Patuxent Policy Group
White Paper

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Consequences of Robotic Progress for Society, Markets and U.S. Defense

Produced by

The Center for the Study of Democracy
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The Patuxent Partnership

CENTER FOR THE STUDY OF DEMOCRACY
... a joint project of St. Mary's College of Maryland and Historic St. Mary's City

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This paper was produced by Dr. Matthew Fehrs and
Dr. Michael J.G. Cain for the Patuxent Policy Group, a
collaboration of The Patuxent Partnership and
the Center for the Study of Democracy.

Consequences of Robotic Progress for Society, Markets and U.S. Defense

Introduction

The Patuxent Policy Group, a collaboration of The Patuxent Partnership and the Center for the Study of Democracy, hosted a group of experts at St. Mary's College of Maryland on March 23rd, 2010 to discuss the future of robotics. The working group, facilitated by Vice Admiral Joe Dyer, (USN, Ret.), President of the Government and Industrial Robots division of the iRobot Corporation, brought together participants with unique talent and experience from academia, industry and government to present their ideas about the implications and future of robotics technology for different sectors of society, including the U.S. military. This white paper organizes and summarizes the main themes that emerged from this policy discussion.

The views expressed in this paper reflect the output of a group discussion and are not intended to represent the views of any particular individual who participated in the working group. The paper was produced by Dr. Matthew Fehrs and Dr. Michael J.G. Cain from St. Mary's College of Maryland. The layout was produced by Alicia Lyons.

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St. Mary's College of Maryland
at Historic St. Mary's City

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Main Findings

1. The rate of technological progress in robotics is outpacing the rate of computing progress, achieving rates of progress that are faster than changes hypothesized by Moore's law. This situation is creating new obstacles for the implementation and integration of robotics technologies within the military, difficulties in bringing new technologies into businesses, and complications for adapting our institutions to absorb the benefits of robotics technology.

2. Military institutions must update their regulations and strategies to reflect the growing importance of robotics while clearly articulating the ways in which robotics will be different from the manned world. While military leaders have embraced robotic technology, innovation is still hampered by regulatory and planning requirements designed for humans (and not robots).

3. Introducing robots into a battle zone exponentially increases the complexity of the interactions robots face: environmental complexity, mission complexity, and the rules governing the interactions with robots in the air, land and sea.

4. While robotic technology may be introduced to serve a specific purpose, once it is employed, people will find new uses for it. Thus, the actual uses for a given product are likely to extend far beyond what is foreseeable at the time it is introduced. This requires additional foresight to envision how robotics may change the military's entire approach on the battlefield, not just how current operations are conducted. In order for this type of innovation to occur, there must be a bridging of two distinct cultures: soldier and technician.

5. Currently it takes at least one person, and often, more than one person, to control a single robot. However, this will change in several areas, and institutions need to plan for transitioning to a state when one person is able to control several robots simultaneously and robots are able to cooperate with one another. Future planning requires achieving robot interoperability over multiple platforms.

6. When the increased situational autonomy of robots is fused with increasing levels of robotic decision-making capacities, we can expect new ethical and legal challenges to emerge. These challenges require future research into the laws and rules governing the integration of robots into our social activities.

7. The role of autonomous robots in war poses significant ethical dilemmas. For example, will robots be vested with autonomous lethal capability or will lethal strikes always require humans involved in any such processes? As robotic autonomy increases, institutions will need to examine more fully and unambiguously determine who or what will be the locus of legal and moral responsibility for unintended harms.

8. As it currently stands, the process of moving technology to the market is too decentralized and uncoordinated. The primary players – academia, industry, and government – need to work together to make a clearer pathway from innovation to market. This will allow the U.S. to build on any comparative advantages it achieves in robotics research.

I. Human-Robot Interaction

This topic generated significant discussion along a number of different axes, but the overriding theme is that more thought needs to be given to the social implications of robotics. First, there was general agreement that a generational change is making robotics more accepted among young service members and young consumers. The popularity and proliferation of video games has made young people much more willing to accept technological change and allows them to feel more comfortable with the notion of remote control or piloting. In addition, years of playing video games and experience in virtual reality settings makes them enthusiastic about robotics and speeds the learning process.

Second, a reciprocal relationship develops between technology users and technology itself. While some technology may be introduced to serve a specific purpose, once it is employed, people will find new uses for it. Thus, the actual uses for a given product are likely to extend far beyond what is foreseeable at the time it is introduced. The final step in this process, and the most difficult one, is when the new technology actually changes how things are done. This requires the foresight to envision how robotics may change the military's entire approach on the battlefield, as opposed to how current operations are conducted. In order for this type of innovation to occur, there must be a bridging of two distinct cultures: soldier and technician.

Not surprisingly, how people are interacting with robots is changing dramatically. Instead of simply viewing robots as tools, robots will become teammates to which soldiers can assign tasks. Eventually, robots will be able to function as more independent units that are increasingly autonomous. It is therefore incorrect to think in terms of humans versus robots, when instead we need to think about how to effectively blend the skills and abilities of each into unified groups who together achieve goals in our society.

The use of robots instead of humans for a particular task can be conceived as existing along a continuum. There will always be some tasks that are best suited to humans, and it is critical for developers constantly to ask and answer the question of why an unmanned craft or unit is superior to a manned one. Those tasks where robots are most likely to be used will tend to cluster around "dirty, dangerous, and dull."

One significant barrier to the use of robotics is fear. For some, fear rests in the unknown or in preconceived ideas provided by Hollywood movies on robots. This may be particularly true for an older generation that views new technology with skepticism. For others, fear comes from the belief that robots will replace them or make their jobs obsolete. Overcoming these cultural and social problems will go a long way towards making the change towards robotics occur more quickly and with less resistance.

II. Unmanned Systems and Robot Autonomy

A significant problem identified by several participants was how to deal with the appropriate level of robot autonomy. Given that the vision for robots is to delegate tasks to them with little human guidance, what issues arise? In general terms, those areas where robots tend to have the highest level of autonomy, such as a car assembly line, are also situations that are highly controlled and lack complexity. On the other hand, introducing robots into a battle zone greatly increases the issues involved: environmental complexity, mission complexity, and how robots will interact with humans.

In particular, having robots operate autonomously means dealing with many different environments: air, land, and water. Further, robots will need to interact with humans while also adapting to inevitable but unanticipated situations. Currently, for many Unmanned Aircraft Systems (UAS), the level of autonomy is restricted by the machine's preprogrammed responses, which are limited to navigation. Today's UAVs are either remotely piloted (e.g., Predator) or assigned only the task of navigating to a point in space (e.g., Tomahawk). New environments will also necessitate examining potential airspace and waterway conflicts and right-of-way issues.

For Naval Air Systems Command (NAVAIR), the Navy's command for full life cycle support of naval aviation aircraft, weapons and systems, the future of robotics includes the research and development, testing and evaluation of multiple autonomous aircraft working in concert, integrating unmanned systems to support ground-sea-air communications and operations.

To the degree that robots are controlled by humans, changes need to be made to increase efficiency. In the current situation, most UASs today have a one-to-one relationship between robot and operator, sometimes more than one if there is a weapons operator. If a manned vehicle is taken as the baseline for comparison, the framework for thinking about the potential benefit of robots should be based on the improvement over this baseline. That means transitioning to a state when one person is able to control several robots simultaneously and robots are able to cooperate with one another.

A related issue is raised by the need for interoperability. To what degree is the control of robots a centralized or diffused system? Further, there exists the need to be able to guide robots from multiple platforms: ships, ground vehicles, and centralized stations.

There are also potentially significant problems related to human operators of robots. The world in which these people live, operating in a battlefield while at work and then returning to normal social interaction in their free time, has the potential to be psychologically taxing. Over time this dichotomous existence, which is at odds with soldiers serving in an actual war zone, will take a toll on operators and needs to be further investigated and studied.

III. From Technology to Products, with the U.S. Military as End User

If the meeting illustrated a particular point, it is that there is a surplus of innovative technology being developed; however, the task of getting this technology from the laboratory to those in the field is non-linear. The problems with the marketplace for this type of technology are significant, and the role of U.S. military purchasing in that market was frequently lamented. While in a previous era the military was a driver of innovation through its purchase of technology, it is no longer a cutting-edge player. In fact, in some areas the technology is so dated that firms do not sell to the military because the technology requested is too old.

As it currently stands, the process of moving technology to the market is a random walk. The primary players – academia, industry, and government – need to work together to make a clearer pathway from innovation to market. At a theoretical level, getting technology to market requires overcoming gaps in the development cycle. The first gap exists between laboratory development (often at a university) and the market. The current method for overcoming this gap is venture capital, but this system is not necessarily efficient. Instead of a rationalized process for moving the best ideas into production, current methods are haphazard. Further, there is a significant amount of lag between a product's invention and when it actually hits the market. The second gap exists once the technology has been introduced, between early adopters and the early majority.

Another hurdle to the introduction of new technology is the lack of skill overlap between researchers developing technology and business executives. The result is that to a significant degree the decision on whether or not to fund an invention is not based on the inherent value of the technology, but rather on the ability of the inventors to show that they have a business plan that will make money. More overlap in training is required: business people spending time in research and development and university researchers immersing themselves in the business world.

Naturally, much of the use of robotics will not occur within the military. In incentivizing the production of new technologies, it should be remembered that many of these technologies will have lucrative applications for consumers. Returning to the issue of what sorts of tasks are best suited for robots, routine or dangerous tasks seem particularly likely for consumer use. Among the notable markets are agriculture, and particularly specialty harvesting and mining and other subterranean uses. Domestically, as societies in Japan, Europe, and the United States age, robots will play an increasingly important role in everyday life and as supplemental caregivers or aides.

There is some disagreement on the nature of the robotics industry and the degree to which it is consolidating or becoming increasingly diverse. Those in the consolidation camp noted that the big players in the market are buying up smaller players, leading to a substantial reduction in potential suppliers. The contrasting view holds that small companies can still be successful by selling their products to larger producers rather than being purchased themselves.

IV. New Regulations and Requirements

The military must update its regulations to reflect the growing importance of robotics and how this will necessarily be different from the manned world. While military leaders have embraced robotic technology, innovation is still hampered by regulations and requirements that were designed for humans and not robots.

Operators of robots form a separate group that needs to receive specialized training. Although these people are piloting aircraft, they are not doing so in the conventional sense. Therefore, it makes sense for them to receive specialized training and adhere to a set of regulations developed with robots in mind. With new training methods should also come novel ways of rewarding operators. Should these operators be compensated at the same level as those who are undertaking the same task in a manned vehicle (i.e., flying a fighter versus flying a UAS)?

Not surprisingly, the default for new technology is to fall back on existing regulations that were developed for old technologies. In many cases these regulations are not only nonsensical, they can be counter-productive. Outmoded regulations may also stifle innovation by preventing the introduction of technology, or preventing it from being used most efficiently. In addition, the lack of new regulations on robotics creates problems for producers who are unsure how to tailor their products to the military's needs. Fixing these problems will come down to the painstaking task of revising requirements and regulations line-by-line, to update them for the introduction of robotic systems.

V. Special Technologies

At a general level, the speed of innovation robotics is exponential. "Red's Law" argues that the rate of progress in robotics is outpacing the rate of progress in computing - faster than Moore's law. Still, there are many existing needs in robotics. One of the most significant is for new technologies in artificial intelligence, sensors, and communication to increase the ability of robots to operate in more complex environments. While UASs may currently only have automated take-off and landing, technological developments will make more processes and responses routine.

Miniature robots offer some unique benefits for potential battlefield deployment. These technologies, drawing on the natural world for inspiration, consist of robotic forms of insects, such as ants or flies. Part of the innovation in this area involves understanding how insects have evolved to deal with the complexity in their environments and then seeking to create technologies that mimic these attributes. These nano-robots use motion sensors to mimic an insect's ability to detect patterns and to understand how they are moving within their environment.

The size of these robots gives them particular advantages for use in surveillance, mapping, or inspection. Such nano-robots could ideally operate in the last 100 yards of a mission, which is most likely to be deadly for soldiers. Still, at this point these technologies are limited in important ways. More research is required to overcome problems with maneuvering, sensitivity to environmental perturbations, and movement in cluttered environments.

VI. Ethics

It is a testament to the increasing significance and relevance of robotic technology that one of the most important areas of future development involves ethics and not technology. In many ways technological innovation has become the 'easy part' of robotics, and the social and ethical issues the 'messy, hard parts.' This discussion remains more open-ended, as the increased employment of robots in both combat and peacetime roles will lead to new scenarios and will raise further ethical questions that require careful investigation.

One basis for laws of robotics comes from Isaac Asimov. The first law states that robots may not injure a human, or through inaction allow humans to be harmed. The second states that robots must obey commands from humans, unless they conflict with the first law. The final law is that robots protect their own existence, except when this conflicts with the first or second laws. Of course, since robots are to be used in combat, the first law would have to be altered. This illustrates the need to think through such issues in much greater detail.

While the image of robots being harmful or even lethal to humans may be more science fiction than fact, increasing levels of robot autonomy do present new ethical challenges. The notion of a completely autonomous robot with weapons is likely to be met with significant resistance on ethical grounds. Therefore, one solution is to ensure that humans are always in control whenever lethal force is applied. While the use of deadly force may constitute a bright line in robot ethics, ethical issues will increase in significance in tandem with higher levels of autonomy.

VII. Suggested Readings

- Office of Secretary of Defense, *FY 2009-2034: Unmanned Systems Integrated Roadmap*
- Peter Singer, *Wired for War: The Robotics Revolution and Conflict in the 21st Century* (New York: Penguin Press HC, 2009)
- Rodney Allen Brooks, *Flesh and Machines: How Robots Will Change Us* (New York: Pantheon Books, 2002)
- Sanjiv Singh & Peter Corke, *Journal of Field Robotics* (Hoboken, NJ: Wiley Periodicals, Inc., A Wiley Company 2010)
- Wendell Wallach Colin Allen, *Moral Machines: Teaching Robots Right from Wrong.* (Oxford University Press, 2008)

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