. As the Army continues to work more and more in a Joint and Inter-agency environment, the use of terminology that is understood and accepted across all government agencies will only help to enable clear communication.

Section 3, Theories for Innovation and Development, covers theories and concepts used in the past to achieve successful innovation. Williamson Murray and Allan R. Millett's military innovation theory as described in *Military Innovation in the Interwar Period* provides emphasis on the importance of developing a culture of innovation over a period of time, understanding the strategic framework of the time period, the need to focus on specific challenges such as defining the threat, and the importance of objective experimentation. This work also provides some of the major factors that lead to poor innovation such as rigid thinking, working in an ambiguous strategic situation, financial challenges, and misusing history or twisting lessons to justify current approaches.[5]

Organizational learning, particularly in a large bureaucracy, is a focus of the ideas of Stephen Peter Rosen in *Winning the Next War*. Rosen, a former professor in the strategy department at the U. S. Naval War College and director of political-military affairs at the National Security Council during the Reagan administration, is the Beton Michael Kaneb Professor of National Security and Military Affairs at Harvard University. He stresses that, first, innovators must understanding the strategic situation such as future threats and operational

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[4] ALFUS Working Group, "ALFUS Objectives," National Institute of Standards and Technology, http://www.isd.mel.nist.gov/projects/autonomy_levels/objectives.htm (accessed November 4, 2008). The mission of NIST is "to promote U.S. innovation and industrial competitiveness by advancing measurement science, standards, and technology in ways that enhance economic security and improve our quality of life." Work at NIST in definition and standards development often leads to acceptance as the government and industry standard against which performance is measured.

[5] Murray, 319-325.

environments. They also must use history to intelligently inform development. Rosen also emphasizes the importance of a holistic strategy for innovation and development. Successful "peacetime military innovation occurs when respected senior military officers formulate a strategy for innovation, which has both intellectual and organizational components."[6] Rosen also discusses wartime innovation. While he limits his definition of wartime to conflicts that threaten national survival, his ideas must be explored during present day conflicts. One of the necessary keys in evaluating major innovations is the importance of simulations that provide usable results to make informed decisions.

Social factors will also shape the outcome of development programs. The importance of recognizing and accounting for the elements of the Army's culture that might resist the proper analysis and acceptance of a new system is highlighted by noted historian and intelligence analyst Robert O'Connell in *Sacred Vessels: The Cult of the Battleship and the Rise of the U.S. Navy*. O'Connell's work illustrates how belief, military service culture, and tradition can have a significant role in the process of military development and this role can be detrimental if it is not acknowledged.[7] O'Connell also highlights that conditions in politics, the military, and society interact and can shape the direction of technology development.

The Army, as part of the Department of Defense and greater U.S. government, must account for the effects of working in a large, complex bureaucracy. The Bureaucratic Politics Model (BPM), developed by noted social scientists and scholars Graham T. Allison and Morton H. Halperin, highlights the importance of the need for the Army to be proactive in shaping the discussion of social issues or at least taking the issues into account ahead of time rather than

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[6] Stephen Peter Rosen, *Winning the Next War* (Ithaca: Cornell University Press, 1991), 21.

[7] Robert L. O'Connell, Sacred Vessels: The Cult of the Battleship and the Rise of the U.S. Navy (Boulder: Westview Press, 1991), 3-7.

being reactive to outside influences.[8] While BPM was originally conceived as a theory to help explain decisions in international relations, it can be applied to the development and introduction of autonomy on UGVs. BPM helps explain why decisions within and between large, bureaucratic organizations do not always follow rational actor models but, if analyzed at an appropriate level of detail, the interactions of the many players can be predicted to some degree. Stephen Rosen's earlier mentioned theory looks at innovation largely as an organizational learning issue within the dynamics of a bureaucracy. Thomas L. McNaugher's work, *The M16 Controversies*, provides an in depth look into the development of the M16 rifle and the influence of bureaucratic dynamics in the Army's research, development, and acquisition system. BPM is included to help developers and innovators think about and account for factors in and out of the Army that might compete with or work against the introduction of autonomous UGVs for military purposes.

Section 4, Overview of UGV Development, provides an overview of activities surrounding the development of UGVs in the past, present, and future. The history of basic UGV programs begins in the early 20th century during World War I. While researchers and innovators attempted to develop unmanned systems with specific capabilities such as demolition breaching, autonomous moving ground vehicles did not really begin to be developed until the 1980s. The more robust and successful use of Unmanned Air Systems (UAS) with greater autonomy and better UGVs during Desert Storm seemed to usher in what might be considered the modern era of UMS. Today, UGVs are in use by all services in the DoD. Most of today's fielded systems are remote control and tele-operated, wherein an operator controls a UGV through a camera and other on board sensors, and operates at relatively short distances from the controller. However, there are some fielded systems with increasing levels of autonomy. Concurrent with this activity,

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[8] Graham T. Allison and Morton H Halperin, "Bureaucratic Politics: A Paradigm and Some Policy Implications," *World Politics* 24 (Spring 1972): 40-79.

Army modernization programs, primarily as part of the Future Combat Systems, are seeking to develop and field large UGVs with much higher levels of autonomy. This section looks at the past, present, and the future of military UGV activities. The section then looks at the current developmental activities that are helping us get to the future state by looking at the activities through the lens of the theories discussed in Section 2. For any gaps identified, ideas are developed for the U.S. Army to consider in order to increase the level of success in development and, ultimately, employment of autonomous UGVs throughout the force.

Section 5, Summary of Recommendations and Conclusion, provides a summary of the recommendations made throughout this monograph.

Key Terms and Ideas Surrounding Autonomy and UGVs

Why unmanned systems?

As mentioned in the introduction, Congress stated two goals for the DoD for unmanned systems development in Section 220 of the Floyd D. Spence National Defense Authorization Act for Fiscal Year 2001:

> by 2010, one-third of the aircraft in the operational deep strike force aircraft fleet are unmanned; and
> by 2015, one-third of the operational ground combat vehicles [i.e. from the Army's Future Combat Systems] are unmanned.[9]

These directives came about as a result of technology development that has proven its worth over time to include increasing use in combat operations. During Operation DESERT STORM, only a few UGVs were used, largely after combat operations and UAS missions, while successful, were limited in number. As of October 2006, Soldiers used UGVs to respond to over 11,000 IED incidents, Unmanned Air Systems (UAS) had flown almost 400,000 hours in support of Operation Enduring Freedom (OEF) and Operation Iraqi Freedom (OIF), and Unmanned

[9] National Defense Authorization Act for Fiscal Year 2001.

Maritime Systems provided security to ports. The DoD also recognizes high potential in the use of UMS by describing it as "an evolution in technology that is creating an entirely new capability to project power through the use of unmanned systems while reducing the risk to human life."[10]

In simple terms, UMS provide the ability to take on the dull, dirty, and dangerous tasks in order to displace a Soldier from an area of potential harm and conduct a task through a system to increase safety and survivability or conduct 'duller,' repetitive tasks for a Soldier in order to allow the Soldier's skills to be used in more optimal areas. Some examples include:

- Reconnaissance and surveillance tasks such as guard duty, surveillance named areas of interest, other long duration observation missions.
- Target identification and designation such as the capability to loiter, positively identify and precisely locate targets of value, reduce the time required to precisely engage targets, and operate in high threat environments.
- Countermine warfare to detect, investigate, and disarm explosives. Improvised Explosive Devices (IEDs) cause the greatest number of casualties in OIF and OEF.
- Chemical, Biological, Radiological, Nuclear, and Explosive (CBRNE) reconnaissance such as the ability to find, detect, survey areas without putting humans at risk.[11]

As a result of the continued successful use in current operations and technological maturity, UMS are increasingly desired by Army leaders and Combatant Commanders. The U.S. Army's priorities are reflected in TRADOC's work to identify solutions for gaps in Army capabilities, both for the current force and future force. Unmanned systems (including UGVs) are seen as a significant part of the materiel solution to fill many current and future force capability gaps. As part of this process, the U.S. Army, through TRADOC, identifies the priority operational capabilities or "Warfighter Outcomes" that help guide science and technology investment. Autonomous UGV movement and autonomous UGV tactical behaviors are directly

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[10] U.S. Department of Defense, *Unmanned Systems Roadmap 2007-2032* report from the Office of the Secretary of Defense (Washington, D.C., December 10, 2007), i. This number does not include hand launched systems. The number would be much higher if it included smaller UAS such as the Raven and the Mav.

[11] Ibid., i-ii.

identified as two of the top 37 capabilities desired and UGVs could directly contribute to meeting at least another eight.[12]

What is a robot? What is an unmanned system?

The terminology surrounding unmanned systems is not always clear. At times, military programmatic documentation, books, articles, and other documents refer to terms such as robotic, automated, autonomous, and unmanned. In 1920, a Czechoslovakian writer, Karel Kapek wrote a play called *R.U.R.* In the play, a man named Rossum designs and builds automatons that look like human beings to do work for humans. The initials R.U.R. in the title are the name of Rossum's factory and mean "Rossum's Universal Robots." Kapek appears to have derived the name 'Rossum' from the Czech word meaning "reason" or "intelligence" and the word 'robot' from the Czech word meaning an "involuntary worker" or "slave."[13] Webster's dictionary supports this origin as it states that the etymology of the word robot is Czech from the word "robota" which means compulsory labor[14]

Specific to the military, the more contemporary term in use today is unmanned system (UMS). An unmanned system is an

> electro-mechanical system, with no human operator aboard, that is able to exert its power to perform designed missions. May be mobile or stationary. Includes categories of unmanned ground vehicles (UGV), unmanned aerial vehicles (UAV), unmanned underwater vehicles (UUV), unmanned surface vehicles (USV), unattended munitions (UM), and unattended ground sensors (UGS).   Missiles, rockets, and their submunitions, and artillery are not considered unmanned systems.[15]

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[12] US Army Capabilities Integration Center, *Warfighter Outcome Analysis* briefing, (Fort Monroe, December 2007), 14-15.

[13] Isaac Asimov,. *How Did We Find Out About Robots?* (New York: Walker and Company, 1984), 25-26.

[14] Webster's Third New International Dictionary, s.v. "robot."

[15] National Institute of Standards and Technology, *Autonomy Levels for Unmanned Systems (ALFUS) Framework: Volume I: Terminology*, ed. Hui-Min Huang (Gaithersburg, 2004), 20.

The Department of Defense defines an Unmanned Vehicle as

> a powered vehicle that does not carry a human operator, can be operated autonomously or remotely, can be expendable or recoverable, and can carry a lethal or nonlethal payload. Ballistic or semi-ballistic vehicles, cruise missiles, artillery projectiles, torpedoes, mines, satellites, and unattended sensors (with no form of propulsion) are not considered unmanned vehicles. Unmanned vehicles are the primary component of unmanned systems."[16]

This definition acknowledges that there is a broader category of unmanned systems in which unmanned vehicles are a part.

While this monograph focuses on UGVs, discussion and development of any UMS needs to consider a holistic view of the entire system that enables the UMS to operate. The development of all UMS must consider the human supervisor, the interface device(s) through which the UMS receives instructions and provides feedback to the supervisor, and the means with which the UMS and the supervisor communicate. The interface device must enable rapid, effective communication between the UMS and the operator. At the lowest tactical levels, this could mean a Soldier on the ground speaking, typing, or visually sending messages to the UGV. If the Soldier-supervisor is riding in a vehicle, passing instructions to the UGV using a keyboard and mouse is likely to be too cumbersome to be responsive in a timely manner. For the Soldier-supervisor that may be in a dismounted formation, the developer of the interface device must consider the size and weight as well as the need for the Soldier to potentially use his weapon. The UGV must also send messages and feedback to the Soldier-supervisor. The interface device must allow for rapid understanding and consumption of the information that the UGV is sending to the Soldier-supervisor such as vehicle status information or pictures and video from sensors. For all these messages and information to go back and forth, the Soldier and the vehicle must have some means to pass those messages between the interface devices. This could potentially be

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[16] US Department of Defense, Unmanned Systems Roadmap 2007-2032 , 1.

a radio, visual cues (hand and arm signals, following a vehicle), audio cues (speaking to one another), through a wire, or a combination of all of these. These components are all part of the system. Focusing only on the vehicle or device without the human on board misses a significant part of the development challenge.

What is autonomy?

Adding to the confusion of terminology, the idea of autonomy and autonomously moving systems conjures many different images. Many households in the U.S. already utilize an UMS to help with cleaning. The "Roomba," made by iRobot, automatically vacuums a floor, moves around furniture, and re-docks itself in a charging station. Competing with these images of a system with a relatively low level of independence are more human like systems that talk, interact, and even fight with Will Smith in the movie "I, Robot". Finkelstein and Shaker, in *Unmanned Vehicle Systems: Military and Civil Robots for the 21st Century and Beyond,* do not directly address the definition of autonomy but, through their explanation of semi-autonomous vehicles, imply that autonomy is "where a computer aboard the vehicle provides…the control."[17] Army Future Combat Systems (FCS) programmatic documentation provides some insight as to how the Army views the terms. As part of the capabilities described for the Armed Robotic Vehicle-Assault (Light) (ARV-A(L)), the FCS program provides the rationale that

> autonomous operation with tactical behaviors will greatly enhance the capability of the ARV-A(L) to conduct missions with a more Soldier like behavior avoiding detection during reconnaissance or moving into firing positions. The tactical behaviors will include movement behaviors to avoid exposure, to position itself with an advantage, and to avoid obstacles.[18]

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[17] Robert Finkelstein and Steven Shaker, *Unmanned Vehicle Systems: Military and Civil Robots For The 21st Century and Beyond* (Arlington: Pasha Publications Inc., 1994), 1.

[18] US Army Future Force Integration Directorate, *FCS Capability Development Document for the Future Combat Systems* (Fort Bliss: 2008), 220.

Other programmatic documentation for FCS describes 10 levels of autonomy for FCS systems. While acceptable for their purpose in the FCS program, these definitions are specific to the FCS systems and are not necessarily applicable to a wider audience.[19]

In order for professional discourse to be of value, members of a community of practice must have some clear, common language in order to communicate clearly. Due to the high interest and potential implications of autonomous UGVs on the battlefield, a clear, common definition of autonomy that permits explanation of degrees is needed. As autonomous systems will likely impact all types of war fighting units and skills, it requires military professionals of all ranks and specialties to develop, learn, and adhere to a common language.

Perhaps the clearest definitions with broadest applicability come out of the National Institute of Standards and Technology (NIST). The Autonomy Levels For Unmanned Systems (ALFUS) working group is an open, intergovernmental agency sponsored by NIST taking efforts to develop a "framework to facilitate characterizing and articulating autonomy for unmanned systems" part of which entails developing standard terms and definitions for requirements specification.[20] Members of the U.S. Army TRADOC Army Capabilities Integration Center (ARCIC)[21] and FCS development community continue to actively participate in and support this effort.[22]

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[19] Kerry Pavek, email with author, January 22, 2009.

[20] Autonomy Levels for Unmanned Systems Working Group, "Autonomy Levels for Unmanned Systems Objectives," National Institute of Standards and Technology, http://www.isd.mel.nist.gov/projects/autonomy_levels/objectives.htm (accessed November 4, 2008).

[21] ARCIC's mission is to "lead the development and integration of force capabilities across the [spectrum of Doctrine, Organization, Training, Materiel, Leader Development, Personnel, and Facilities (DOTMLPF)] for the Army within a Joint and Multinational environment to support Joint Force Commanders." Participation in the ALFUS Working Group ensures that FCS and greater Army interests are represented in the final standards.

[22] LTG Michael A. Vane, interview by author, Fort Leavenworth, KS, October 23, 2008.

As defined by ALFUS documentation, the basic definition of autonomy is "the condition or quality of being self-governing." Specific to unmanned systems, autonomy is an "unmanned system's own ability of sensing, perceiving, analyzing, communicating, planning, decision-making, and acting/executing, to achieve its goals as assigned"[23]

The independence of the unmanned system from the human operator is the key component. UMS that can accomplish their assigned tasks with little interaction with their human operator are perceived as having high levels of Human Independence (HI) and, conversely, UMS that require a great deal of interaction with their human operator would have low levels of HI. This definition by itself is not complete to understand the sophistication of the UMS to perceive, interact, and react to changes in the environment.

A fuller understanding of the level of autonomy for an UMS can be attained by measuring two additional factors that provide context: the complexity of the mission and the difficulty of the environment in which the UMS is expected to operate. Mission complexity (MC) is defined first through the mission, or the highest level task, that is given to the UMS. Greater mission complexity is indicated through such categories as the number and variety of subtasks and skills needed, the amount of collaboration the UMS must conduct, the types and amounts of decisions the UMS must make, the amount of situational awareness needed, and the relative speed at which the tasks must be accomplished.[24]

Environmental complexity (EC) is defined by such categories as the static nature of the environment (terrain type, soil type, air qualities, etc.), dynamic objects with which the UMS must contend (frequency, density, type, etc.), weather factors, and threat factors that purposefully inhibit the UMS's completion of the mission.

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[23] National Institute of Standards and Technology, *Autonomy Levels for Unmanned Systems (ALFUS) Framework: Volume II: Framework Models*. ed. Hui-Min Huang, (Gaithersburg, 2007), 16.

[24] Autonomy Levels for Unmanned Systems (ALFUS) Framework: Volume II: Framework Models, 20-21.

The level of autonomy for an UMS is determined by establishing the level of independence from the human operator that a system requires to accomplish its mission (i.e. establishing the HI). The Contextual Autonomous Capability is determined by placing the HI in context with the mission complexity and the environmental complexity. Graphically, the Contextual Autonomous Capability model for a system is indicated in Figure 1 below.

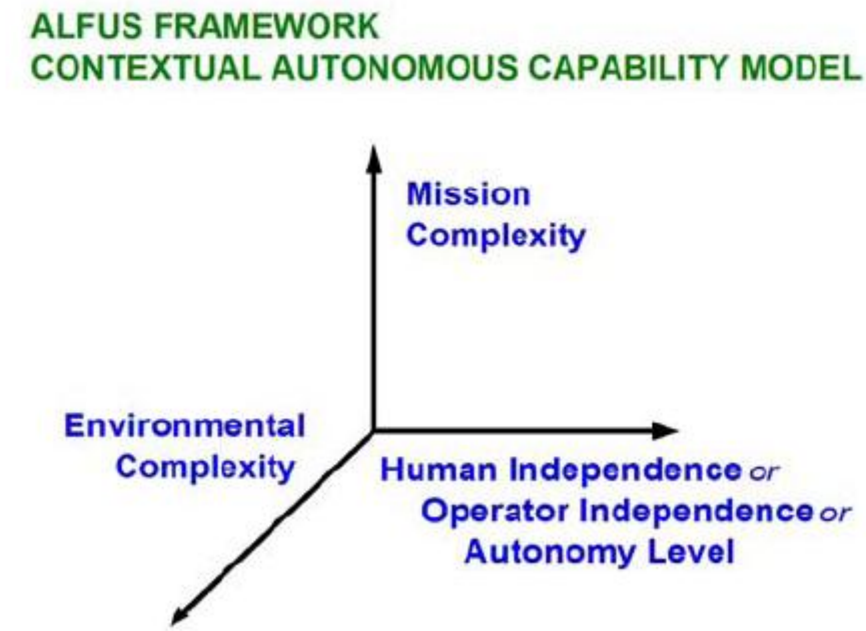

Figure 1. ALFUS Contextual Autonomous Capability Model[25]

The above detailed model is useful in UMS development in order to understand and clearly articulate what one means when talking about a level of autonomy in a certain context. However, once a group agrees upon the nature of the environment in which the UMS will work and the task types and performance standards desired, the group can focus on the HI or level of autonomy. Figure 2 illustrates this concept.

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[25] Autonomy Levels for Unmanned Systems (ALFUS) Framework: Volume II: Framework Models, 19.

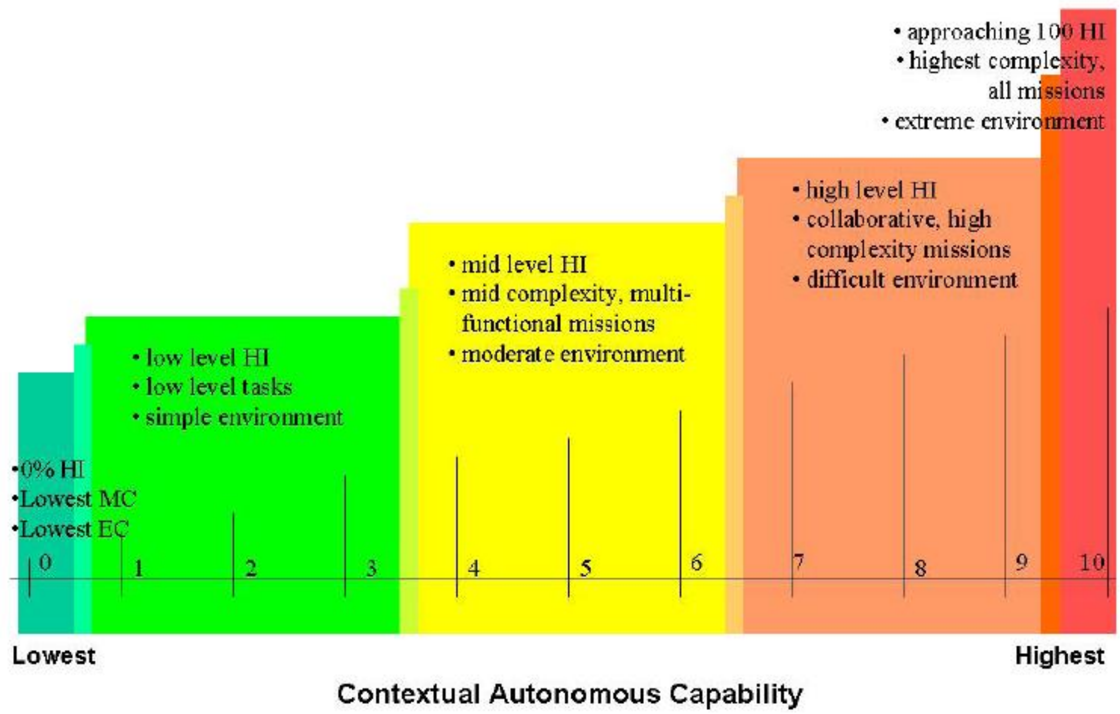

Figure 2. Illustration of ALFUS Contextual Autonomous Capability[26]

The need for detailed definitions will help guide clear, effective communication throughout the Army and the development community with regards to the levels or amounts of autonomy desired for various unmanned systems. Without clear definitions, professional discussion on a desired end state will be vague and potentially ineffective.

What is the goal of the Army…what is the Army working towards?

The goal of U.S. Army innovation is to make the Army more capable and effective in one or more of its functions. Innovation can occur in many different domains to include doctrine, organization, training, leadership, materiel, facilities, and personnel. The more any particular innovation may impact on the Army's core mission or the more broad in potential application, then, arguably, the more resources should be applied to developing a well thought out plan.

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[26] Autonomy Levels for Unmanned Systems (ALFUS) Framework: Volume II: Framework Models, 20.

UGVs with high levels of autonomy (that is the ability to accomplish complex missions in difficult environments with low levels of human interaction) will likely have significant impacts on the tactics units use, the manner in which joint forces conduct operations, and, potentially, even the policies and strategies developed by the Combatant Commanders or National Command Authority. The DoD recognizes this potential and established policy stating "[t]he DoD will develop and employ an increasingly sophisticated force of unmanned systems over the next 25 years (2007-2032)."[27] More specifically, the DoD plans to "pursue greater autonomy in order to improve the ability of unmanned systems to operate independently, either individually or collaboratively, to execute complex missions in a dynamic environment."[28]

The Army's long-term vision of what it desires with UGVs is perhaps best described in the TRADOC ARCIC's description of its developmental priorities that help shape science and technology investment:

> UGV Autonomous Movement – UGV's will need autonomous movement with tactical behavior to support operations in a full spectrum operational environment with varying terrain, weather, and battlefield conditions to include an urban environment. It will operate in support of mounted and dismounted forces conducting offensive, defensive, security, stability, and support operations. They must be capable of following or moving independent of mounted and dismounted Soldiers across rolling and open terrain, constrictive, complex terrain at a distance of at least 2km with a desired distance of 10km.
>
> UGV Autonomous Tactical Behaviors – Unmanned systems must be able to execute complex tactical behaviors with minimal required operator control or intervention during a mission of 72 hours or less thus freeing the Soldier/Robotic Controller to be able to accomplish other mission essential tasks such as monitoring the unmanned systems mission package and the tactical situation. These systems will allow

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[27] US Department of Defense, Unmanned Systems Roadmap 2007-2032 , 1.

[28] Ibid.

for greater Soldier standoff, provide early threat and hazard detection, conduct breaching operations, assist in reconnaissance, and perform high-risk clearing operations.[29]

Specific to the Future Combat Systems UGVs, the documents and field manuals being produced by the Future Force Integration Directorate (FFID) at Fort Bliss, Texas also describe the high level of autonomy desired. The FFID has the mission to develop, test, and validate the Army's Future Combat Systems (FCS) program. For example, in addition to the previously mentioned autonomous tactical behaviors, the FCS ARV-A(L) "must autonomously respond to threat attacks detected by its integrated countermeasures suite". The system must sense the attack with no human aid and make the appropriate response."[30]

As the Army warfighting and technology development leadership moves forward, the potential end users of the equipment must be able to clearly articulate their needs to help focus the developers. As robust as some of the descriptions may be, there is still room for interpretation that requires further refinement. For example, what does it mean to move tactically? Which tactical behaviors are the most important? What is the appropriate amount or level of autonomy that an UGV should have with respect to firing a weapon? The use of precise language that is accepted and understood by all the players affected by UGV development is the starting point to help bridge the gap between the capability we have today and that which we desire in the future.

Theories for Innovation and Development

The combat development and acquisition system can be a complex process with many stakeholders. Even the process to improve an already existing system is not simple. Whenever systems that are brand new or have had little precedent come about, the course to determining the best answer is rarely clear and usually full of debate. History is replete with examples, both

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[29] US Army Capabilities Integration Center, Warfighter Needs to Shape Army Science and Technology Investment Memo Enclosure, (Fort Monroe, December 2007), 3.

[30] FCS Capability Development Document for the Future Combat Systems, 225.

successful and unsuccessful, that provide opportunity to learn. This section does not propose to find the single, cookie cutter solution to the 'right' way to develop UGVs. Peter Rosen's study on innovation highlighted that "as one study found a factor that seemed to be associated with innovation, another would find evidence of innovation when that factor was absent, or even when the opposite of that factor was present."[31] Rather, by reviewing some previous authors' analysis and theories of prior experiences, today's developers may find some ideas worth applying to the present environment of autonomous UGV development.

Murray and Millett

In *Military Innovation in the Interwar Period*, historians Williamson Murray and Allan R. Millett describe and analyze some of the major military innovations that took place between the two World Wars. Nations whose militaries were very similar in capabilities during World War I approached interwar innovation differently and possessed vastly different capabilities and organizations at the start of World War II. Development during this period took place with "less money and greater ambiguities about potential opponents and the nature of the wars they [military institutions] [would] have to fight."[32] Murray and Millett emphasize the importance of understanding this strategic context in which innovative activity takes place.[33] In a democracy, military development and innovation in large part depends on policy determined by civilian leadership.

For example, the failure of the British Army to successfully develop doctrine, organizations, and a better material solution for armored vehicles during the interwar period is in large part a result of the higher level policies concerning the British Army. In the 1930s, British

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[31] Rosen, 3.

[32] Murray, 300.

[33] Ibid., 305.

tendencies were isolationist. The strategy of 'limited liability' stated that Britain would not commit troops to the European continent. The British Chief of the Imperial General Staff (CIGS) following World War I allowed for considerable independence with regard to armored experimentation but fiscal constraints did not allow continued support. The stated de-prioritization of preparing for war on land and the resulting lack of budget led to a lack of development. The service culture and organization also contributed to poor innovation. The British War Office did not prepare a full report of the lessons of the British Army until the 1930s. Once complete, the CIGS did not allow the full report to be sent to the officer corps and had sections omitted that would have taught serious lessons but possibly cause professional embarrassment. While there were some bright spots of armored warfare innovation, the lack of emphasis from above on preparation for war on land hurt any overall innovation effort.[34] The overall effect of this lack of support for experimentation and analysis of the full implications of armored warfare was that the British Army was not prepared for the battlefield of the 1940s. While government leadership and its policies must set conditions to enable innovation, these decisions are largely based on assessments of future threats. In large part, these assessments come from military sources. Military leaders have a responsibility to take part in and inform the debate on the nature of potential threats as military development will take place against this future threat backdrop.

Murray and Millett describe most innovation as being evolutionary in nature, meaning taking place over an extended period of time with gradual changes in areas such as materiel, doctrine, organization, and procedures. Revolutionary change, while possible, rarely occurs. Typically, a result of top-down emphasis, the leader must possess technical understanding of the

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[34] Williamson Murray, "Armored Warfare: The British, French, and German Experiences," in Murray and Millett, 19-28.

subject or system as well as conceptual understanding. Revolutionary innovation and change carries risk of catastrophic loss of lives and materiel and even national sovereignty. "If you are right, top-down leadership will allow you to get it very, very right. If you get it wrong, however, you will get it very, very wrong."[35]

Rather than reliance on a single, strong leader, "evolutionary innovation depends on organizational focus over a sustained period of time."[36] Murray and Millett stress the critical need for the creation and sustainment of a culture of innovation. For example, the German leadership created a culture of innovation in the Reichswehr that "placed a high value on study and analysis of changes in doctrine, tactics, and technology."[37] Overall, military leadership must "think in terms of creating an officer corps educated and encouraged to innovate."[38]

Primary in any problem solving process is establishing a clear understanding of the problem. The idea of specificity in innovation is a precondition to a successful innovative process. First, leaders must thoroughly understand the gaps between what the force is capable of doing versus what is required. This gap identifies the "presence of specific military problems the solution of which offered significant advantages."[39] For example, the American and Japanese navies were confronted with the issue of extending reach across the Pacific Ocean. These navies and their respective government leadership could more easily see the value of carriers. On the other hand, European navies did not have these conditions. Most European countries did not perceive a requirement to project large quantities of air power across an ocean to support other

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[35] Murray, "Innovation: Past and Future," 308.

[36] Ibid., 309.

[37] Ibid., 310.

[38] Ibid., 325.

[39] Ibid., 311.

military operations and concluded that land based air was sufficient and large scale carrier development was not necessary.

The overall military culture plays the most significant role. Defined as the "sum of the intellectual, professional, and traditional values of an officer corps; it plays a central role in how that officer corps assesses the external environment and how it analyzes the possible response that it might make to "the threat."""[40] For evolutionary innovation to be successful in solving complex problems, "officers require a dedicated commitment to their profession."[41] This begins with having interest in and valuing the study of history, theory, and doctrine. Military policies must support this value if it is to be reinforced. This intellectual curiosity extends to technical areas as it is "essential that officers have connections with, and an understanding of, the technologies in a civilian world dominated by innovation and technology."[42] The ability to conduct this study is effected by the amount of time available in the assignments timeline and schedule of units. Leaders need time to think and reflect not only in school but also in operational units. "The value of exercises in the end depends entirely on the willingness and ability of their participants to think through the implications of what has gone well and what had gone badly."[43] The ability to critically evaluate must be accompanied by brutally honest assessment to prevent false or biased conclusions. This is especially challenging for 'real-world' events when the leaders conducting analysis are part of the same organization that participated in the action. When the actions are part of exercises or war games, the use of realism and imagination must be emphasized. The

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[40] Ibid., 313.

[41] Ibid., 325.

[42] Ibid., 325.

[43] Ibid., 327.

conduct of the experiment or exercise and follow on analysis must be realistic, honest, thorough, and unbiased. Leaders cannot 'drive' a solution in order to state an already preconceived idea.[44]

When organizations fail to innovate properly, there are some common mistakes that can be seen in hindsight. One of the more common issues is the misuse or misinterpretation of history. While history cannot provide a step-by-step answer to a problem, ignoring history or ignoring the context of discrete events can lead to faulty conclusions. Rigidity in outlook and interpretation is also a common mistake. Viewing doctrine as a prescriptive answer can potentially lead to faulty conclusions. Failure to gain a comprehensive understanding of the operational environment or a potential adversary's capabilities may also lead to misapplication of doctrine or historical lessons.[45] These pitfalls can be exacerbated by a culture of "institutional biases against feedback that [contradict] doctrine, conceptions, or preparations for war."[46] Military organizations must continually develop feedback loops to honestly determine if the right lessons are being learned.

Rosen

Stephen Peter Rosen, a former professor in the strategy department at the U. S. Naval War College and director of political-military affairs at the National Security Council during the Reagan administration, is the Beton Michael Kaneb Professor of National Security and Military Affairs at Harvard University. Just after leaving his position at the U.S. Naval War College, he wrote *Winning the Next War* on the subject of military innovation. Looking at the military as a large bureaucracy, he wrote that "the problem of military innovation is necessarily a problem of

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[44] Ibid., 316-317.

[45] Ibid., 319.

[46] Ibid., 323.

bureaucratic innovation" and "organizational learning."[47] One of the primary ways he defines major innovation is as "a change in one of the primary combat arms of a service in the way it fights or alternatively, as a creation of a new combat arm."[48] Certain uses of UGVs, and even UMS in general, have the potential to make such a change. Even if UGVs do not completely change the way the Army fights, Rosen's ideas still apply as a major innovation also could involve "downgrading or abandoning of older concepts of operations and possible of a formerly dominant weapon."[49] With the broad functions of UGVs applying to potentially all branches and all parts of the battlefield, Rosen's ideas have broad relevance for Army leaders.

Rosen defined three broad categories of innovation: peacetime, wartime, and technological innovation. For peacetime innovation, working within the bureaucracy is important. Although militaries can be slow to adjust and can frustrate the efforts of those attempting to bring about change, innovators should work within the processes already established. Efforts to circumvent established processes or military leadership have historically been shown to harden leaders' minds against the innovation in question and ultimately work against the incorporation of the innovative idea.[50]

Within the bureaucracy, different subordinate organizations will compete for "the relative priority of roles and missions" and ultimately "about the relative resources of each branch."[51] These decisions boil down, in large extent, to the agreement "about what the next war will or

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[47] Rosen, 2-4.

[48] Ibid., 7.

[49] Ibid., 7-8.

[50] Ibid., 13. Liddell Hart and de Gaulle were both advocates of tank warfare and increasing the size of the mechanized force. They made appeals to their civilian leadership to 'force' military leadership to make the change. Ultimately, this had the result of "reduced willingness of the professional military to consider innovation."

[51] Ibid., 19.

should look like" and how the branches or services will fulfill their roles during that war.[52] Rosen's idea matches Murray and Millett's discussion that innovation is more likely to succeed when there is a clear threat and defined strategy to meet that threat.[53] For peacetime innovation, this threat does not necessarily have to be tied to a specific enemy capability but rather a change to the environment in which potential threats may operate. This security environment must be understood by leaders throughout the organization. Ultimately, Rosen suggests "that peacetime military innovation occurs when respected senior military officers formulate a strategy for innovation, which has both intellectual and organizational components."[54]

One of the critical areas that supports the innovative effort is the role of experimentation and simulations. From the use of aircraft carriers prior to World War II to the desire for greater battlefield mobility during the Cold War and the maturation of helicopter operations, Rosen provides numerous examples that realistic, detailed experiments and simulations are critical for successful innovation. Certainly, simulations can never replace live experiments and real-world usage. However, when full prototypes of new systems can not be put into the field but their form factor and operational performance criteria are known or can be approximated, then simulations are the next best thing to help learn about these new systems and the effects they will have, good and bad, on the battlefield. "Simulating new forms of warfare will always be full of uncertainties, because there is no reality to test the simulation. Yet there may be no better way to think through innovative practices in peacetime."[55]

Wartime military innovation, in contrast to peacetime innovation, takes place during a major war. Rosen defines this as during a conflict when national survival is at stake. For

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[52] Ibid., 10.

[53] Murray, "Innovation: Past and Future," 312.

[54] Rosen, 21.

[55] Ibid., 75.

example, he does not include innovation during the Vietnam War as wartime innovation.[56] While the ongoing conflicts in Iraq and Afghanistan would not meet Rosen's idea of a major war, the ideas he offers are worth considering for today's UGV developers. With the proliferation of UGVs in combat, innovators need to consider how lessons learned in theater on systems that are less autonomous than what is envisioned in the future can (or should) be applied.

First, problems on the battlefield can cause leaders to develop innovative responses and use existing technology in new and creative ways. As UGVs become more ubiquitous across the formation, these lessons must be captured for developers to incorporate and improve.[57] Second, new technology development is often surrounded by stories of how the new system was resisted. Rosen suggests the "real problem was one of learning how to measure the effectiveness."[58] The challenge is finding a way to capture battlefield information and the conditions under which a new system or technique was used effectively and when it was not. From the beginning, leaders must critically analyze the organization that is in place to capture these lessons, pass them on to the developers of future systems, and ensure that the lessons are correctly understood and applied. "The intellectual and organizational changes necessary to evaluate new ways of fighting are as important as the development and production of new technologies."[59]

The third type of innovation Rosen covers is technological innovation. Whereas, peace and wartime innovation is social innovation concerned "with changing the way men and women in organizations behave," technological innovation is concerned with the development of new

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[56] Ibid., 105.

[57] Ibid., 24. Battlefield problems during WWI (ex. lack of progress in trench warfare) contributed to the first amphibious assault at Gallipoli and creation of tank

[58] Ibid., 110.

[59] Ibid., 128.

materiel.[60] While technological innovation is largely the realm of the engineers and scientists in the development of new systems, Army leaders play a critical role in arming them with the critical information they need to understand the system's operational role. For example, as new systems get tested, Army leaders must inform the measurements of effectiveness in order to help evaluate the costs and benefits of these new systems that do not yet exist. Army leaders must also continuously interact with the technical developers to determine if these autonomous systems have the potential to characterize a large break from the past and not just an incremental shift. If this is possible, leaders must carefully consider how decisions about research and development will be made. In the end, while technological innovation is "concerned with building machines," Army leaders, the 'warfighters,' must continuously interact with these technical innovators in order to monitor and inform the process.[61] This interaction requires Army leaders to obtain a high level of technical understanding in order to better understand the realm of the possible with regard to a new technology and communicate more effectively with the technical experts.

Managing risk and uncertainty is a critical component of the innovation process. This is especially true during times of budgetary constraint when many different programs compete for limited funds and attention. This is an even greater challenge when future threats are not as clear as in the past. During these challenging times, Army leaders play a critical role by developing strategies to manage these uncertainties. These strategies not only balance the costs and benefits between various programs but also bridge programs that have direct benefit to the current force to programs that will enable our Soldiers to remain dominant in the future. Internal to an individual program, these strategies also help developers make decisions when tradeoffs must be made

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[60] Ibid., 39-40.

[61] Ibid., 40, 227.

between two capabilities on a single platform. "If the future is uncertain, then it pays to be flexible."[62]

Social Shaping of Decisions and Technology

The theories of both Rosen and Murray and Millett discuss the importance of culture and social influences to the innovative process. Noted historian and intelligence analyst, Robert O'Connell, in his book *Sacred Vessels: The Cult of the Battleship and the Rise of the U.S. Navy*, illuminates the idea that human perceptions strongly influence the course of technology and the way people value weapons. *Sacred Vessels* primarily examines the military's culture of resistance to change by examining the U.S. Navy's activities surrounding battleship development through the Cold War. He explains that human beliefs, culture, and traditions play an important but unacknowledged role in development and decisions at all levels both in and out of a military service. O'Connell states the "manner in which people alter the course of technology is subtly influenced by a number of characteristically human perceptions and conventions…which are themselves often irrelevant or even inefficient and whimsical."[63] While most of O'Connell's book stands as a warning to the negative consequences these perceptions can have, not all of these influences are bad. Many of the cultural values that impact development arose over time for good reason. As the present day Army continues to modernize, it is critical for leaders to be aware of these social influences and be self-critical of their influence upon decision makers and their choices.

Specific to UGV development, O'Connell offers critical insights applicable to the Army. The importance of thorough, objective analysis is especially important during a period when little actual field experience can be gained with actual or similar systems. During the 19th Century, few

[62] Ibid., 243.

[63] O'Connell, 5.

large naval battles took place but the technology surrounding battleships, mostly due to steam power and steel hulls, was changing at a rapid pace. In hindsight, little objective analysis was completed to look at the effects of the change in technology and the "balance struck was generally more a product of theory rather than experience."[64] Naval leaders resorted to making battleships bigger as it was "irresistible to a profession whose whole history had taught its members to equate size with power."[65] Critical analysis is essential not only in evaluating the next iteration of a current system but also in comparing older systems with newer systems of unknown potential. O'Connell describes how naval officers initially did not accept submarines and even considered them "an utter breach of tradition" when compared to surface war fighting ships.[66] While early experiments failed, innovators saw through the failure to envision the future potential. Even when the submarine was technically feasible, many did not understand the critical pairing of submarine technology with torpedo technology. They "failed to understand that the sub-torpedo system…was at the beginning of its cycle of evolution."[67] Innovators must not only envision a new system as a discrete entity but also must see how it fits inside of the larger organization and what critical components make it a complete system.

The perceptions of decision makers are critical to understand. As previously discussed, naval leaders did not initially accept and even ignored the first submarines. First, the submarine's manner of attack went against Navy culture. There was no large 'boom.' Leaders referred to the submarine's operation as "skulking, treachery, deception" and called it the "Pig Boat."[68] The boat was not seen as survivable by those who resisted. Proponents advocated that survivability

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[64] Ibid., 48.

[65] Ibid., 49.

[66] Ibid., 139-140.

[67] Ibid., 146.

[68] Ibid., 148.

was obtained through stealth and not through heavy, thick armor that caused battleships to undertake an impressive size and weight.[69] Overall, the paradigms under which naval leaders operated effected the way in which they judged the new system. Rather than use thorough analysis and experience to objectively weight the costs and benefits, leaders allowed social norms to dictate their decisions.

Social factors external to the military must be considered as well as those inside the service culture. The Army is funded through the government and the perceptions of its civilian leadership have direct impact on budgeting and employment decisions. The decisions of these civilian leaders are affected, in no small part, by the perceptions of the voters that put them in office. After World War I, President Wilson placed personal emphasis on the U.S. Navy's battleship program and used the battleship as a symbol of power in order to advance some of his foreign policy goals.[70]

For U.S. Army UGV development, consideration must be given to how various groups will perceive autonomous systems. Internal to the Army, the culture of Soldiers and their leaders will impact their acceptance especially if autonomous UGVs are portrayed to *replace* Soldiers rather than *enhance* a Soldier's capabilities or *displace* a Soldier from harm's way. External to the military, the ethical considerations and trust of autonomy can potentially have a large impact on policy decisions or even laws that govern autonomous system usage. From the voting public to law makers to the Commander in Chief, the perceptions of these players are already being shaped. These social considerations must be a part of the strategy development process for autonomous UGVs.

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[69] Ibid., 148.

[70] Ibid., 234-235.

Bureaucratic Politics Model

All previously discussed theories touch upon the need to understand any innovation in the context of the bureaucratic processes that take place in and around the organization. The Bureaucratic Politics Model (BPM) was originally conceived as a theory to help explain decisions in international relations decision making. However, the basics of the model can be applied to many bureaucracies to include the Army and the issues surrounding the application of autonomy on UGVs. Originally articulated by noted social scientists and scholars Graham T. Allison and Morton H. Halperin, BPM states "the "maker" of government policy is not one calculating decision-maker, but rather a conglomerate of large organizations and political actors who differ substantially about what their government should do on any particular issue and who compete in attempting to affect both governmental decision and the actions of their government."[71] Decisions concerning the use of autonomy and UGVs will not only be determined by decisions made within the Army but also influenced by factors outside of the Army. These factors include national security issues, domestic policy issues such as economics and the perception of the public and their influence upon lawmakers, and foreign policy issues such as the perception of allies and other foreign powers to operating around and interacting with autonomous UGVs.

The first organizing concept of BPM is determining who are the major players "whose interests and behavior have an important effect on the government's decisions and actions."[72] The reaction of American government leadership, their voters, and allies may ultimately influence the decision to procure or not use these systems in a particular way. The Army needs to anticipate this, plan for it, and work to ensure these players have an objective, thorough understanding of the issues rather than letting these players be influenced by misperceptions and

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[71] Allison and Halperin, 42.

[72] Ibid., 47.

false information. While the players who have critical interest may be a sizeable group, the final decisions may be influenced by a smaller group of leaders. This small group of final decision makers should, of course, be the focus. Implementing actions, however, may be influenced by a much larger group. Educating the Army's leaders and influencing their perceptions early on can affect successful fielding and use.

The second key organizing concept of BPM is determining "each player's stand" and the "perceptions and interests which lead to a stand."[73] The major factors for this are national security interests, domestic interests, organizational interests, and personal interests. For the elected leaders that influence Army issues, the perception of their voters is critical. The domestic interests of the players who are elected officials must be considered. Personal interests of each major player or group of players must be considered whether they be individual high level decision makers or the executors of the decisions such as those Soldiers and their first line leaders who will ultimately employ autonomous UGVs. Internal to the Army, organizational interests will be significant. Different sub-organizations may perceive gains or losses of personnel, money, or influence due to large scale adoption of autonomous UGVs. These interests must be anticipated and accounted for in the process.

The third major organizing concept of BPM is determining how "the players' stands [are] aggregated to yield decisions and actions of a government."[74] The action of each player is affected by the advantages and disadvantages that each possesses. "Each player's probability of success depends upon at least three elements: bargaining advantages, skill and will in using bargaining advantages, and other player's perceptions of the first two ingredients."[75] While this

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[73] Ibid., 48.

[74] Ibid., 50.

[75] Ibid., 50.

seems intuitive, the important emphasis is on the perceptions that each player thinks are his advantages and disadvantages and not necessarily what they actually are. The other critical component is considering those areas that are not decided "because they are not recognized, raised too late, or misunderstood."[76] While the Army cannot communicate perfectly with all the players in the process, the greatest sin would be an outcome that is not perceived to be in the Army's interest and that, in hindsight, is due to the lack of action or forethought on the part of Army leaders. This includes not only senior Army leaders but also junior leaders who take part in the discussion and inform the debate.

Thomas L. McNaugher provides an important example of the BPM as applied to the Army's development and acquisition process in his book *The M16 Controversies*. McNaugher explains that it is critical for Soldiers to stay involved in a system development process as stakeholders. While requirements for systems that will be used on the battlefield start off based solely on operational requirements, the outcome can also become "the byproduct of intense intraservice bargaining and consensus building."[77] Involvement of users, the 'warfighters,' will better inform decisions when trade-offs need to be made and will lead to a better final product. However, even the group of 'warfighters' will not likely be from a homogenous organization. Each sub-organization may have its own unique requirements. Rather than supporting a technical process that has a "need for austere requirements, simplicity, and flexibility," the end result of bringing many organizations together often leads to a long list of requirements on a single system.[78] The overall effect of this long list of requirements may ultimately make the system an expensive, technical challenge.

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[76] Ibid., 53.

[77] Thomas L. McNaugher, The M16 Controversies: Military Organizations and Weapons Acquisition (New York: Praeger Publishers, 1984), 181.

[78] Ibid.

Theo Farrell, advisor to the United Kingdom Minister of Defense and leading professor at Kings College, London, in his book *Weapons Without a Cause*, provides "three sets of issues – strategic, institutional, and budgetary, [that] must be analyzed when explaining why certain weapon programs succeed and others fail." [79] These issues, if considered in advance, can help developers anticipate issues to help increase chances of success. Strategic issues include articulating the "strategic rationale for the program."[80] Ensuring that any system carries out "a necessary military mission" and is "capable of carrying out its military mission" is the first issue that must be addressed.[81] The tougher aspect to address under strategic rationale is determining if more cost-effective options exist that also meet that articulated mission. Institutional issues include "the organizational and presidential politics surrounding weapons acquisition."[82] These issues include looking at all the sub-organizations within the Army and what their self-interests may be with regard to autonomous UGVs. Within the greater government bureaucracy, the Army must understand the political issues that the elected leaders must consider. Budgetary issues are critical. Not only must the Army look at the cost of the programs but the overall budget conditions must be considered.[83] Total costs, cost effectiveness, and the potential of costs to increase in the future are critical factors for stakeholders to understand and anticipate.

Overview of UGV Development

The U.S. Army is currently involved in a tremendous amount of developmental activity surrounding the progress of unmanned systems and increased autonomy. Leaders in the Army continue to ask for UGVs with increased capabilities to support operational missions in the field.

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[79] Theo Farrell, *Weapons without a Cause* (New York: Macmillan Press LTD, 1997), 22.

[80] Ibid., 9.

[81] Ibid.

[82] Ibid., 11.

[83] Ibid., 14.

The addition of sophisticated autonomy to UGVs and the resulting dynamics that will emerge on the battlefield require careful consideration. Looking at some of the Army's major developmental activities through the lens of the previously discussed theories can enable leaders to critically evaluate the efficacy of the Army's efforts, help anticipate unwanted effects, enable innovation and organizational learning, and ultimately field better systems to our Soldiers.

The Past

Before looking at current activities, putting today's efforts in the context of their World War I origins is necessary. Due to the slaughter on the western front, by 1915, efforts to break the stalemate of trench warfare heightened the imagination of innovators. Felix Sabah designed a remote control land torpedo the size of a small gasoline powered car that had caterpillar wheels and wire cutters. Carrying about 1000 pounds, Sabah ""envisioned a cheap, unmanned vehicle which could carry either a high-explosive mine, shrapnel, missile, or a combination payload."[84] Victor A. Villar and Stafford C. Talbot patented another design for a land torpedo in 1917. Powered by a small steam engine, the vehicle was designed to be cheap and expendable in order to be driven toward an enemy obstacle and detonated in order to create a breach for friendly troops to assault through.[85] In 1918, E.E. Wichersham of the Caterpillar Tractor Company designed another remote control demolitions carrier which was powered by batteries and controlled by cable. U.S. engineers John Hammond and B.F. Meisser developed the first radio controlled UGV at the Naval Research Laboratory in the early 1920s. Naming it the Electric Dog, they designed a three wheeled cart fashioned from the frame of a child's tricycle that followed a person while carrying a light. This UGV's control system was a significant

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[84] Finkelstein and Shaker, 9.

[85] Robert T. Rhode, "Ingenious Applications of Steam Power," Farm Collector Magazine, http://www.steamtraction.com/archive/5520/ (accessed February 17, 2008).

technological breakthrough for unmanned control systems.[86] This technology was subsequently developed, however, for use on remotely piloted vehicles and remote controlled naval target ships rather than on ground vehicles. Following World War I, research for unmanned systems came almost to a standstill as defense forces and budgets were slashed.

As World War II began, the first UGVs were wire controlled mine clearing systems developed by the German army. In 1939, the Borgward Company of Bremen developed an 8,000 pound, full tracked, remote controlled vehicle named the B1V. With a hull made of concrete and towing a steel-roller device, the operator would drive it to the last point of safety, dismount, remotely drive the vehicle to the mines, emplace a demolition charge, and then back the B1V away to a safe distance.[87] The Germans improved upon this idea with the design of the much smaller Goliath and the use of it not only for mine clearance but also in offensive roles such as demolition of enemy fortifications and even as an anti-tank mine capability on the Atlantic coast.[88] In 1944, the Germans again improved these models and replaced the B1V and the Goliath with the Springer.[89]

Allied UGV development during World War II was limited to nonexistent. British UGV research focused on an idea centered on the horse's perceived superior mobility. Since mechanized vehicles still had not surpassed the horse's performance in broken terrain, British developers sought to create a mechanized horse. While initial models had limited success,

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[86] Steven M. Shaker and Alan R. Wise, *War Without Men: Robots on the Future Battlefield* (McLean: Pergamon-Brassey's International Defense Publishers, 1988), 15.

[87] Finkelstein and Shaker, 15 and Shaker and Wise, 15.

[88] Shaker and Wise, 16. The Goliath looked like a small version of a World War I era tank. With electric motors powered by batteries, the operator used a small hand-held box to transmit driving and firing signals to the vehicle. The vehicle could deliver up to a 132 lb. explosive. A second version powered by a gasoline powered motorcycle engine was also developed and could deliver a 220 lb. explosive. Over 2500 battery operated and over 4500 gasoline powered Goliaths were produced.

[89] Finkelstein and Shaker, 15-16. The Springer was based on a motorcycle half-track, were protected by some armor, and could carry a greater weight of explosives.

funding was cancelled to focus on higher priority research at the time.[90] U.S. unmanned research focused primarily on air platforms that could precisely attack hardened enemy targets that, up until that point, were resistant to bombing. Some aircraft were converted manned airplanes outfitted with cameras and radio control systems. Others, such as the XBQ1 and XBQ2a, were specially made aircraft designed for unmanned employment. Controlled via radio signals and equipped with television cameras, these aircraft transmitted signals back to the operator in order to fly the explosive-laden aircraft into an enemy target.[91]

While most research for unmanned system technology immediately following World War II focused on Unmanned Air Systems (UAS), the U.S. Army did conduct some limited testing looking at their own versions of vehicles with legs. While these walking vehicles had an operator on board, they utilized a lot of robotic technology. Although the system was capable of accomplishing the tasks assigned, the man-machine interface proved complex and exhausting for the operator.[92] This system highlighted the principle that the entire system, starting at the interface, must be considered and not just the system doing the task.

UGV development continued with greater interest in the mid 1980s with the idea of using UGVs for security operations. Initially developed at the Naval Postgraduate School starting in 1980, ROBART I and ROBART II were designed to be platforms to demonstrate technology developments. These were the first platforms to integrate sensors that developed a picture of obstacles in the UGVs environment to aid in navigation decisions.[93] In 1983, Robot Defense Systems (RDS) out of Thornton, Colorado developed the PROWLER (Programmable Robot

[90] Shaker and Wise, 17.

[91] Finkelstein and Shaker, 13-14.

[92] Shaker and Wise, 17-19. and Finkelstein and Shaker, 16-17.

[93] H.R. (Bart) Everett, “A Brief History of Robotics in Physical Security,” Space and Naval Warfare Systems Center, http://www.spawar.navy.mil/robots/land/robart/history.html (accessed February 17, 2009).

Observer With Logical Enemy Response) that eventually achieved the ability to autonomously follow a non-linear fence line as part of a test at Fort Lewis, Washington for the U.S. Army and the Defense Advanced Research Project Agency (DARPA).[94] Research with the Army, Marine Corps, and DARPA continued in the 1980s with tele-operated and autonomous prototypes of M113-size vehicles. In the mid-80s, The U.S. Army Tank and Automotive Command (TACOM) developed the ROBAT (Robotic Obstacle Breaching and Assault Tank), an M60 tank chassis designed to displace Soldiers from dangerous breaching tasks.

Following the earlier PROWLER successes, the Army sought a smaller platform with increased capability in part due to transportability concerns. Focusing on the need for anti-armor capability at the time, the UGV was named the Tele-operated Mobile Antiarmor Platform (TMAP). Congressional language, however, restricted the use of funds for the development and evaluation of new weapons on robotic platforms and the platform was therefore changed to a reconnaissance role and renamed the Tactical Multipurpose Automated Platform. Due to increased interest in UGV research and a desire to eliminate redundancy, a 1988 congressional mandate created the Robotic Systems Joint Project Office, a joint Marine-Army office to coordinate ground robotic platform acquisition efforts.

A renewed focus on UMS across the DoD emerged with Operation DESERT STORM. While UGV usage was limited to a few smaller Emergency Ordnance Disposal (EOD) systems and a system for mine clearing based on an M60 chassis, UMS in the air and on and under the sea also saw increased use. Not only were the platforms more capable in all these domains but the enabling technologies, such as computing and communications systems, were also more mature and proven.[95] The 1990s therefore saw an expansion of research and development programs and

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[94] Ibid.

[95] Finkelstein and Shaker, 20-21.

an increase in confidence of the future potential. The increased technological maturity and recognition of military utility resulted in the 2001 National Defense Authorization Act in which Congress established robust requirements for the DoD UMS development and acquisition.[96]

The Present

Today, UGVs are in combat use by all the services in the DoD. Almost all of the systems in combat are tele-operated through radio controls or a wire sending pictures and other information back to the operator's interface device. The primary use of UGVs in support of operations in Iraq and Afghanistan is for detection, inspection, and neutralization of Improvised Explosive Devices (IEDs). UGVs deployed to Iraq for use in an EOD role started with a handful in 2003, increased to 162 in 2004, and now stands at well over 4,000.[97] Small tele-operated UGVs are also used for short range reconnaissance missions. UGVs such as iRobot's PackBot and ThrowBot and Automatika, Inc.'s Dragon Runner are man-packable, operate on military batteries, and allow the operator to peer around corners and down alleys while not having to needlessly expose a Soldier or Marine. These systems can be outfitted with daylight, low light, or infrared cameras or other sensors to detect chemicals, biological or radiological agents, or explosives. Armed systems such as the Special Weapons Observation Reconnaissance Direct-action System (SWORDS) and Gladiator have also been used in theater in reconnaissance or direct action roles. While SWORDS is still a relatively small system, it is still too large to carry on a Soldier's back. Gladiator, a UGV about the size of a large golf cart, is a system developed for the Marines by BAE Systems and the National Robotics Engineering Consortium at Carnegie Mellon University. It can be outfitted with cameras for reconnaissance and also control lethal and nonlethal systems for direct engagement. Force protection is another function provided by

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[96] National Defense Authorization Act for Fiscal Year 2001.

[97] US Department of Defense, Unmanned Systems Roadmap 2007-2032, 19.

today's UGV programs. The Mobile Detection and Assessment Response System (MDARS) is a system produced by General Dynamics Robotic Systems that is designed to provide fixed site security by autonomously patrolling an area and detecting intruders. MDARS is the first official Army program of record to use autonomous navigation capability to randomly move about a fixed site, detect objects in the vehicle's path, and move around them all the while monitoring the site for broken locks, signs of disturbance, and other intrusions. MDARS has been in operation at Hawthorne Army Depot in Hawthorne, NV since 2004.[98]

The Future…Applying the Theories to Bridge the Gap

The Army desires high levels of autonomy from its future UGVs. These systems must operate in complex environments performing challenging tasks with little interaction from the Soldier-operator.[99] The first versions of these future UGVs are being developed as part of the Army's FCS program and the research and development efforts supporting the FCS program. The programmatic documents and field manuals being produced by the FFID at Fort Bliss, Texas describe FCS unit operations which include the integration of autonomous UMS in manned formations. The Army also envisions that FCS UMS with autonomous capability, once developed, will be part of a spin out to help modernize other types of Brigade Combat Teams (BCTs).

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[98]General Dynamics Robotics Systems, "Mobile Detection Assessment and Response System (MDARS)," http://www.gdrs.com/programs/program.asp?UniqueID=27 (accessed February 17, 2009).

[99] See Section 1: What is the goal?...What is the Army Working Towards?

Establishing Strategic Context, Defining the Problem, Articulating the Strategy

Bridging the gap between the present day, lower level of autonomy and capability on UGVs and the future higher levels requires careful consideration of Army leaders at all levels. High levels of autonomy on ground vehicles present a different dynamic. Displacing (not necessarily replacing) the human farther and farther from the dangers of the battlefield has the potential to produce emergent strategic implications in addition to the tactical advantages. Rosen, Murray, and Millett all emphasize the importance of understanding the strategic context during periods of innovation. As UGVs continue to provide the capability to keep Soldiers out of harms way in Iraq and Afghanistan, Army leaders will continue to ask for this capability and developers will continue to strive to make the systems ever more capable. As technology programs continue to meet and exceed technological goals, government, DoD, and Army leaders will continue to see greater potential and look for ways to leverage these opportunities. A prolonged economic crisis and subsequent budget pressures will continue to put demands on the Army to find ways to get more work done with fewer Soldiers and fewer dollars. Whether the goal is to cover ever increasing amounts of battlespace with the same number of Soldiers, gain access to denied terrain due to political concerns, or lift, move, or manage many heavy items in a warehouse or maintenance area, the promises of autonomy could ostensibly touch all elements of the Army. Government and other senior leadership may see demonstrations or reports of these new systems and form an immediate impression as to their utility and potential. As history has proven, the first impressions of technology and subsequent use can lead to considerable gaps in understanding a new system’s overall impact.

The ethical concerns of autonomous UGVs (and autonomous UMS in general) are a key part of the strategic setting that will shape decisions for development and employment. While some argue that a robot should never be allowed to use lethal force, others see the outcome as inevitable and therefore belies an obligation to set the precedent in a responsible manner. Dr. Ronald Arkin, Regents' Professor and Director of the Mobile Robot Laboratory at Georgia Institute of Technology, was hired by the U.S. Army Research Office to conduct research concerning embedding ethical behavior into autonomous UMS. Dr. Arkin's "research hypothesis is that intelligent robots can behave more ethically in the battlefield than humans currently can."[100] On the other hand, the US Army's chief scientist, Dr. Thomas Killion, stated that "It will be a while before we can give a robot a gun or missile and allow it to operate in an environment without a human" and that lethal engagement will take place with "a human in the loop to make that kind of decision."[101] Dr. Arkin's study indicates that the debate over having a human in the loop is a question of degree or level. "Will it be confirmation prior to the deployment of lethal force for each and every target engagement? Will it be a high-level mission specification, such as "Take that position using whatever force is necessary"?"[102] The DoD already deploys systems, such as the Phalanx system, that can be employed in an autonomous mode to shoot incoming anti-ship missiles or a modified version used in Iraq to shoot incoming mortar rounds. Human operators supervise the system and set the parameters under which they can fire but the system autonomously shoots once those parameters are set. The South Korean Army, likewise, has a robotic platform deployed in the Demilitarized Zone that has the capability of scanning, identifying, and lethally engaging intruders.[103]

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[100] International Herald Tribune, "Robot May be More 'Humane' Soldier," Military.com, http://www.military.com/news/article/robot-may-be-more-humane-soldier.html?col=1186032310810 (accessed November 26, 2008).

[101] Kris Osborn, "Soldier tools of the future," *Army Times*, January 12, 2009.

[102] Ronald C. Arkin, "Governing Lethal Behavior: Embedding Ethics in a Hybrid Deliberative/Reactive Robot Architecture" (Research report for U.S. Army Research Office, Georgia Institute of Technology, 2007), 4.

[103] Arkin, 5.

The idea that autonomous UGVs could be more humane than a Soldier also stirs debate. Arkin's conclusion is based on the idea that autonomous systems will not feel fear, excitement, and other emotions that cause degradations in human judgment. In addition to lacking emotional bias, the sensors and processing capability on UGVs will be ultimately be greater and faster than that of a human under similar conditions. While autonomous systems will not be perfect, Arkin concludes that it is possible to make UGVs act more ethically than humans under similar battlefield conditions.[104]

Tied to the ethical debates in the military, government, and society is the perceived need for precision and the potential for UMS to provide an answer– "one conundrum faced by political leaders today is that there is still a need to use armed force, but interconnectedness and other factors have made it difficult to mobilize and sustain the level of passion and hate necessary for total war. Strategists thus need some way to coerce or punish an enemy elite, or at least disrupt their plans, without the wholesale destruction of infrastructure or killing of noncombatants."[105]

Whatever the answer to these and other ethical questions, they are part of the strategic setting that surrounds the development of autonomous UGVs and must be proactively addressed. In a research monograph concerning the legal and ethical impacts of robots, Colonel Thomas Cowan, Jr. stated that "we cannot allow [the U.S. Army's] development of robotics to be artificially limited by ethical dilemmas that are based on fear and artificial Hollywood portrayals of robots run amok."[106] These questions must be accounted for in the strategic context of the Army's autonomous UGV development and a continued part of the debate and research.

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[104] Ibid., 7-8.

[105] Steven Metz, "The Next Twist of the RMA," Parameters (August 2000), http://www.carlisle.army.mil/usawc/Parameters/00autumn/metz.htm (accessed November 26, 2008).

[106] Thomas H. Cowan, Jr., "A Theoretical, Legal, and Ethical Impact of Robots on Warfare," (master's research project, U.S. Army War College, 2007), 12.

The strategic setting for the Army also includes guidance from the Office of the Secretary of Defense. The Joint Ground Robotics Enterprise (JGRE), under the Undersecretary of Defense for Acquisition, Technology, and Logistics, is responsible for ensuring unmanned ground systems support the DoD's goals of fielding transformational capabilities, establishing joint standards, and controlling costs. As part of this responsibility, the JGRE produced the Unmanned Systems Roadmap (2007-2032) to "provide Defense-wide vision for unmanned systems and related technologies" and "plan for future prioritization and funding of these systems development and technology, thus ensuring an effective return on the Department's investment."[107] While comprehensive and providing a good overview of DoD UMS programs, the Roadmap is primarily a business strategy to minimize investment risk, "prioritize funding", and "reduce acquisition costs."[108] At the DoD level, this document is in line with Rosen's idea being part of an overarching strategy that enables efficiencies and collaboration of various agencies as a matter of policy. Technological risk is also helped as the OSD Roadmap articulates the policy that helps synchronize procurement with research priorities. Where the OSD Roadmap leaves off and what the operational Army must pick up is in determining the impact of autonomous UGVs on warfare, military strategy, and operations – issues that the acquisition and research and development communities can support but not direct.

Once the strategic setting is analyzed, Army leaders must begin to articulate an overall strategy for UGV development. Any overarching strategy must be in line with the already established programs and policies for the integration of all Army modernization efforts. Articulating the threat (which has its own debate given the nature of globalization and ongoing conflicts) is not the only challenge. Development of autonomous UGVs must also consider

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[107] US Department of Defense, Unmanned Systems Roadmap 2007-2032, i.

[108] Ibid., 1.

future allies, partners, and host nation armed forces and citizens. If the U.S. policy and future strategy is based on engagement, it must consider the impacts that autonomous UGVs will have on coalition partners and populations with whom the UGVs will likely interact.

Currently, no single agency within TRADOC is focusing on operational UGV issues. The work at FFID at Fort Bliss is robust but primarily focused on FCS UGV issues and not UGVs in general. The work at FFID is also largely focused on tactical employment issues within the FCS equipped BCT and not on overarching operational or strategic issues. For the Army, both the research and development community and the acquisition community have proponents that coordinate overall UGV issues in the technical and acquisition arenas while the operational aspects, as traditionally covered within TRADOC, do not have a single proponent.

The Army Capabilities Integration Center (ARCIC), as part of TRADOC, has the overall mission to "lead the development and integration of force capabilities across the [spectrum of Doctrine, Organization, Training, Materiel, Leader Development, Personnel, and Facilities (DOTMLPF)] for the Army within a Joint and Multinational environment to support Joint Force Commanders."[109] Lieutenant General Michael A. Vane, the Deputy Commanding General, Futures and Director, ARCIC, understands the challenges associated with assessing trends in global environment and determining threats, U.S. strategy, and looking at the Army's role and approach. Specific to UGVs and the impact of increasing autonomy, he and his staff are working to address the Army's needs during a challenging time of many important, competing priorities.[110] At the time this monograph was being written, ARCIC was exploring options to develop a single UGV proponent similar to the current UAS proponent. This effort should be continued.

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[109] Michael A. Vane, "ARCIC Overview," (lecture to students at the School of Advanced Military Studies, Fort Leavenworth, KS, October 23, 2008).

[110] Vane, interview.

Testing

Rosen and Murray and Millett all agree on the importance of realistic, imaginative wargames, simulations, and experimentation. Developers have a significant challenge in this regard with respect to autonomous UGV operations. Researchers and developers need to make valid conclusions about not only the tactical applicability of autonomous UGVs but also determine potential operational or strategic impacts. To get there, they must base their analysis on simulations that accurately portray autonomous UGV capabilities and Soldier interactions in an operationally relevant environment. While the simulations that units such as FFID use are very good in many respects, the autonomous UGV capabilities are not replicated sufficiently and Soldier interface devices do not represent task load issues realistically. TRADOC's ARCIC realizes these shortcomings with respect to autonomous UGV representation. "The ability to accurately reflect the behavior and capabilities of UMS in our Modeling and Simulations has been a concern to DoD in general. There have been several initiatives in the [Modeling and Simulations] world especially for the constructive simulations to better represent UMS (especially UGV) in our models so we can get a better feel for their contribution to force effectiveness." [111]

This is not a simple problem given the many competing priorities in simulations funding and the evolving nature of UGV capabilities. The danger of not fixing the problem is that emerging doctrine relevant to autonomous systems and the organizations surrounding them potentially based on analysis of unrealistic simulations. Until numerous prototypes of autonomous UGVs can be tested and subsequently operate in field exercises, simulations are a critical component to getting the best answers. To remain at the forefront of the debate and to be confident in the Army's understanding of the second and third order effects of many autonomous

[111] Ibid.

UGVs interacting with Soldiers and other cohabitants in the contemporary operational environment, the Army must prioritize this work.

Culture

The culture of innovation surrounding autonomous UGV development is another critical component to any strategy. While important for UGV development, this dynamic should be part of a greater Army effort to establish conditions that enable developers to think originally and experiment with new ideas. The rapid adjustment of Army leaders and Soldiers at all levels to the challenges of Iraq, Afghanistan, and other problems provides evidence that this dynamic exists. Institutional Army leaders are encouraging innovative thinking in addition to leaders conducting wartime operations. Leaders must be aware that this dynamic exists and take measure to further its growth. One of the great examples of a period of Army history of intellectual growth, study, and debate took place during the development of the AirLand Battle doctrine. This time period was not just about developing the doctrine but resulted in the "inculcation of a tradition of creativity and introspection" and "institutionalizing creativity and conceptual thinking within the Army."[112] Interest in education and the study of doctrine and debate were valued and encouraged. The same should be continued today.[113]

The Army education system is one area that could be improved in order to inform leaders on the potential effects of autonomous systems and further the debate. The Army War College offers an elective attended by only a few students each year that looks at the development of UMS and discusses issues such as autonomy and its potential effects on the future of warfare. Again, this is not an easy issue to resolve as there are many competing priorities for students'

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[112] Metz.

[113] Vane, "ARCIC Overview." ARCIC is leading Professional Discourse Collaboration Groups on Manned-Unmanned Teaming, Fostering a Culture of Adaptability and Innovation, and other topics.

time at all Army education courses. However, as Army technology advances, students must be made aware of the significant changes taking place and think about the tactical, operational, and strategic impacts they will have.

Tied to the professional discourse and outcomes from experiments and testing is ensuring thorough communication. The Bureaucratic Politics Model (BPM) and O'Connell's ideas of the social shaping of technology highlight the need to ensure that influencers and decision makers are informed. A centralized advocate for UGV development could help shape, coordinate, and communicate appropriate messages for various audiences.

O'Connell's work also highlights the importance of Army leaders to remain aware of professional cultural biases for or against the adoption of autonomous UGVs. Communicating accurate, thorough, transparent information enables leaders to form good judgments and work through biases. A study of Army officer attitudes in 2000 and 2002 showed mixed results for acceptance of some of the ideas of Army transformation.[114] While this study looked at Army transformation as a whole, an integral part is the ubiquitous presence and use of UAS and UGVs starting at squad level. A later study sponsored by the Naval War College specifically looked at military officer attitudes toward the adoption of UMS. The study specifically sought "to determine whether there might be latent institutional biases that could serve to impede the future employment of autonomous systems" given the increasing numbers of UMS in Iraq and Afghanistan.[115] Of note, a considerable portion of respondents expressed concern over some aspects of autonomous operations. The authors concluded that "in the area of preprogrammed computer "decisionmaking" in determining how and where to employ lethal force…officers will

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[114] Thomas G. Mahneken and James R. FitzSimonds, "Tread-Heads or Technophiles? Army Officer Attitudes Toward Transformation," *Parameters* (Summer 2004): 70.

[115] James R. FitzSimonds and Thomas G. Mahnken, "Military Officer Attitudes Toward the Adoption of Unmanned Systems: Exploring Institutional Impediments to Innovation," (paper presented at the Annual Meeting of the International Studies Association, San Diego, CA, March 22-25, 2006), 1.

likely insist upon direct communications with unmanned systems for the application of lethal force – with the resulting provision for secure communications pathways between the system and the human controller regardless of distance or enemy actions."[116] While these studies were limited in scope and some results precede significant changes to Army operations tempo and transformation activities, the results provide a glimpse into some of the internal cultural attitudes inside the Army formation that might apply to UGV development.

Risk management

One final area that needs continued consideration to help bridge the gap from today's UGV capability to the future highly autonomous capability is in risk management. The works of both Rosen and McNaugher highlight the need to manage uncertainty when pursuing any innovative effort. Inherent to managing risk in uncertain environments is maintaining flexibility. While TRADOC's ARCIC is working with the Army's research and development community, this is a tough, complex problem. With few actual UGVs for the Army's FFID to experiment with, ARCIC "continues to support flexibility in employment [of UGVs] as our TTPs and uses for these systems evolve."[117] At the time of writing, ARCIC leadership was working with leadership within the Army's Research, Development, and Engineering Command (RDECOM) on a formal agreement partnership for UMS development to help focus science and technology investment based on TRADOC's warfighter needs analysis. This partnership must not be limited to only one element of the RDECOM. To be fully effective, the partnership should align with all members of RDECOM that participate in and enable the development of UMS. Similar to TRADOC's UAS Capability Manager, a proponent for UGV issues would help provide a single,

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[116] Ibid.

[117] Vane, interview.

responsive proponent with whom members of RDECOM's Robotics Integrated Product Team could coordinate activities.

The argument for more accurate simulations that include better replication of autonomous UGVs can function as part of the risk management strategy. Simulations can enhance flexibility by relatively easily changing system capabilities, organizations, and employment methods to provide numerous areas for comparison. Continued inclusion and emphasis on autonomous UGV issues during other exercises such as the War College's annual Unified Quest exercise that, in part, looks at future warfare issues should also be sustained.

With increasing numbers of UGVs being employed in Afghanistan and Iraq, emphasis should be put on ensuring lessons being learned in theater are being captured and analyzed by developers of the Army's future UGVs. In the absence of autonomous UGV prototypes to be used in field experimentation, all avenues of learning should be captured to increase the degree of success with future systems. TRADOC partnership with Special Operations Command's UGV activities, such as the Combat Autonomous Mobility System (CAMS) Joint Capability Technology Demonstration (JCTD) program, must be increased in order to leverage lessons learned in other programs that are bringing mature autonomous UGV technology to the field.

Creating a centralized proponent with TRADOC to work within ARCIC and the Schools and Centers of Excellence is central to coordinating the operational components of the overall autonomous UGV development strategy. The UGV proponent would be critical in maintaining communication and coordination with counterparts in the UGV acquisition and research and development community but also better enable coordination of overall Army UGV operational issues. This proponent could coordinate and over watch most, if not all, of the previously discussed activities to enable organizational learning with respect to autonomous UGVs to help educate and train junior leaders and inform decision makers.

Summary of Recommendations and Conclusion

UGVs are already providing Soldiers a great capability in ongoing operations in Afghanistan and Iraq. The overall impact of unmanned systems on military operations is increasingly visible and viable. From the ability to perform repetitious activities and which allow Soldiers to conduct more meaningful tasks, to enabling Soldiers to conduct monitoring of a contaminated area without exposing their safety, to displacing a Soldier from direct threat when conducting reconnaissance of an alley where armed insurgents seek to ambush friendly forces, UGVs continue to be used by Soldiers in innovative ways. The potential uses and benefits from UGVs will continue to increase.

Increasing levels of autonomy on UGVs will have significant effects across the levels of war that require Army leaders to learn about, think through, and develop solutions for these unsolved issues. UGVs will directly interact with friendly, enemy, and neutral people in the operational environment. The perceptions of Soldiers, the American public and lawmakers, allies, and foreign populations need to be considered as the Army develops autonomous UGVs. These unknown yet highly significant second and third order effects of autonomous UGV employment make this issue a high priority for the Army.

One of the first priorities is to establish clear language around the concepts surrounding autonomy. As the Army continues the discourse of what the long term objectives and vision are or should be, leaders entering the debate must be able to understand one another. The ALFUS definitions provide an effective solution. Developed not only by UMS experts across the DoD, the definitions have applicability across other agencies in the U.S. government. As the military continues to emphasize and increase joint and interagency operations, our language should be developed and accepted by as many members of the joint and interagency organizations as possible.

Another initial priority should be to establish a consolidated proponency for UGVs within TRADOC. This proponent would act as a counterpart to the UGV proponents in the acquisition and research and development communities and help coordinate operational issues across the Army. Working across the DOTLMPF domains, incorporation of autonomy issues into future warfare education would increase awareness, decrease uninformed misconceptions, and add to the professional discourse. A UGV proponent within TRADOC would also help to continue to support and refine ARCICs efforts to analyze the global environment and role of land power in the future with emphasis on how autonomous UGVs will contribute. Ethical issues are one of the most important areas that need focused attention. How adversaries, partner nations, and the U.S. domestic audience will initially perceive autonomous UGVs will significantly impact the way the Army is able to use autonomous UGVs and even UMS in general.

All leaders must continue to support Army efforts to encourage a culture of innovation with specific emphasis on UGV issues where possible. As UGVs are capable of higher levels of autonomy, leaders must keep an open mind to new tactical and operational methods. While Army Soldiers and units at the tactical level are typically quick to adapt on the battlefield, military organizations are often slow to accept change on a larger level. Emphasis on educational issues surrounding autonomy and future technology will bring awareness to potential cultural impediments to change and further add to the discourse by bringing more leaders into the conversation.

The current state of simulations with respect to autonomous UGV operations should be thoroughly assessed and improved. Current simulations do not adequately replicate Soldier interfaces or projected capabilities of the autonomous UGV platforms. Inadequate work load and interface measurements on the Soldier-operator end and poorly replicated UGV capabilities on the other end will cause flawed analysis. Better simulations will also contribute significantly to helping predict operational and strategic effects beyond the immediate tactical employment considerations. Until numerous capable prototypes are available for use in the field, realistic simulations remain an important tool in defining how UGVs can contribute across the spectrum of conflict and in different environments.

While the aforementioned recommendations are some of the most important actions that need consideration, they are by no means without room for improvement or addition. Development of autonomous UGVs is clearly not a simple issue as there are many other important issues all competing for time, attention, and money during an era of rapid change and high operational tempo. The possibility of tighter budgets makes the issue even more complicated. Despite these challenges, Army leadership continues to support autonomous UGV development through a myriad of activities. Due to the significant impact that autonomous UGVs may have within the Army and nation, on international partners, and in the environments in which we will operate, this area warrants extra attention. Using insights from the past and theories for military innovation, Army leadership can gain insight for the conduct of current innovative development. The progress of technology has often been faster than our doctrine and policy development. As challenging as the time, money, and manpower might be to focus on autonomous UGV issues, the potential benefits of autonomy to the nation's Soldiers are too great not to make the investment.

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