Backgrounder

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Robotics and the Next Steps for National Security

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Abstract: *When it comes to robotics technology, the future is here. Robots across the world now traverse hazardous terrain, carry out surveillance missions, and perform remote surgery. They are becoming ever more sophisticated and autonomous. Robots easily and safely perform tasks that would otherwise endanger human lives, and do so faster and more efficiently than is possible with conventional methods. Robots are used by private industries and by the federal government. Robots play a vital role in maintaining the competitive edge in national security. This Heritage Foundation analysis explains why it is vital that Congress continue to fund robotics research and development in the U.S.*

Technology does not win wars or make nations safe. The quest for national security is shaped by larger cultural, economic, and political factors and strategic choices. Yet governments always seek out technological innovations that can offer competitive advantages over adversaries. Innovation will always be a national security wild card. New technologies may unleash or accelerate social and cultural changes that affect how nations protect themselves—on the battlefield or behind the scenes.

Over the course of the 20th century, America's genius consisted of its capacity to ride the wave of technological change. That may not be the case in the future. American technological prowess is at risk. Congress will have to play an active role in ensuring that the United States does not lose its competitive edge.

Talking Points

- American technological prowess is at risk. Without technological innovation, the country faces imminent dependence on other nations and a decrease in competitive advantage against adversaries.
- Whether in manufacturing, defense, disaster relief, border security, or medicine, robots can go where humans cannot, and can do what humans cannot—saving time, money, and lives.
- A new legislative framework is needed to encourage robotic innovation—one that is focused on combatant needs, that encourages the development of emerging technologies, as well as a visa system that attracts the best and the brightest foreigners to study and work in the competitive technologies field in the United States.
- Without competitive robotics design and manufacture, America's economy and defense will be in the hands of other countries that have spent the early 21st century developing robot technologies.

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Emerging technologies will have a dramatic impact on the future of U.S. national security. In the short term, these technologies will include possible immunity against biological agents, better cargo and passenger screening at airports and ports, more efficient information-gathering techniques, and better armor for soldiers. In the long term, the sky is the limit. The fields of medicine, homeland security, defense, and manufacturing will be at the center of scientific advances for years to come and perhaps will redefine not only U.S. national security capabilities, but also how Americans conduct their daily lives.

One such technology is robotics. From manufacturing to defense, from surgery to disaster relief, robots can go where humans cannot go, and can do what humans cannot do. The majority of recent technological advancements could not have been accomplished without the help of robots.

While the potential for robotic technology continues to increase, government funding for robotics research in recent years has remained flat or even declined. The effects of the government's decrease in robotics funding are far-reaching, affecting American industry, decreasing technological advancement at universities, and threatening national security. Without advancement in robotics, the U.S. will become dependent on other countries for manufacturing, health care, and ultimately, defense.

Ensuring that America stays at the forefront of technological development in robotics will require a commitment from Congress and the Obama Administration. It will take a legislative framework, focused on combatant needs, that encourages the development of emerging technologies, as well as a visa system that attracts the best and the brightest to study and work within the competitive technology fields in the United States. Given the national security implications of robotics, it is vital that federal agencies efficiently and effectively fund research and development in robotic science and encourage concurrent innovation in the private sector.

Robotics in Brief

The term "robotics" applies to how robots are designed, manufactured, programmed, and used. Robotic technology is not new. In ancient times, Ctesibius, an Alexandrian inventor and mathematician, invented a robotic water organ; 1,500 years later Leonardo da Vinci developed a mechanical knight. With the advent of industrialization, robots have transitioned from entertaining conversation pieces into assembly line necessities. According to the Institute of Electronics and Electrical Engineers (IEEE), the world's robot population had reached 4.49 million in 2008, a number likely to almost double by 2010.[1] While most industrial robots are made in Asia, many military robots are made in the United States.

One of the biggest impacts of robotics on the world economy resulted from automation. "Automation" refers to robots whose actions are dictated by a computer program. Before automation, humans controlled the robots' actions in real time through joysticks and other wired or remote controllers. With the advent of automation, robots like those in factories could run with minimal human presence.

The Current Robotics Landscape in Five Sectors. The potential uses for robotics are as diverse and far-reaching as the robots themselves. While robots have had a considerable impact on multiple aspects of human life, five major or emerging sectors are: (1) manufacturing, (2) defense, (3) disaster preparedness, response, and relief, (4) border security, and (5) medicine.

1. Manufacturing. Manufacturing makes up 14 percent of U.S. gross domestic product (GDP).[2] From cars to computers, from Ritalin to Twinkies, robotics and automation play a part in creating many types of consumer goods. Bottling plants, automotive makers, and appliance manufacturers

1. Erico Guizzo, "10 Stats You Should Know About Robots but Never Bothered Googling Up," Institute of Electronics and Electrical Engineers, March 21, 2008, at *http://spectrum.ieee.org/blog/robotics/robotics-software/automaton/10_stats_you_should_know_about_robots* (November 12, 2009).
2. Nelson D. Schwartz, "Rapid Declines in Manufacturing Spread Global Anxiety," *The New York Times*, March 19, 2009, at *http://www.nytimes.com/2009/03/20/business/worldbusiness/20shrink.html* (November 12, 2009).

have increased the number of industrial robots in their assembly lines. In fact, "a total of 7,172 robots valued at $425.8 million have been ordered by North American manufacturing companies through September [2009]."[3] Robots make manufacturing processes more efficient by making assembly faster and more consistent. [4] Robots can work in unsafe conditions and in tight spaces. They can do heavy lifting, work overtime, and never need workman's compensation. A single software engineer can "retrain" an entire fleet of robotic assembly line workers in a matter of minutes.

The majority of industrial robots are made and used overseas—as more funds go to overseas companies, the capabilities of foreign robotics manufacturers will surpass those of American plants.

Beyond the rote economics, robots are becoming a necessary tool in maintaining America's position on the world's innovation stage. The physical size of technological machinery has been shrinking at an amazing rate.[5] Today, the manufacture of many of the world's most innovative technologies and nanotechnologies requires super-human precision.[6] The steadiest of human hands cannot consistently place one molecule of carbon on another to create a synthetic diamond,[7] or correctly place a microscopic electrode onto a Micro-Electro-Mechanical Systems (MEMS) device.[8] Manufacturing top-level new technologies often requires automation, and automation requires robotics engineers.

The majority of industrial robots are made and used overseas. As more funds go to these overseas companies, the capabilities of foreign robotics manufacturers will surpass those of American plants. Without the ability to design, engineer, and create robots domestically, the U.S. will become increasingly dependent on foreign manufacturing for both current and future products. The U.S. must retain leading-edge robotics manufacturing capabilities in order to maintain a technological advantage in weapon systems, reconnaissance technologies, and other national security products. If current trends continue, the U.S. will be forced to outsource the majority of its manufacturing, thereby giving economic resources and top-notch design plans to the very countries that threaten its national security.

2. Defense. The impact of robots on national security does not stop at manufacturing. Many of the most advanced U.S. defense technologies are robots. Thousands of robots are deployed in Iraq and Afghanistan supporting military operations on land, sea, and in the air. Some robotic military technology is completely autonomous.[9] Intelligence-gathering is often achieved by unmanned aerial, ground, or underwater vehicles. Unmanned autonomous vehicles have been deployed for reconnais-

3. Robotics Industry Association, "Robot Orders Down 30% Through September," November 11, 2009, at *http://www.robotics.org/content-detail.cfm/Industrial-Robotics-News/Robot-Orders-Down-30-Through-September/content_id/1842* (November 20, 2009).
4. RobotWorx, "Robotic Assembly Automation," Robots.com, at *http://www.robots.com/applications.php?app=robotic+assembly* (November 12, 2009).
5. For the past half-century, the size of technologies has been shrinking exponentially. Since the 1958 invention of the integrated circuit, the number of transistors that can be placed inexpensively on an integrated circuit has doubled approximately every two years. This exponential reduction in size of technology is referred to as Moore's Law.
6. Nanotechnologies involve structures of 100 nanometers (100 x 10^-9 m) or smaller and the development of materials or devices within that space.
7. Freitas R. Merkle, "Theoretical Analysis of a Carbon-Carbon Dimer Placement Tool for Diamond Mechanosynthesis," presented at the 10th Foresight Conference on Molecular Nanotechnology, October 10, 2002.
8. MEMS are devices that are less than 1 mm in size. Examples of devices using MEMS technology: inkjet printers (which use the MEMS to deposit ink on paper) and Nintendo Wii's game controller (shaking the controller gets Mario to move forward due to a MEMS-enabled accelerometer).
9. While there are many benefits to unmanned autonomous vehicles, the technology is relatively new. Unmanned autonomous vehicles cannot sense objects in their path, and are therefore likely to collide with commercial airplanes or flocks of birds.

sance (such as detecting anti-ship mines in littoral waters),[10] monitoring coastal waters for adversaries (like pirate ships),[11] and precision air strikes on evasive targets.[12]

Some of the most exciting military technologies center on robots working in concert with humans. Boston Dynamic's robotic Big Dog (a remote-controlled robot that looks like a big dog) enables soldiers to transport heavy equipment over ice, heavily forested areas, and steep, narrow foothills. Robot-powered exoskeletons give soldiers super-human strength.[13] Remote-controlled explosive-disposal robots, such as Talon, keep soldiers from physical danger while the robots destroy mines.[14] Andros II and Mini-Andros are used by bomb squads across the country; they can see in the dark, and defuse or detonate bombs without risking human life.[15]

Advancements in military robotics have been adapted for commercial use and vice versa. DEKA and other companies make commercial robotics products like the Segway, which the military adapts for combat use.[16] Another company, iRobot, made military robots such as the PackBot and transformed the technology into a consumer good (the Roomba, a robotic vacuum).[17]

As robotics technology continues to advance, the military–industrial partnership should be maintained and encouraged through legislative, policy, and organizational innovations to ensure that top-level robotics continue to be applied to national defense. To maintain world class military technology, the federal government must continue to invest in these technologies in accordance with combatant needs. As the population of other countries increases (China's population now outnumbers the U.S.'s 5 to 1), the U.S. may not have enough sheer manpower to defend itself. While robotics are not a panacea for all situations where manpower is necessary, they are a vital tool in America's military prowess.

3. Disaster Preparedness, Response, and Relief. Disaster preparedness, response, and relief are vital elements of homeland security, and robotic technologies are some of the most innovative and effective means of carrying out these activities. In the event of a national disaster, roads may be in rubble or flooded. Telephone or Internet lines may be down. Supplies and equipment may need to be transported quickly over non-traversable terrain.

Small autonomous unmanned aerial vehicles (UAVs) are robots that can be used to carry supplies to remote areas. Denel Dynamics has developed a "homing pigeon" UAV that can fly supplies to a disaster area, drop them off, and return to home base all without human intervention, and faster than conventional carriers.[18] UAVs could also deliver anti-venom to snakebite victims in remote places faster than conventional methods. In the event of a bio-terrorist attack, these UAVs could

10. Blue Fin Robotics, "Bluefin-21 BPAUV," at *http://www.bluefinrobotics.com/bluefin_21bpauv.htm* (November 12, 2009).
11. Monica Heger, "Technology vs. Pirates: Unmanned Aircraft may be the best bet to fight Somalian piracy," Institute of Electronics and Electrical Engineers, February 2009, at *http://www.spectrum.ieee.org/feb09/7369* (November 12, 2009).
12. The Predator is an example of unmanned aircraft. It was recently used by the U.S. Air Force in Afghanistan to locate high-priority targets for air strikes.
13. Will Knight, "New Exoskeleton Lightens the Load," NewScientist, September 20, 2007, at *http://www.newscientist.com/blog/technology/2007/09/exoskeleton-lightens-load.html* (November 12, 2009).
14. Candice Lombardi, "A Talon for land mines and heavy debris," CNET News, December 10, 2008, at *http://news.cnet.com/8301-17912_3-10120147-72.html* (November 12, 2009).
15. Northrop Grumman, "Products," at *http://www.ms.northropgrumman.com/Remotec/products.htm* (November 12, 2009).
16. Michael Regan, "Military Wants to Transform Segway Scooters into Robots," Associated Press, December 2, 2003, at *http://www.seattlepi.com/business/150662_segway02.html* (November 12, 2009).
17. The PackBot is a deployable backpack robot that can clear caves and bunkers, search buildings, and cross live anti-personnel minefields.
18. Flora Graham, "Robot spyplanes get new role as medical couriers," NewScientist, September 12, 2008, at *http://www.newscientist.com/article/dn14718-robot-spyplanes-get-new-role-as-medical-couriers.html?feedId=online-news_rss20* (November 12, 2009).

deliver face masks or antidotes without risking a pilot's health.

UAVs could also be used to create self-contained communications networks. If a disaster destroys Internet or phone connections, communication among rescue workers is at risk. Currently, satellite communication networks are used, but weather and other conditions, particularly after a large explosion, could render current technology useless. The Laboratory of Intelligent Systems at the Swiss Institute of Technology in Lausanne (EPFL) has designed a Swarm of Micro Air Vehicles capable of autonomously establishing an emergency wireless network between ground users in a disaster area. These robots could replace damaged and congested networks.[19] The advantage of the robotic disaster-relief technologies is that they can be built ahead of time, and be deployed only if they are needed. While an adversary could plan to knock out, say, satellites, it would be much more difficult to destroy un-deployed response robots, especially if their storage location is classified.

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After an earthquake, missile attack, or tsunami, robot-assisted rescue may be America's most effective course of action. Robots can venture into areas that are unsafe for humans. Robug III, designed after the Chernobyl nuclear-reactor accident, can explore areas where extreme radiation levels would kill a human being.[20] Researchers at Japan's Tohoku University have developed the camera-carrying Snakebot, a robot capable of "slithering" on its own over and through earthquake rubble. Snakebot can quickly locate trapped victims, sending images of them to rescuers in real time without unnecessarily putting responders at risk.[21]

4. Medicine. While robot-assisted disaster relief is relatively new, robot-assisted surgery has been occurring for more than a quarter of a century.[22] Since the 1980s, robots have been assisting doctors in repairing knee ligaments, removing gallbladders, and performing hysterectomies. With the help of better and smaller robotic tools and software systems,[23] patients require smaller incision wounds and shorter time under anesthesia than with conventional surgery, which translates into faster healing times, less pain, decreased risk of infection, and less blood loss.[24]

Beyond making surgery safer and more accurate, robots are increasing the number of people with access to top medical care. In remote surgery, or telesurgery, a doctor controls a robot that works on a patient—even if that patient is thousands of miles away. With remote surgery, city doctors can operate on rural patients, decreasing transportation costs and increasing options for both patients and doctors.[25]

In the current surgical world, the majority of doctors are limited to a geographic location and

19. The SMAVNET Project, "Swarming Micro Air Vehicle Networks for Communications Relay," at *http://lis.epfl.ch/?content=research/projects/SwarmingMAVs/* (November 12, 2009).
20. B. L. Luk *et al.*, "Robug III: a Tele-Operated Climbing and Walking Robot," proceedings of the UKACC International Conference on Control 1996 (Conf. Publ. No. 427), Vol. 1 (September 1996), pp. 347–352.
21. Val Wang, "Send in the Rescue Robots: Testing emergency-response robots in Disaster City, Texas," *Popular Science*, May 5, 2009, at *http://www.popsci.com/scitech/article/2009-05/send-rescue-robots* (November 12, 2009).
22. Yik San Kwoh *et al.*, "A Robot with Improved Absolute Positioning Accuracy for CT Guided Stereotactic Brain Surgery," IEEE *Transactions on Biomedical Engineering*, Vol. 35 (1988), pp. 153–161.
23. Providing three-dimensional views, robot-assisted surgical software can improve the surgeon's depth perception views. Laproscopic techniques provide only two-dimensional views.
24. Robotics allow motion-scaling: large, imprecise motions can be scaled down to small, precise motions providing surgeons with increased accuracy in tight spaces. One inch of movement on the part of the surgeon can translate to an eighth-inch movement on the part of the robot. Moreover, the surgical field can be magnified so that 1mm arteries can be enlarged to appear as large as drinking straws.

population. As a result they need to be able to perform a broad range of services. If, for instance, the world's best clubbed-foot specialist lived in Dallas, the number of people in the Dallas-area born with clubbed feet every year could not keep that doctor busy full-time because the birth defect is quite rare (1 in 1,000 live births). With remote surgery, a doctor could theoretically serve as the clubbed-foot specialist for the entire South, becoming a "super-specialist" for clubbed-foot surgery.

In the U.S., many states have begun to report doctor and dentist shortages, especially in rural areas. Remote robotic-assisted surgery would mitigate or even solve this problem: Not only would it bring medical access to people in rural areas, it could also be useful for new doctors who currently must choose between location and specialty. Moreover, in the event of a bio-terrorist attack or an epidemic, immune robotic medical personnel may be the best solution to contain and cure infected individuals.

In military medical care, remote surgery can help provide soldiers with medical care more quickly than under current conditions. Modified tanks could house remote operating rooms. These tanks could accompany soldiers into battlefields. Soldiers often lose their limbs or even their lives because it simply takes too much time until they reach a medic or hospital. With telesurgery, a medic could perform a life-saving operation on a remote injured soldier. Moreover, fewer medics would be required in the field, since a single medic could perform surgeries on soldiers from geographically disparate platoons.

The Food and Drug Administration and other health-related agencies should work with medical professionals and policy experts to promote scientific exchange and revolutionize the health care industry through robot-assisted surgery. Congress and the Administration should ensure that product development of other robot-assistance devices in the medical field, such as robotic prosthesis, remains competitive on a world stage.

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5. Border Security. Robots have the potential to serve as excellent border security devices. Robots can be transformed into light, adaptable, and cost-friendly technology for a whole host of security functions. A robotic "ferret" has been developed for airports and seaports, which can detect tiny particles of dangerous substances in cargo containers. [26]

Robots are even being deployed on the southwest border to investigate tunnels used to smuggle illegal immigrants, drugs, and weapons into the U.S. Robots like the Talon and PackBot are able to traverse these tunnels even if communication with controllers is lost, thereby removing the risk of booby traps for agents. Such success was recently experienced when U.S. Customs and Border Protection and the Idaho National Laboratory, an applied-engineering laboratory that aims to develop new energy and national security systems, sent a Talon into an old 50-foot-long tunnel.[27] Despite mud, water, and loss of communication, the Talon was able to traverse the tunnel and return mapping information, as well as chemical and gas levels.

UAVs can also be used for border security measures. With more than 700 miles of border between the U.S. and Mexico, the manpower simply does not exist to provide continuous border surveillance without the use of robot technologies. UAVs can fly between the ports of entry (POEs) that are used by illegal immigrants and for smuggling. UAVs can patrol the border for at least 30 hours without refueling; helicopters average two hours.[28] This

25. One example was "Operation Lindburgh," when a doctor in New York removed the gallbladder of a patient in France. Jacques Marescaux *et al.*, "Transatlantic Robot-Assisted Telesurgery," *Nature*, Vol. 413 (September 27, 2009), pp. 379–380.
26. Press release, "Robotic Ferret Will Detect Hidden Drugs and Weapons," Engineering and Physical Sciences Research Council, June 12, 2009, at *http://www.epsrc.ac.uk/PressReleases/robotferret.htm* (November 12, 2009).
27. Kortny Rolston, "Using Smart Robots to Navigate Smugglers' Tunnels," Idaho National Laboratory, at *https://inlportal.inl.gov/portal/server.pt?open=514&objID=1269&mode=2&featurestory=DA_325880* (November 12, 2009).

robotics technology is also capable of tracking movement by means of thermal-detection sensors in densely wooded areas and mountainous regions that helicopters and foot patrolmen may not be able to reach.

The Robotics Future

The opportunities to use robotics to further the safety and security of the United States are many. Without competitive robotics design and manufacture, America's economy and defense will be in the hands of other countries that have spent the early 21st century developing robot technologies. Tomorrow's products will be made by today's robots. The U.S. government and industry must work together to keep America competitive with foreign robotics capabilities. Congress and the Obama Administration should:

- **Establish a Framework for National Security Research and Development.** Congress should establish a framework that will facilitate national security research and development programs and that will address concerns about risks to humans with legislative guidelines for liability and safety issues in research, development, and procurement.
- **Facilitate Interagency Coordination.** Currently, each military service prefers separately managed programs geared to its individual needs. The Government Accountability Office (GAO) concluded that the military could save money and resources by combining the services' 13 UAV programs. The GAO cited the Fire Scout UAV program as an example of interagency coordination. The Army and Navy are pursuing common components under a Navy contract, saving an estimated $200 million in research and development costs.

  The Department of Defense should accelerate this type of cooperation, promoting common configurations, harmonizing performance requirements, and drawing on common testing, evaluation, and support. Cooperation should extend to the Department of Homeland Security, supporting the UAV requirements of the Coast Guard and the Customs and Border Protection.
- **Support the Continuance and Expansion of the SAFETY Act.** Robotics has no future without further innovation. Unfortunately, post-9/11 liability fears have made many companies reluctant to pursue technological development for national security. Therefore, the protections offered by the Support Anti-terrorism by Fostering Effective Technologies (SAFETY) Act are key. Congress passed the act in 2002 to lower the liability risk to manufacturers, distributors, and providers of "qualified anti-terrorism technologies." Since then, approximately 200 companies have obtained certification under the program. The third-party liability protections of the SAFETY Act can help ensure that companies are willing to continue progress on robotics technologies to be deployed in national security.
- **Continue Funding Robotics Research**. Congress should continue to fund robotics research, development, and procurement. The success of robots on the battlefield merits the resources necessary to meet the Pentagon's goal of replacing one-third of its armed vehicles and weaponry with robots by 2015.[29] Furthermore, homeland security science and technology funds should be used to advance robotics research for disaster response and border security.
- **Increase Brainpower**. Many of the robotics engineers trained in the U.S. are foreign students. The current visa system prevents a sizeable number of these students from staying in the U.S. postgraduation. Visa reform should be enacted to allow more H1-B visas for robotics engineers, especially for those trained in U.S. universities. Currently, the law permits only 65,000 H-1B visas to be granted each fiscal year. If top robotics engineers cannot stay in or even come to the U.S., they will be forced to seek work helping other govern-

28. Christopher Bolkcom and Blas Nuñez-Neto, "Homeland Security: Unmanned Aerial Vehicles and Border Surveillance," *CRS Report for Congress*, May 13, 2009, at *http://assets.opencrs.com/rpts/RS21698_20080513.pdf* (November 12, 2009).
29. "Robot Wars," *The Economist*, April 17, 2007, at *http://www.economist.com/science/tq/displaystory.cfm?story_id=9028041* (November 19, 2007).

ments and foreign industries—using their skills to compete directly against America. The U.S. should increase H-1B availability in order to encourage foreigners educated in science, technology, engineering, and math (STEM) to work in America. Congress must also promote STEM skills at home starting at the K–12 level. This will require drastic educational reforms that improve student learning on a state and local basis such as school choice, charter schools, emphasizing teacher quality, ending social promotion, and changes in how teachers are hired and compensated. This will also require school systems to reach out to industry professionals in order to educate students in robotics and automation.

America's capability to seize and maintain a strategic advantage in robotic development and applications cannot be sustained without a firm commitment from the Administration and Congress. Congress should provide adequate funding, promote increased coordination, and craft policies that encourage prudent investment in robotic technology for the government as well as the private sector. The country's safety depends on it.

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