U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON ENERGY AND COMMERCE

September 12, 2016

TO: Members, Subcommittee on Commerce, Manufacturing, and Trade

FROM: Committee Majority Staff

RE: Hearing entitled "The Disrupter Series: Advanced Robotics"

I. INTRODUCTION

On September 14, 2016, at 10:30 a.m. in 2322 Rayburn House Office Building, the Subcommittee on Commerce, Manufacturing, and Trade will hold a hearing entitled "The Disrupter Series: Advanced Robotics."

II. WITNESSES

- Jeff Burnstein, President, Robotic Industries Association;
- Meg Jones, Ph.D., Assistant Professor, Communication, Culture, and Technology, Georgetown University;
- Dean Kamen, Founder, Deka Research;
- Sridhar Kota, Ph.D., Herrick Professor of Engineering, University of Michigan.

III. BACKGROUND

The word "robotics" sparks a range of associations from favorite childhood comic strips and science fiction books to the latest and greatest technology toys at trade shows.[1] The Oxford English Dictionary includes the following definitions of "robot:" "(1) Chiefly *Science Fiction*. An intelligent artificial being typically made of metal and resembling in some way a human or other animal; (2) a machine capable of automatically carrying out a complex series of movements *esp*. one which is programmable."[2]

Bridging the gap between science fiction, the laboratory, and commercially viable applications has been one of the key challenges for inventors, entrepreneurs, businesses, and research institutions. Manufacturing, logistics, healthcare, agriculture, consumer products, medicine, defense, and many other diverse industries stand to benefit from advanced robotics developments.

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[1] *See* "Robots at CES 2016: XYZ Robot", CNet, http://www.cnet.com/pictures/robots-at-ces-2016-pictures/; "Robots at CES 2016: Grill Bot", CNet, http://www.cnet.com/pictures/robots-at-ces-2016-pictures/5/.
[2] http://www.oed.com/view/Entry/166641?rskey=Ka67o8&result=2#eid ("Originally with reference to the mass-produced workers in Karel Capek's play *R.U.R.: Rossum's Universal Robots* (1920).")

This hearing will explore the future of advanced robotics applications, educational initiatives, and how the United States is positioned to leverage these innovations in the future.

A. Commercial Application Development and Research

The range of commercial applications for advanced robotics continues to grow. From personal care robots transforming in-home care for the elderly to prosthetic limbs for disabled veterans there are an endless number of potential commercial and personal examples.[3] Smart robots integrate the power of the Internet of Things, as well as machine learning and artificial intelligence, to power robots that can learn and react to their environment in a way that was not possible only a few years ago.[4]

A consortium of universities published "A Roadmap for U.S. Robotics: From Internet to Robotics" and outlined roadmaps for robots in manufacturing, healthcare, service industries, defense, and space.[5] The summary of findings includes a list of critical capabilities that apply across robotic applications including: 3-D perception, planning and navigation, human-like dexterous manipulation, intuitive human-robot interaction, and safe robot behavior.[6] In manufacturing, the report highlights how robotics have allowed major companies to inshore manufacturing, including Apple, Lenovo, Samsung, and Foxconn.[7] In surgical procedures, the use of robots can reduce complications by eighty percent and reduce recovery time.[8]

An emerging field in robotics is known as "soft robotics."[9] Researchers at the Harvard Biodesign Lab are working on a soft exosuit that assists "with locomotion and perform[s] small levels of assistance to a wearer (such as a soldier) and a glove that assist with grasping motion for those with hand impairment."[10] Moving from Marvel's Iron Man suit with super human abilities to testing a soft material based suit to assist and improve basic function for patients with muscular dystrophy or ALS is the perfect example of how real-world applications in advanced robotics are continuing to move from science fiction to individual's day-to-day lives.[11]

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[3] Care-O-bot® 4 "Making of the new service robot generation" FraunhoferIPA, https://www.youtube.com/watch?v=OwAF8hsO58o&feature=youtu.be; Dean Kamen, "Luke, a new prosthetic arm for soldiers" TED2007, March 2007, https://www.ted.com/talks/dean_kamen_previews_a_new_prosthetic_arm?language=en.
[4] Steve Crowe, "6 Robotics Sights to See at CES 2016," Robotics Trends, http://www.roboticstrends.com/article/6_robotics_sights_to_see_at_ces_2016.
[5] March 20, 2013, https://robotics-vo.us/sites/default/files/2013%20Robotics%20Roadmap-rs.pdf (Universities include Georgia Institute of Technology, Carnegie Mellon University, University of Pennsylvania, University of Southern California, Stanford University, University of California-Berkeley, University of Washington, Massachusetts Institute of Technology.)
[6] *Id*. at 2.
[7] *Id*. at 3.
[8] *Id*.
[9] Nancy S. Giges, "Next-Generation Wearable Medical Robot," ASME.org, October 2015, https://www.asme.org/engineering-topics/articles/bioengineering/nextgeneration-wearable-medical-robot.
[10] *Id*.
[11] *See id.*

Robots have transformed a number of industries from manufacturing, health care, energy, and beyond. The International Federation of Robotics (IFR) reports that global sales of industrial robots rose twelve percent in 2015 to 248,000 units.[12] By 2018, the IFR estimates that 2.3 million robotic units will be deployed worldwide in factories, a fifty percent increase from 2009.[13] The United States saw a three percent increase in sales during that time frame.[14] Sales in South Korea, Japan, China, Germany, and the United States account for seventy five percent of the world's industrial robotics sales.[15] Top industries purchasing industrial robots include the metal industry, the plastics and rubber industry, and the electronics industry.[16]

Major universities across the country have developed robotics centers. For example, Carnegie Mellon is home to the Robotics Institute's National Robotics Engineering Center focused on connecting research and development with commercialization through established proof of concepts and pre-production prototypes.[17] Stanford University is home to the Stanford Robotics Lab where OceanOne, a "bimanual underwater humanoid robot with haptic feedback," completed its maiden voyage in April 2016.[18] Massachusetts Institute of Technology's Biomimetic Robotics Lab is working on the HERMES humanoid robot system,[19] and the Field and Space Robotics Laboratory is working on a sensorless tactile exploration application for oil well mapping and long-life micro fuel cell power-supplies for field sensors.[20] These are only a few examples, but they are illustrative of the breadth and depth of work in the United States dedicated to advanced robotics technologies and applications.

B. Industry Standards

There are a number of industry standards initiatives attempting to provide a common vocabulary, performance testing methods, programming methods, and interoperability requirements for robotics at a basic level. The varying types of applications and industries utilizing robotic technology highlights how important a common language and implementation framework are for widespread adoption.

The International Standard ISO 8373 defines as "robot" as an "automatically controlled, reprogrammable multipurpose manipulator programmable in three or more axes."[21] ISO 13482:2014 "specifies requirements and guidelines for the inherently safe design, protective

[12] IFR Press Release, "World Record: 248,000 industrial robots revolutionizing the global economy." International Federation of Robotics, June 6, 2016, http://www.ifr.org/news/ifr-press-release/world-record-816/.
[13] *Id.*
[14] *Id.*
[15] *Id.*
[16] *Id.*
[17] http://www.nrec.ri.cmu.edu/about/overview/. *See also* "History of the Robotics Institute" Carnegie Mellon University, https://www.ri.cmu.edu/ri_static_content.html?menu_id=247 (Picture of 1981 "Bow Leg Hopper and Thumper" demonstrating the principle of dynamic balance.)
[18] Bjorn Carey, "Maiden voyage of Stanford's humanoid robotic diver recovers treasures from King Louis XIV's wrecked flagship," Stanford News, April 27, 2016, http://news.stanford.edu/2016/04/27/robotic-diver-recovers-treasures/.
[19] http://biomimetics.mit.edu/
[20] http://robots.mit.edu/projects/index.html
[21] "Standardization ISO" International Federation of Robotics, http://www.ifr.org/standardisation/.

measures, and information for use of personal care robots, in particular the following three types of personal care robots: mobile servant robot; physical assistant robot; and personal carrier robot."[22] This standard does not cover flying robots (i.e., drones), industrial robots (covered by ISO 10281), medical device robots, or military robots.[23]

In 2015, the Institute of Electrical and Electronics Engineers (IEEE) Standards Association announced the finalization of a new standard to "capture and convey the knowledge that robots possess."[24] This project is a starting point for "knowledge representation and reasoning in robots, as well as a formal reference vocabulary" to standardize how robots and humans communicate.[25]

C. Select Federal Activity

The National Robotics Initiative (NRI) was launched in 2011 and has a defined goal of accelerating "the development and use of robots in the United States that work beside or cooperatively with people."[26] The NRI is supported by the National Science Foundation (NSF), the National Aeronautics and Space Administration (NASA), the National Institutes of Health (NIH), the U.S. Department of Agriculture (USDA), the U.S. Department of Energy (DOE), and the U.S. Department of Defense (DOD).

The program encourages collaboration among academia, industry, non-profit, and other organizations to create stronger links between "fundamental science and technology development, deployment and use."[27] The program anticipates awarding between twenty-five and seventy grants with anticipated funding between thirty and fifty million dollars per year.[28]

The National Institute of Standards and Technology (NIST) is engaged in an effort to standardize the language and comparison metrics for robotics. In October 2013, NIST launched a Performance Assessment Framework for Robotic Systems and lists the following milestones over the last few years:[29]

- Creating a methodology for assessing human detection and tracking perception systems;
- Standard methodology for evaluating pose determination systems and comparing alternative systems; and,

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[22] http://www.iso.org/iso/catalogue_detail.htm?csnumber=53820
[23] *Id. See also* ISO "Robots and robotic devices" ISO/TC 184/SC 2, http://www.sis.se/popup/iso/isotc184sc2/about_work_objektives.asp.
[24] Mark Bello, "Standard Knowledge for Robots" NIST *Tech Beat*, May 19, 2015, http://www.nist.gov/el/isd/standard-knowledge-robots-051915.cfm.
[25] IEEE Standards Association, 1872-2015 – IEEE Standard Ontologies for Robotics and Automation, http://standards.ieee.org/findstds/standard/1872-2015.html.
[26] National Robotics Initiative (NRI), National Science Foundation, https://www.nsf.gov/funding/pgm_summ.jsp?pims_id=503641.
[27] NRI, Program solicitation, NSF 16-517, p. 2, https://www.nsf.gov/pubs/2016/nsf16517/nsf16517.pdf.
[28] *Id*. at 3.
[29] https://www.nist.gov/programs-projects/performance-assessment-framework-robotic-systems

- Creating performance metrics and benchmarks to advance the state of robotic grasping and demonstrating test methods at IEEE's International Conference on Robotics and Automation 2015.

D. Educational Initiatives

Science, technology, engineering, and math (STEM) education initiatives have gained traction in local, state, and federal levels of government and in schools across the country. At a hearing in the 113th Congress, this Subcommittee received testimony from witnesses about the importance of STEM education for the future workforce in the context of nanotechnology.[30]

There are a number of robotics competitions that have developed across the country to encourage the development of STEM related skills. For example, the Miami-Dade Public Schools Science-Technology-Engineering-Arts-Mathematics (STEAM) resource guide includes a number of different events such as the MINI-URBAN Challenge using LEGO MINDSTORMS kits and the Miami-Dade Youth Fair, which hosts BattleBots and VEX Robotics competitions.[31] The Robotics Education & Competition Foundation hosts a calendar of events for elementary school, middle school, high school, and collegiate competitors.[32] There are even programs designed for children in kindergarten within the FIRST program portfolio that hosts competitions and creates mentorship opportunities for all ages through high school.[33]

IV. ISSUES

The following issues may be examined at the hearing:

- What cutting-edge commercial advanced robotics applications are available today?

- What does the pipeline of talent look like for American companies interested in deploying robotics technology? How will that pipeline of talent impact commerce, manufacturing, and trade in the next five to ten years?

- What are the most significant barriers to investment in advanced robotics? What can be done to promote investment? What barriers exist for transforming basic scientific research on robotics into commercial applications developed here in the United States?

- What are the legal and regulatory hurdles to the further adoption of advanced robotic technologies?

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[30] *See* Dr. Christian Binek testimony, "Nanotechnology: Understanding How Small Solutions Drive Big Innovation" Subcommittee on Commerce, Manufacturing, and Trade, 113th Congress 2nd Session, July 29, 2014, http://docs.house.gov/meetings/IF/IF17/20140729/102566/HMTG-113-IF17-Wstate-BinekC-20140729.pdf at 11; *see also* http://stemchallenge.org/.

[31] "Robotic Competitions" http://stem.dadeschools.net/Initiatives.html.

[32] https://www.robotevents.com/

[33] FIRST, http://www.firstinspires.org/; *see* University of Florida, College of Education, STEM Education Initiatives, https://education.ufl.edu/stem/;

- What technology or best practices are being developed to address safety, cybersecurity, and privacy concerns?

V. STAFF CONTACTS

If you have any questions regarding this hearing, please contact Paul Nagle or Melissa Froelich of the Committee staff at (202) 225-2927.