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Accelerating U.S. Robotics for American Prosperity and Security

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OVERVIEW

Robotics is driving the world forward in ways previously unimaginable. In the past decade, advances in robotic tools have enabled less invasive surgical procedures, exploration robots have enhanced human presence in planetary systems, robotic vehicles have autonomously driven millions of miles, and manufacturing robotics have positioned the United States as a leader in advanced manufacturing. The benefits of automation, however, do not come without their challenges. According to a recent study by the McKinsey Global Institute, 30 percent of responsibilities in 60 percent of jobs have the potential to be automated—that's 18 percent of all work. But the same study states that even as jobs become automated, worker demand is likely to grow as new occupations develop alongside the new technologies. Recent advancements in sensing, computational intelligence, and big data analytics have also been rapidly transforming and revolutionizing the manufacturing industry towards robot-rich and digitally connected factories, including efficient and safe coordination between human and robots on the factory floor. The U.S. Federal government has an important role to play in this transition by preparing and equipping society for these new jobs and embracing the benefits that will come with integrated robotics.

The Federal government has a vested interest in the future of the U.S. robotics industry as it will greatly affect the overall U.S. economy, our global competitiveness, and our military capabilities. It is imperative that the U.S. establish policies to encourage growth in the domestic robotics sector so that our technological capabilities do not fall behind those of other nations. This includes making investments in programs that support basic and applied robotics research and development (R&D) and the integration of robotics into society. The Federal government must also monitor and prepare for workforce changes that will come with automation and invest where necessary to ensure proper workforce transition, including in STEM education, training programs, and re-skilling current workers so they are prepared to meet future workforce needs.

FEDERAL COMMITMENT AND LEADERSHIP

In May of 2018, the White House announced a new Select Committee on Artificial Intelligence (AI) under the National Science and Technology Council and chaired by the White House Office of Science and Technology Policy (OSTP), the National Science Foundation (NSF), and the Defense Advanced Research Projects Agency (DARPA).

> *"The Select Committee will address significant national and international policy matters that cut across agency boundaries and shall provide a formal mechanism for interagency policy coordination and the development of Federal artificial intelligence activities, including those related to autonomous systems, biometric identification, computer vision, human-computer interactions, machine learning, natural language processing, and robotics."*

This announcement shows that the Federal government recognizes an increasing role for robotics technologies across Federal agencies and the private sector as well. American leadership in AI and robotics requires increased emphasis on R&D and workforce development to help ensure the economic prosperity and security of the nation. In considering the future of AI in the United States, the Federal government must invest equally in the development of robotics technologies that enable AI to be more readily utilized in manufacturing and other real world applications. The benefits that come with an AI-integrated society (driverless cars, drones, factory robotics, automated medical procedures, etc.) are all highly dependent on the ability of the robotics technologies to maintain pace with advances in software. Conversely, advances in software are highly dependent on the physical systems that support them. This symbiotic relationship must be maintained to realize the full potential of these new technologies in strengthening the U.S. economy and fortifying the national security supply chain.

> **Recommendation 1**
> Ensure a coherent and holistic approach to robotics R&D, including both the future physical systems and AI technologies.

NATIONAL ROBOTICS INITIATIVE (NRI)

In the past, the U.S. Federal government has relied on the National Robotics Initiative (NRI) to bolster domestic robotics capabilities. The NRI supports fundamental research in the United States that will accelerate the development and ubiquitous use of collaborative robots (co-robots) that work beside or cooperatively with people. The NRI was founded under the Advanced Manufacturing Partnership (AMP) program at the White House Office of Science and Technology Policy (OSTP) in June 2011. Under the program, Federal agencies can choose to invest in projects that meet their individual mission and needs while advancing the U.S.'s overall robotics capabilities. In FY12, NRI invested just under $50 million[i] in R&D, and in FY13, the program saw $38 million in investments across participating agencies. Due to the success of the program, a renewed effort called "NRI 2.0" was established in FY16, promising $225 million in robotics investments. With anticipated funding of $30M-$45M in FY17, NSF funded 27 NRI projects; the United States Department of Agriculture (USDA) funded 3 NRI projects; and the Department of Energy (DOE) funded 0, despite having received many worthy proposals. Agencies made fewer awards than desired because of the budget uncertainties in FY17. In FY18, with anticipated total funding ranging from $25-$35 million, NSF funded 32 NRI projects; USDA funded 5 NRI projects; and DOE again was unable to make any awards due to funding constraints.

While the NRI continues to successfully fund important R&D, the number of worthy projects that can be funded is highly dependent on the volatile appropriations cycle, especially because there is no line item in the Federal budget dedicated to the National Robotics Initiative. Instead, agencies are expected to fund the projects out of existing appropriations, which has led some agencies to disengage, leaving the future of U.S. robotics highly vulnerable. More consistency is needed in current Federal R&D efforts to ensure the U.S. robotics sector continues to grow to meet the needs of the nation. Further, the Federal government must increase its commitment to developing and deploying robotics technologies, and to readying the workforce and society for robotics integration.

[i] *https://www.nsf.gov/news/news_summ.jsp?cntn_id=125390*

Recommendation 2

Commit to growing robotics R&D—including significantly bolstering available funding of the NRI program—to ensure the fundamental research needed for developing robotics capabilities occurs in the United States, and to ensure the U.S. is able to keep pace with the technological advances by competitor nations that have already invested heavily in robotics R&D.

GLOBAL OUTLOOK

While robots were invented in the United States, recent lack of attention and insufficient investment has led to the U.S. falling behind other nations in robotics technology. For the U.S. to regain its position as a global leader in robotics technologies—and in order to achieve the economic and security benefits that result—policymakers must support robust investments in the research and development enterprise, as well as technology integration and deployment efforts.

The International Federation of Robotics [ii] reported that in 2016, 30% of total industrial robot sales were for new installations in China, 14% in the Republic of Korea, 13% in Japan, 11% in the United States, and 7% in Germany. During the same time period, the U.S. GDP was over 1.5 times that of China, 5.3 times that of Germany, 3.7 times that of Japan, and 13.3 times that of Korea. With the U.S. leading the world in GDP, and leading all the aforementioned nations in GDP per capita, it is clear the U.S. has not invested sufficiently to maintain its economic welfare.

The International Federation of Robotics estimates an annual growth rate in industrial robot sales of 14% between 2018 and 2020. Given the forecasted growth in sales in the coming years, governments around the world are increasing their investments in R&D for both existing and potential robotics technologies that support their national interests. In 2015, China announced a $300 billion “Made in China 2025” 10-year plan to invest in China’s advanced manufacturing capabilities and includes robotics as one of its ten key focus areas. In comparison, the United States’ Manufacturing USA program of 14 advanced manufacturing institutes has seen $1 billion of Federal investment with the Advanced Robotics in Manufacturing (ARM) Institute receiving $80 million. [iii]

As far as technological trends are concerned, the International Federation of Robotics outlook for 2019 states that companies will be concentrating on the collaboration of human and machine, simplified applications, and light-weight robots; including two-armed robots, mobile solutions and the integration of robots into existing environments. Likewise, customer demand for industrial robots will be driven by an assortment of factors, such as handling of new materials, energy efficiency, better developed automation concepts, and the connectivity of Industrial Internet of Things.

[ii] *https://ifr.org/ifr-press-releases/news/world-robotics-report-2016*

[iii] *https://www.dodmantech.com/Institutes/Robotics-MII*

Recommendation 3

The U.S. must increase robotics investments to double that of our competitor nations to establish itself as a world leader in robotics technologies. Rarely is there a chance to regain footing in a global technology race, however, the new and advancing field of "smart" robotics—robots backed by artificial intelligence (AI)—has provided the U.S. a unique but waning opportunity to take a leadership position in this emerging field.

NATIONAL ROBOTICS COUNCIL

Creating a National Robotics Council in line with the ideas presented in the Brookings report, "The Case for a Federal Robotics Commission," [iv] would provide great benefits to the Federal government. A National Robotics Council would work to streamline investments across agencies and enable focused efforts in areas of national interest.

The National Robotics Council would be set up in a similar fashion to the President's Council of Advisors on Science and Technology (PCAST) and would serve as an advisory group to policymakers and make recommendations in areas where a deeper understanding of technology is needed. The tasks overseen by this group could include monitoring Federal R&D efforts aimed at solving technology challenges that have far-reaching societal impact, identifying potential hazards of the technology on the wellbeing of society and the economy, and carrying out an overarching national robotics strategy.

Recommendation 4

Form a National Robotics Council to inform and oversee an overarching national robotics strategy and monitor how robotics technologies are impacting society, the economy, and our national security.

ECONOMIC SECURITY: JOBS, AUTOMATION, AND EDUCATION

As automation advances across industries, it is driving a broad range of new job opportunities, from entry-level and blue-collar roles, through professional and high-level positions. These stable, long-term, living-wage positions require employees trained to work with advanced robotic technologies, and the demand for employees with these skills is reaching critical levels. The McKinsey Global Institute suggests that "filling new technical positions is expensive and time-consuming because we have not been turning out enough skilled professionals to keep up with the demand," and suggests we need to adapt our talent strategy and better manage workforce transitions.

While robotics may replace some routine work, it is also true that robotics technology will enhance many of the jobs that exist today. Historically, advances in technology have always ended up creating more jobs than jobs lost, but how smooth that transition is will be determined by our readiness as a country. Therefore, it is vitally important that, in the transition to a robotics-age society, the public sector create opportunities for training and retraining of the existing workforce. Further, increases in automation make high-labor rate countries like the United States more competitive, accelerating the reshoring of manufacturing jobs.

[iv] *https://www.brookings.edu/research/the-case-for-a-federal-robotics-commission/*

In addition to providing training and learning opportunities to current employees and working-age individuals, public policy has a significant role to play in modernizing the educational system to meet the demands of a 21st century workforce. Investments in robotics programs, STEM education, and vocational and community college curriculum will ensure that the U.S. workforce will be ready for the job opportunities that will come with this transformative technology.

> **Recommendation 5**
> Support continuous, broad-based improvements in education that are required for our workforce to stay competitive and fill the jobs of the future.

> **Recommendation 6**
> Monitor the economic impacts of advanced robotics and adapt policies to plan for future shifts in the economy and the job market.

> **Recommendation 7**
> Invest in existing Federal programs engaged in workforce development efforts, such as those underway at the Manufacturing USA Institutes aimed at training an advanced manufacturing workforce able to meet the manufacturing challenges and opportunities that will come with increased automation.

ROBOTICS APPLICATIONS & IMPACT ON SOCIETAL SECTORS

The increased use of robotics technologies across major industrial sectors will lead to massive improvements in quality of life and economic benefits for all U.S. citizens. Introducing innovative robotics technologies will encourage increased productivity at all levels, ensuring the prosperity of the United States and its citizens. Major industrial sectors that will benefit include (but are not limited to):

- Manufacturing and Product Development
- Autonomous Highway Vehicles and Transportation Infrastructure
- Medical and Healthcare
- Agriculture and Food Systems
- National Security, Defense, and the Military

The following sections address each of these sectors in turn, focusing attention on robotics in manufacturing and autonomous vehicles with the understanding that robotics technologies will have significant impact on all these sectors and others as well.

MANUFACTURING AND PRODUCT DEVELOPMENT

The largest application of robotics in the U.S. has been in manufacturing, with a resulting dramatic improvement in productivity and competitiveness. Innovative products are being designed in conjunction with their manufacturing lines so that new kinds of consumer goods can be built efficiently by new machines. These machines are capable of extraordinary mass customizability, which requires advanced robots that are able to adapt to specific tasks, environments, and people (both verbally and non-verbally) with minimal modification to hardware or software. This transformative technology warrants the attention of policymakers as robotics in manufacturing will create opportunities far beyond lowering the cost of production in the United States.

Robots have and will continue to:

- Keep humans from performing dangerous tasks (e.g., drones can perform hazardous inspections and maintenance scans much more quickly and with greater ease, lessening the perils on the American worker).
- Diminish expensive medical problems crippling American workers and the U.S. economy (e.g., robots can be used to preform hazardous work that for humans would lead to carpal tunnel syndrome, back injuries, burns, and the inhalation of noxious gases and vapors).
- Save domestic companies from moving abroad by making them more competitive, and create new jobs without a loss of competitiveness, even though wages are higher.

Now and in the future, current technological innovations are ushering in a new age where robots are intelligent and organized to interact with each other and the humans around them. The widespread use of these new robots will:

- Allow factories to employ human-robot teams that leverage each other's strengths (e.g., humans are better at dealing with unexpected events to keep production lines running while robots are better at performing monotonous tasks requiring precision and often strenuous repeatability).
- Allow humans to perform their jobs more safely, which would likely lead to lower Occupational Safety and Health Administration cases while increasing productivity and reducing the load on the healthcare system (e.g., exoskeletons can be worn by humans so they are able to perform their jobs more quickly and with less physical strain, preventing debilitating injuries).
- Reduce time in the pipeline for finished goods, allowing systems to be more responsive to changes in retail demand.

The benefits listed above can be attained through utilizing technologies pioneered in the U.S. But while other counties are employing these transformative technologies and developing them further, the U.S. hasn't yet seized this opportunity. This has put the U.S. in an unfavorable position where core manufacturing capabilities have been lost,

compromising both our national security and economic welfare. In an effort to combat the weakening of the domestic manufacturing base the Federal government has created Manufacturing USA, a public-private partnership successfully developing advanced manufacturing technologies and capabilities. As previously noted, the Manufacturing USA program is comprised of 14 advanced manufacturing institutes, with one of the institutes specializing in robotics.

Headquartered in Pittsburgh, Pennsylvania, the Advanced Robotics in Manufacturing (ARM) Institute is made up of state and local governments, industry, universities, community colleges, and non-profit organizations from across the country. With the promise of $80 million in Federal funding over five years, the Federal government's investment has catalyzed over $173 million in non-Federal funding from partnering organizations. The Department of Defense even noted that "The substantial cost matching reflects the importance the U.S. robotics community places on this institute and its value to U.S. businesses, academia, and state and local governments." [v]

The ARM Institute aims to improve U.S. competitiveness in manufacturing through advancing robotics manufacturing technologies and by creating a strategy for incorporating these technologies. The Institute places an emphasis on creating a workforce that understands the new technologies being developed and able to fill the new roles the technology yields. The Institute is uniquely equipped to fill the gap that exists between basic research in the robotics field and commercialization as it is able to coalesce stakeholders around common goals. Institute members come together to work on pre-competitive projects that will drive the entire robotics industry forward and achieve the mission of the sponsoring Federal agency, partnerships that would not be possible without the Federal government acting as a neutral convener.

The R&D and workforce development efforts taking place at the ARM Institute are a crucial component for successfully ensuring American leadership in robotics technology.

> **Recommendation 8**
> Continue to fund the Manufacturing USA Institutes and support technology transition from early-stage readiness levels to industrial application and usage.

[v] *https://dod.defense.gov/News/News-Releases/News-Release-View/Article/1049127/dod-announces-award-of-new-advanced-robotics-manufacturing-arm-innovation-hub-i/*

AUTONOMOUS HIGHWAY VEHICLES AND TRANSPORTATION INFRASTRUCTURE

Self-driving robotic vehicles and intelligent highway systems have become part of the national discussion as their benefits range from reducing fatalities to changing the structure of urban mobility. A significant number of technical issues remain, including:

Intelligent highway systems depend on technologists being able to create self-driving robotic vehicles that are suitable for driving on and with traditional road infrastructure. As autonomous vehicles enter our national roadways, there is a need for safe introduction in tandem with the upscaling of our national manufacturing capability so that we have a technical and physical infrastructure that supports and enhances the capabilities of the new robotic technologies.

Safety improvements are already being adopted into today's automobiles, which are yielding great reductions in accident rates (e.g., the adoption of lane departure warnings, impending collision warnings, and parking assist technologies are reducing the number of accidents).

The potential of spin-off technology. As the price curve for vehicle automation drives costs down, other industries—including the defense, agriculture, and mining industries—will reap the benefits of autonomous vehicle-developed technology.

Recommendation 9

The U.S. Department of Transportation should work with states, automobile manufacturers and suppliers, and industry and trade organizations such as ASME to ensure a safe and thorough testing environment for automated components. The U.S. Department of Transportation should lead the effort for open standards for intelligent vehicles. Shared interfaces to maps, to traffic and weather data, to other vehicles and systems, will all accelerate the ability of large and small players to work together.

ADDITIONAL APPLICATIONS

In addition to the above application areas, the Federal government has a key role to play in other areas where robots are having major impact, including:

Medical and Healthcare

The healthcare industry is seeing many advances in patient safety and medical procedures due to the introduction of robotic technologies. Today, robots are used by physicians during orthopedic surgeries, hysterectomy, and prostate surgeries to ensure the procedures are more effective with shorter recovery time for patients. Surgical robots provide a great example of how collaborative robots are revolutionizing the field of medicine. Additional frontiers of medical robotics include:

Exoskeletons for rehabilitation and for helping paralyzed patients, including direct neural interfaces.

Telepresence for remote diagnosis and interventions; providing those needing care in rural and remote regions greater access to medical services.

Robotics assistance for the aging population, which can compensate for the lower number of young people available to care for the elderly.

Robotic-assisted training and manipulation of soft-tissue, as well as in human tissue engineering.

Magnetically-steered microbots for medical procedures (e.g., intraocular surgery).

Agriculture and Food Systems

The agricultural robots market is expected to grow from $2.75 billion in 2016 to $12.80 billion by 2022. [vi] Everything from harvest management and field mapping, to weather tracking and inventory control will benefit from the use of agricultural robotics. Robotics has the potential for transforming many agriculture applications, such as:

Promote the usage of sensor-equipped drones and ground-based robotics for an accurate measurement of the nation's crop yield, water saturation levels, and fertility of the soil. Using sensor technologies in the farming process will yield, tremendous cost-savings, increase crop yield, and proactively fight against diseases within the food chain.

Utilize autonomous robotic technologies to maximize equipment productivity. Technological advances in the agriculture industry has made food 13-times cheaper than it was 100 years ago. By incorporating modern, state-of-the-art robotics technologies into the food supply chain—such as intelligent autonomous systems using GPS signals to plan and control motion in equipment—the U.S. has the potential to see continued savings passed onto the consumers .[vii]

National Security, Defense, and the Military

The Departments of Defense and Homeland Security are considering robotics for a wide range of applications:

Logistics and supply, from unmanned warehouses to semi-automated convoys and aerial resupply.

Reconnaissance, surveillance, and intelligence operations involving observations from remote platforms, such as long-endurance loitering drones.

Hazardous operations, including defusing IEDs.

[vi] *http://www.marketsandmarkets.com/Market-Reports/agricultural-robot-market-173601759.html*

[vii] *https://singularityhub.com/2015/09/21/how-robots-and-sensors-will-transform-transportation-agriculture-and-elder-care/*

Recommendation 10
Just as the ARM Manufacturing USA Institute accelerates the development and deployment of robotics in manufacturing, the Federal government should find other robotics application areas ready for rapid development and should convene public-private partnerships for joint development and training.

Recommendation 11
Federal investments should include emerging robotic application areas that may not be addressed by existing Federal programs, but are of significant importance for U.S. competitiveness and national security.

SUMMARY

Robotics has the potential in the near future to transform every aspect of our society in a positive way, saving time, money, and lives while improving the nation's infrastructure and increasing national and economic security and prosperity. America's free trade partners have out-invested the U.S. in robotics technology and workforce development, requiring the U.S. to respond at scale. This is essential because of the certain penetrating nature of robotics in the near future, ranging from manufacturing robots to autonomous vehicles, and from collaborative robotics working with surgeons to military applications such as drones and bomb-diffusing robots. Robotics has the unique potential to make a high-wage country like the United States competitive with low-wage countries by increasing productivity. The resulting transformation of society promises economic savings and new capabilities that can positively impact the lives of every American.

LIST OF ALL 11 AFOREMENTIONED RECOMMENDATIONS

Federal Commitment and Leadership

Recommendation 1
Ensure a coherent and holistic approach to robotics R&D, including both the future physical systems and AI technologies.

National Robotics Initiative (NRI)

Recommendation 2
Commit to growing robotics R&D—including significantly bolstering available funding of the NRI program—to ensure the fundamental research needed for developing robotics capabilities occurs in the United States, and to ensure the U.S. is able to keep pace with the technological advances by competitor nations that have already invested heavily in robotics R&D.

Global Outlook

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The U.S. must increase robotics investments to double that of our competitor nations to establish itself as a world leader in robotics technologies. Rarely is there a chance to regain footing in a global technology race, however, the new and advancing field of "smart" robotics—robots backed by artificial intelligence (AI)—has provided the U.S. a unique but waning opportunity to take a leadership position in this emerging field.

National Robotics Council

Recommendation 4
Form a National Robotics Council to inform and oversee an overarching national robotics strategy and monitor how robotics technologies are impacting society, the economy, and our national security.

Economic Security: Jobs, Automation, and Education

Recommendation 5
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Autonomous Highway Vehicles and Transportation Infrastructure

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Additional Applications

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