ARTIFICIAL INTELLIGENCE AND THE FUTURE OF WORK

HEARING

BEFORE THE

SUBCOMMITTEE ON RESEARCH AND TECHNOLOGY

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

HOUSE OF REPRESENTATIVES

ONE HUNDRED SIXTEENTH CONGRESS

FIRST SESSION

SEPTEMBER 24, 2019

Serial No. 116–48

Printed for the use of the Committee on Science, Space, and Technology

Available via the World Wide Web: http://science.house.gov

U.S. GOVERNMENT PUBLISHING OFFICE
37–740PDF WASHINGTON : 2019

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C O N T E N T S

September 24, 2019

ARTIFICIAL INTELLIGENCE AND THE FUTURE OF WORK

TUESDAY, SEPTEMBER 24, 2019

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON RESEARCH AND TECHNOLOGY,
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY,
Washington, D.C.

The Subcommittee met, pursuant to notice, at 4:02 p.m., in room 2318 of the Rayburn House Office Building, Hon. Haley Stevens [Chairwoman of the Subcommittee] presiding.

U.S. HOUSE OF REPRESENTATIVES
SUBCOMMITTEE ON RESEARCH AND TECHNOLOGY
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
HEARING CHARTER

Artificial Intelligence and the Future of Work

Tuesday, September 24, 2019
4:00 p.m.
2318 Rayburn House Office Building

PURPOSE

On Tuesday, September 24, 2019 at 4:00 p.m., the Subcommittee on Research and Technology of the Committee on Science, Space, and Technology will hold a hearing to examine the impact of machine learning and artificial intelligence on the workforce, including issues related to worker displacement, retraining of the current workforce, and developing a skilled technical workforce of the future that can thrive in an economy in which AI increasingly plays a role. The Subcommittee will also explore the disparate impacts on different industry sectors and different populations, as well as issues of safety, privacy, and security relevant to the human-technology interface.

WITNESSES

- **Dr. Arthur Lupia**; Assistant Director, Directorate for Social, Behavioral and Economic Sciences; National Science Foundation
- **Dr. Erik Brynjolfsson**; Schussel Family Professor of Management Science and Director, The MIT Initiative on the Digital Economy; Massachusetts Institute of Technology
- **Ms. Rebekah Kowalski**; Vice President, Manufacturing Services; ManpowerGroup
- **Dr. Sue Ellspermann**; President; Ivy Tech Community College

OVERARCHING QUESTIONS

- How will advances in artificial intelligence (AI) technologies, which includes machine learning (ML), affect work today and in the future? How are the potential workforce impacts of AI different from previous eras of technological advances?
- Will increased use of AI technologies exacerbate existing economic inequalities? If so, how, and what policies or practices may mitigate these impacts?
- What needs exist for retraining the current workforce to be successful in an economy with increased use of AI systems? How can educational institutions adapt their curriculum to prepare the future workforce?

- What are the key research questions to improve understanding of AI impacts on the workforce and to inform evidence-based policies and practices to support a well-trained workforce and minimize unintended consequences?

Background

Previous Technological Disruptions

Today, many Americans are concerned about the impact robots and computers will have on jobs. A recent survey conducted by the Pew Research Center found that 65% of respondents think that robots and computers will definitely or probably take over many jobs currently performed by humans. Additionally, only 25% of respondents believe there would be new, better-paying jobs and only 43% believe that the economy would be more efficient if robots and computers were able to perform much of the work currently done by humans.[1] A 2017 Pew Research Center survey found that most Americans (64%) believe it is likely that people will have a hard time finding things to do with their lives.[2]

Major changes brought about by advances in technology and the fears that accompany them are not unique to the fears surrounding advances in AI technologies. An early example of anxiety related to technological advancement dates to the 19th century. The Luddite movement was born out of a fear among some British textile workers that they would be replaced by machines. In another example, advances in manufacturing allowed for production in greater volumes and with interchangeable parts, greatly reducing the amount of work for skilled artisans such as blacksmiths.[3]

Developments in AI

Rapid advances in computing power and the availability of large data sets have made AI systems increasingly efficient and accurate at tasks such as object and speech recognition, and data analysis. AI systems are also being used to aid in weather predictions[4] and medical diagnoses.[5] Much of the advances in these AI systems stem from advances in machine learning (ML), a type of algorithmic model that "learns" from patterns in input data – often but not always labeled training data - and applies that "knowledge" of such patterns to analyze new data. This self-improvement happens continuously as new data is fed into the system. Machine learning is currently used for numerous applications including photo tagging[6] and email spam filters.[7] A particular subset of machine learning algorithms called deep neural networks (DNNs) have been particularly responsible for increases in the accuracy, speed and applicability of ML systems. Despite recent progress, however, humans are still more effective than computers at a wide array of tasks, particularly those that involve creativity, human connection or physical dexterity.[8]

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[1] https://www.pewresearch.org/global/2018/09/13/in-advanced-and-emerging-economies-alike-worries-about-job-automation/
[2] https://www.pewinternet.org/2017/10/04/americans-attitudes-toward-a-future-in-which-robots-and-computers-can-do-many-human-jobs/
[3] https://www.britannica.com/technology/interchangeable-parts
[4] https://spacenews.com/ai-for-earth-observation-and-numerical-weather-prediction/
[5] https://medicalxpress.com/news/2019-05-artificial-intelligence-lung-cancer-radiologists.html
[6] https://hbr.org/2016/11/what-artificial-intelligence-can-and-cant-do-right-now
[7] https://www.sciencedirect.com/science/article/pii/S2405844018353404
[8] https://www.nap.edu/catalog/24649/information-technology-and-the-us-workforce-where-are-we-and

Workforce Impacts of Machine Learning and Artificial Intelligence

Today, most economists characterize jobs as a collection of individual tasks. In general, all or most of these tasks are performed by the worker, and some subset of tasks are done by technology. Technological advances primarily affect these tasks in three ways. The first of these is substitution. A technology can be substituted for certain tasks that were previously performed by a person. One example of this involves automated teller machines (ATMs). ATMs substituted for bank tellers at performing the specific task of withdrawing cash but did not substitute for the entire occupation.[9]

The second way in which technology can affect tasks is to complement the worker. Continuing with the ATM example, ATMs complemented bank employees by freeing up the time they previously spent distributing cash, allowing them to spend more time on customer service and assisting with individual financial issues, tasks that cannot be performed by an ATM.[10]

Finally, technological advances can create new jobs. ATMs decreased the cost of operating a bank and allowed bank employees to spend more time focusing on customer needs. In turn, this led to an increase in the number of bank branches in the U.S. and in more people being hired to work in banks.[11] Technological advances can also create jobs that previously didn't exist; the invention of MRI imaging, for instance, created the need for MRI technicians, a previously nonexistent occupation.[12]

A recent report released by the Brookings Institution found that artificial intelligence and machine learning systems will have some effect on almost all tasks and occupations, though the nature and degree of impact will vary.[13] The strengths of current AI systems include classification and prediction, tasks that are repeatable, that do not need an explanation for how a decision was made, tasks for which a certain amount of error is acceptable and tasks that do not require a high amount of mobility or dexterity.[14] These systems may predominantly affect some of the low-wage, low-skill jobs with repetitive tasks.[15] One such occupation is customer service, with many companies now using AI-powered chatbots to interact with customers who have questions.[16]

Some high-wage, high-skill jobs could also be affected by AI systems. One prominent example of a high-skill, high-wage field where AI systems could increasingly play a role is medicine.[17] Radiology is one of the fields in which AI systems potentially have the greatest utility, given

[9] https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2690435
[10] https://www.pnas.org/content/116/14/6531
[11] https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2690435
[12] https://www.nap.edu/catalog/24649/information-technology-and-the-us-workforce-where-are-we-and
[13] https://www.brookings.edu/wp-content/uploads/2019/01/2019.01_BrookingsMetro_Automation-AI_Report_Muro-Maxim-Whiton-FINAL-version.pdf
[14] https://science.sciencemag.org/content/358/6370/1530
[15] https://www.brookings.edu/wp-content/uploads/2019/01/2019.01_BrookingsMetro_Automation-AI_Report_Muro-Maxim-Whiton-FINAL-version.pdf
[16] https://www.salesforce.com/products/service-cloud/best-practices/how-ai-changed-customer-service/#
[17] https://www.ahajournals.org/doi/full/10.1161/circulationaha.115.001593

their efficiency in pattern recognition.[18] AI systems can be "trained" using x-ray and MRI images that are known to contain certain pathologies and then used by radiologists to scan new images to help detect those pathologies.[19] Another potential application that takes advantage of the strengths of machine learning is scanning documents to classify them or determine their relevance to a specific project. This could be used by any number of professionals including lawyers[20] or law enforcement professionals.

There are a number of factors that will determine how AI systems affect tasks and jobs and these factors are measured differently in different reports. A 2018 report from The Brookings Institution estimates that approximately 25% of U.S. employment will face high exposure to automation (defined as at least 70% of tasks being automatable) in the coming decades.[21] A 2017 study from the McKinsey Global Institute uses a slightly different metric and says that approximately half of current work tasks could be automated with current technology.[22] It is also difficult to predict what new jobs will be created by increased use of AI systems without knowing how sophisticated a technology will become or what industries it could enable.

An example of this can be seen in autonomous vehicles. While one report indicates that the introduction of autonomous vehicles (AV) could directly eliminate 1.3 to 2.3 million jobs in the next 30 years,[23] it is possible that the introduction of autonomous vehicles will produce more jobs than they eliminate both directly related to AV production and maintenance or in related fields such as infrastructure or city planning. However, it is difficult if not impossible to forecast these effects because it is unknown how quickly the technology will develop or how sophisticated it will become.[24]

Disparate Impacts Across Race/Ethnicity and Income

Because of existing structural inequalities and the related demographic distributions across different job categories, there are concerns about AI exacerbating existing racial and ethnic inequalities. Underrepresented minorities are predicted to face greater impacts from automation than white or Asian populations. A 2018 report by The Brookings Institution assessed that on average, 47 and 44 percent of tasks currently performed by Hispanic and black workers, respectively, have the potential to be automated, compared with 40 and 39 percent for white and Asian populations.[25]

In addition to fears that robots and computers will displace workers, Americans are concerned about the impact this displacement will have on wage inequality. In a 2018 Pew Research Center

[18] https://www.sciencedirect.com/science/article/abs/pii/S1361841512000333
[19] https://medicalxpress.com/news/2019-05-artificial-intelligence-lung-cancer-radiologists.html
[20] https://www.forbes.com/sites/bernardmarr/2018/05/23/how-ai-and-machine-learning-are-transforming-law-firms-and-the-legal-sector/#3f83acc432c3
[21] https://www.brookings.edu/wp-content/uploads/2019/01/2019.01_BrookingsMetro_Automation-AI_Report_Muro-Maxim-Whiton-FINAL-version.pdf
[22] https://www.mckinsey.com/~/media/mckinsey/featured%20insights/Digital%20Disruption/Harnessing%20automation%20for%20a%20future%20that%20works/MGI-A-future-that-works-Full-report.ashx
[23] https://avworkforce.secureenergy.org/wp-content/uploads/2018/06/Groshen-et-al-Report-June-2018-1.pdf
[24] https://www.nap.edu/catalog/24649/information-technology-and-the-us-workforce-where-are-we-and
[25] https://www.brookings.edu/wp-content/uploads/2019/01/2019.01_BrookingsMetro_Automation-AI_Report_Muro-Maxim-Whiton-FINAL-version.pdf

survey, 76% of respondents said they believe inequality will be worse than it is today as a result of job automation.[26] Between 1980 and 2017 real earnings rose among adults with college and post-college degrees while they fell for adults without a college degree.[27] A 2017 report by the National Academies of Science, Engineering and Medicine notes that "New computerized technologies do appear to have contributed to increased income inequality and are likely to continue to do so as long as they replace skills and tasks historically associated with low-wage or middle-wage occupations."[28] Given these effects, it is not surprising that people are apprehensive about the potential effects of AI systems on inequality.

Developing a Skilled Technical Workforce

Experts believe AI systems will not eliminate the need for skilled technical workers. Rather, these systems will change the tasks these workers perform and the skills they need to perform them. Predicting what these new tasks and occupations will consist of is difficult, but experts predict there will be a need for workers who can maintain AI systems and workers who can safely work alongside AI-enabled technologies. A recent report by the National Academies of Sciences, Engineering and Medicine noted that by 2022, there may be a shortage of almost 3.4 million skilled technical workers.[29] The same report notes that "The demand for a skilled technical workforce is changing so rapidly that workers, employers, educators, policy makers and civic organizations need to be highly flexible and forward looking."[30]

Issues of Safety, Privacy and Security

AI systems have the potential to introduce several challenges pertaining to safety, privacy, and security. As robots powered by AI systems are increasingly integrated into workplaces, workers need to be able to work alongside those robots safely and to have confidence in the robot's movements and ability to detect people. The use of collaborative robots, which are designed to work alongside humans, will also require companies to rethink their approach to the safety of their workers. Numerous companies today use AI systems to monitor and analyze their workers. These systems can incorporate cameras and other sensors that watch what workers do or analyze their email and meeting habits. The companies may be gathering these data not in the name of surveillance, but in the name of efficiency and even in the name of worker happiness (e.g. creating workspaces more responsive to worker needs). However, the privacy issues associated with these systems are vast and it can be unclear what rights workers have regarding AI monitoring. The increasing use of AI systems in the workplace also presents security concerns. As with any computer system, there is a risk that the AI systems could be corrupted in a way that potentially harms workers.

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[26] https://www.pewresearch.org/global/2018/09/13/in-advanced-and-emerging-economies-alike-worries-about-job-automation/
[27] https://workofthefuture.mit.edu/sites/default/files/2019-09/WorkoftheFuture_Report_Shaping_Technology_and_Institutions.pdf
[28] https://www.nap.edu/catalog/24649/information-technology-and-the-us-workforce-where-are-we-and
[29] https://www.nap.edu/catalog/23472/building-americas-skilled-technical-workforce
[30] https://www.nap.edu/catalog/23472/building-americas-skilled-technical-workforce

Role of the Federal Government

There are a number of Federal efforts focused on the workforce issues presented by advances in AI. In 2016, NSF Director France Córdova unveiled the 10 Big Ideas for Future NSF Investments that are "meant to define a set of cutting-edge research agendas and processes that are uniquely suited for NSF's broad portfolio of investments, and will require collaborations with industry, private foundations, other agencies, science academies and societies, and universities."[31] One of the 10 Big Ideas is the "Future of Work at the Human-Technology Frontier" which features four research themes: building the human-technology partnership, augmenting human performance, illuminating the socio-technological landscape, and fostering lifelong learning.[32] The Big Idea is also the focus of a Convergence Accelerator track; the track is funded at $30 million in the FY 2020 budget proposal with the intention to raise $20 million from external partnerships.

The 2019 *Executive Order on Maintaining American Leadership in Artificial Intelligence* directs the National Science and Technology Council Select Committee on Artificial Intelligence to provide recommendations to the NSTC Committee on STEM Education "regarding AI-related educational and workforce development considerations that focus on American citizens."[33] The Select Committee will also provide technical expertise to the National Council for the American Worker on "matters regarding AI and the American workforce."[34] The 2019 "National Artificial Intelligence Research and Development Strategic Plan" contains a strategy titled "Develop Effective Methods for Human-AI Collaboration" and a strategy titled "Understand and Address the Ethical, Legal, and Societal Implications of AI."[35] "The Networking & Information Technology Research and Development Program Supplement to the President's FY2020 Budget" also details a key program titled "Promote safe and effective methods for human-AI collaboration" and one titled "Develop methods for designing AI systems that align with ethical, legal and societal goals."[36]

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[31] https://www.nsf.gov/about/congress/reports/nsf_big_ideas.pdf
[32] https://www.nsf.gov/news/special_reports/big_ideas/human_tech.jsp
[33] https://www.whitehouse.gov/presidential-actions/executive-order-maintaining-american-leadership-artificial-intelligence/
[34] https://www.whitehouse.gov/presidential-actions/executive-order-maintaining-american-leadership-artificial-intelligence/
[35] https://www.nitrd.gov/pubs/National-AI-RD-Strategy-2019.pdf
[36] https://www.whitehouse.gov/wp-content/uploads/2019/09/FY2020-NITRD-AI-RD-Budget-September-2019.pdf?utm_campaign=the_algorithm.unpaid.engagement&utm_source=hs_email&utm_medium=email&utm_content=76813461&_hsenc=p2ANqtz-9YwlzM0xzEZXjAp9IJ9TDAORRDSDf0IYgS3XXyApa81aE6sjWrwk4YzCe_bhLX-UPfbbvEUMVDpvOuLLjU69oK8HOj9cBEfUFIz3lak83mNfCXFrs&_hsmi=76813461

Chairwoman STEVENS. This hearing will come to order. Without objection, the Chair is authorized to declare recess at any time. Good afternoon. Welcome, and thank you to our witnesses for joining us here today. We are all looking forward to your testimony. Thank you also for your flexibility with the later start this afternoon. I'd like to take a moment to offer my deepest sympathies to Majority Whip Clyburn on the passing of his beloved wife, Emily. My thoughts are with him and his family during this time of sorrow.

We are here today to examine the role of artificial intelligence in shaping the work of the future. Recent developments in machine learning algorithms, combined with increasing computing power and data generation, have enabled rapid advances in the accuracy, efficiency, and applicability of artificial intelligence (AI) systems. AI systems have already begun to change the nature of work and the workforce. They are being used in manufacturing processes, medical care, and customer service.

As we talk—and we will talk about this—as we talk about job loss that will occur as advanced technology increasingly affects all occupations and wage levels, companies in my district in southeastern Michigan are also telling me how much trouble they are having trying to fill the jobs they have available. A 2017 study by the McKinsey Global Institute found that approximately half of all work activities could be automated by technologies that are already available today, so we need to start having the discussion at a broader level about how available jobs will transform, rather than disappear, as specific tasks are taken over by AI systems, and the workers take on new job roles. The advances enabled by artificial intelligence also have the potential to create new kinds of jobs, and in doing so, elevate the standard of living and quality of life for many.

Sixty-five percent of children entering elementary school today, in the year 2019, will ultimately end up working in completely new job types that currently do not exist. As the integration of these technologies transform work and create new jobs, there will be significant need to ensure we are training workers to succeed at all levels, from the factory floor worker to the radiologist. The key is ensuring that the gains from AI systems are shared by all Americans, increasing the quality of life for everyone. As we discussed at a hearing in this Committee in June, if our Nation leads in the responsible development of AI, we can help set the standards and norms the rest of the world will follow. That applies equally to the use of AI in the workplace.

We are holding this hearing today to discuss what we do know, and also explore what we do not know, and the compelling topic of the future of work has certainly compelled many. Research studies, companies who are organizing and orienting their organizational development, academic institutions, and this very body, are compelled to act. As AI-powered robots become more common, the question we ask is, how do we ensure worker safety alongside these robots? Will artificial intelligence be routinely used to monitor workers, as some companies do today? How do we balance privacy rights with the potential productivity benefits and worker benefits these analyses could provide? How do we keep this data secure, and prevent its malicious use? And finally, how do we get a better understanding of the macroeconomics and labor outlook so that the government, companies, colleges, universities, and workers can all plan for this transition? It's the question hanging above us in this 21st century age. These are just some of the questions the researchers are pursuing.

So I am greatly looking forward to today's hearing, because we are compelled to act, to explore, to develop good policy, to stand up for the value of work, what knowledge and tools, researchers, companies, and workers need going forward, and how Federal science agencies, such as the NSF (National Science Foundation), are helping to lead the way.

Before I recognize Dr. Marshall for an opening statement. Wait, hold on 1 second. We're pausing on an opening statement. OK. Before we move on for opening statements, what I'd like to do at this time is to present for the record a letter from Kelly Services in support of this hearing, and I would also like to submit the executive summary from the 2018 report written by the great Mark Muro, and his team from The Brookings Institution, titled "Automation and Artificial Intelligence: How Machines Are Affecting People and Places", a great read that's recommended by many.

[The prepared statement of Chairwoman Stevens follows:]

Good afternoon, welcome and thank you to our witnesses for joining us here today, I'm looking forward to hearing your testimony. Thank you for your flexibility with the late start today. I'd like to take a moment to offer my deepest sympathies to Majority Whip Clyburn on the passing of his wife; my thoughts are with him and his family during this time of sorrow.

We are here today to examine the role of artificial intelligence in shaping the work of the future. Recent developments in machine learning algorithms, combined with increasing computing power and data generation, have enabled rapid advances in the accuracy, efficiency and applicability of artificial intelligence systems.

AI systems have already begun to change the nature of work and the workforce. They are being used in manufacturing processes, medical care, and customer service.

As we talk about the job loss that will occur as advanced technology increasingly affects all occupations and wage levels, companies in my district are telling me about how much trouble they are having trying to fill the jobs they have available. A 2017 study by the McKinsey Global Institute found that approximately half of all work activities could be automated by technologies that are already available today.

We need to start having the discussion at a broader level about how the types of jobs available will change rather than disappear, as specific tasks are taken over by AI systems and the workers take on new tasks.

The advances enabled by artificial intelligence also have the potential to create new kinds of jobs, and in doing so, elevate the standard of living and quality of life for many. 65% of children entering elementary school today will ultimately end up working in completely new job types that currently do not exist.

As the integration of these technologies changes jobs and creates new jobs, there will be a significant need to ensure we are training workers to succeed at all levels, from the factory floor worker to the radiologist. The key is ensuring that the gains from AI systems are shared by all Americans, increasing the quality of life for everyone. As we discussed at a hearing in this Committee in June, if our Nation leads in the responsible development of AI, we can help set the standards and norms the rest of the world will follow. That applies equally to the use of AI in the workplace.

We are holding this hearing today to discuss what we do know, but the fact is there is a lot we still do not know. As AI-powered robots become more common, how do we ensure worker safety alongside these robots? Will artificial intelligence be routinely used to monitor workers, as some companies do today? How do we balance privacy rights with the potential productivity benefits and worker benefits these analyses could provide? How can we keep this data secure and prevent its malicious use? And finally, how do we get a better understanding of the macroeconomics and labor outlook so that the government, companies, colleges and universities, and workers can all plan for the transition? These are just some of the many questions researchers are pursuing.

I look forward to hearing from today's distinguished panel who will help us understand what we do know now, what knowledge and tools researchers, companies, and workers need going forward, and how Federal science agencies such as NSF are helping to lead the way.

Chairwoman STEVENS. So at this time I would like to introduce our witnesses. Our first witness is Dr. Arthur Lupia. Dr. Lupia is the Assistant Director of the Directorate for Social, Behavioral, and Economic Sciences at the National Science Foundation. He also serves as the Hal R. Varian Collegiate Professor of Political Science at the University of Michigan. Delighted to have you here on behalf of the University of Michigan, as well as the NSF, Dr. Lupia, and you also serve as the co-Chair of the Office and Science and Technology Policy's Subcommittee on Open Science. Dr. Lupia's research focuses on processes, principles, and factors that guide decisionmaking and learning. He earned his bachelor's degree in economics from the University of Rochester, and his social science Ph.D. from the California Institute of Technology, Caltech.

Our next witness is Dr. Erik Brynjolfsson. Dr. Brynjolfsson is the Schussel Family Professor of Management Science and Director of the MIT Initiative on the Digital Economy. His research focuses on the effects of information technologies on business strategy, productivity and performance, digital commerce, and intangible assets. He is the author and co-author of several books, including "The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies." We applaud you for this milestone work that you have published, sir. We are delighted to have you here at this hearing, and we also note that you received your bachelor's and master's degrees in applied mathematics and decision sciences from Harvard University, and a Ph.D. from MIT in managerial economics.

Our third witness is Ms. Rebekah Kowalski. Ms. Kowalski is the Vice President of Manpower Manufacturing, a role she has held since January 2019 throughout her long and remarkable career at ManpowerGroup. Her current portfolio focuses on developing solutions that help organizations and leaders deal with the implications of the shortage of skilled workers, and the evolution of roles and skills. She previously led the team that worked with MXD, a digital manufacturing institute, to identify how roles and skills will evolve as manufacturing changes with the increasing introduction of digital technologies, a truly profound work of primary research that has helped many companies orient and prepare for the future of work. Ms. Kowalski received her B.A. in English from the University of Wisconsin-Parkside.

Our final witness, Dr. Sue Ellspermann, is the President of Ivy Tech Community College of Indiana. Prior to her role at Ivy Tech, Dr. Ellspermann was Indiana's 50th Lieutenant Governor, from 2013 to March 2016. As Vice Chair of the Indiana Career Council, she led efforts to align the State's education and workforce development system to meet the needs of employers, a continued focus for her as President of Ivy Tech. She certainly focuses on the cross-cutting collaboration that is so needed with our training centers and our employers. And Dr. Ellspermann earned her bachelor's of science in industrial engineering from Purdue University, and her master's of science and Ph.D. in industrial engineering from the University of Louisville. Absolutely fabulous.

As our witnesses should know, you will each have 5 minutes for your spoken testimony, and your written testimony will be included in the record for the hearing. When all of you have completed your spoken testimony, we will begin with questions. Members will have 5 minutes to question the panel. And at this time, Dr. Lupia, we'd like to start with your 5-minute testimony. Thank you.

TESTIMONY OF DR. ARTHUR LUPIA, ASSISTANT DIRECTOR, DIRECTORATE FOR SOCIAL, BEHAVIORAL AND ECONOMIC SCIENCES, NATIONAL SCIENCE FOUNDATION

Dr. LUPIA. Thank you. Good afternoon, Chairwoman Stevens, Representative Marshall, and Members of the Subcommittee. My name is Dr. Arthur Lupia. I am the Assistant Director of the Social, Behavioral, and Economic Sciences Directorate at the National Science Foundation. It is a pleasure to be with you this afternoon to discuss how NSF is helping our fellow citizens prepare for the future of work.

Work is a vital and dynamic element of our society. Work powers our offices and our factories. It supports our communities, and our Nation. And as we can all see, work is changing. We know that AI and related technologies can increase national competitiveness by making businesses, governments, and social organizations more competitive and more effective. These technologies can also create many new careers. If these technologies are applied with sufficient foresight, they can create new opportunities for workers, and improve quality of life for communities across the country.

How can we achieve a future where technological change benefits as many people as possible? At the National Science Foundation, we believe that achieving this future requires working together. Our Future of Work at the Human Technology Frontier Program treats future work, future technology, and future workplaces as deeply integrated and intertwined elements of our Nation's work-based ecosystem. In NSF's Future of Work approach, we collect data on worker experiences to inform social and behavioral research on workers and workplaces. This research, in turn, can guide technological development. Work like this can reveal new ways to empower workers, and increase productivity.

Studying workers, workplaces, and technology together are the key to creating benefits that everyone can realize, and pioneering research of this kind is already underway. On the screen is one of the projects NSF has recently supported. This is a human being in an exoskeleton. Today's exoskeletons help human beings transport very large objects, and navigate impossible situations. But this project is about tomorrow's exoskeletons. The device that you see here is not just an exoskeleton of the body. It's an exoskeleton of the mind. This exoskeleton of tomorrow provides information to the worker through an augmented reality system. The system empowers the worker to process information, and make better decisions, with unprecedented speed. This type of technology is awesome, and it'll have impacts far beyond factory floors. Today, for example, the Veterans' Administration is one of the Nation's leading users of exoskeletons. Tomorrow's exoskeletons will open new opportunities for our veterans.

NSF's Future of Work Program supports this technology by incentivizing developers, AI experts, and workplace specialists to collaborate. Working together, researchers and developers can increase performance, decrease injury, expand access, and improve quality of life in ways that just would not be possible if any of these groups worked alone. That's what NSF can do. To date, NSF's Future of Work Big Idea supports projects in a wide range of work contexts, including health care, power grids, farming, learning, scientific research, transportation, emergency response, and, of course, manufacturing.

NSF not only supports fundamental research in these areas, but also supports efforts to bring these big ideas to market. For example, NSF recently unveiled new Future of Work awards from its Convergence Accelerator. NSF's Convergence Accelerator is designed to fund technology-based partnerships that simultaneously advance national priorities and create new opportunities for American workers. For example, a project based at the University of Michigan is examining how to combine research in AI, data science, and industrial psychology to find better ways to link workers with innovative new training and educational opportunities that will help them not only contribute, but thrive, and build amazing careers in their new workplaces.

This is an exciting time for our country, and, like you, NSF is grateful to see our Nation's brightest minds collaborating on the fundamental research that will transform our workplaces, empower our workforce, and provide tremendous new sources of innovation for our Nation. So thank you for having this hearing today, and for the opportunity to testify. I'm happy to answer any questions you may have.

[The prepared statement of Dr. Lupia follows:]

Dr. Arthur Lupia
Assistant Director for Social, Behavioral and Economic Sciences
National Science Foundation

Before the
Subcommittee on Research and Technology
Committee on Science, Space and Technology
United States House of Representatives

on
"Artificial Intelligence and The Future of Work"

September 24, 2019

Introduction

Chairwoman Stevens, Ranking Member Baird, and members of the subcommittee, it is a privilege to be with you today to discuss how the National Science Foundation (NSF) is positioning the United States to continue our strong leadership in the development of new technologies and to also respond to the challenges and opportunities those new technologies present for the future of jobs and work.

Established by the National Science Foundation Act of 1950 (P.L. 81-507), NSF is an independent Federal agency whose mission is "to promote the progress of science; to advance the national health, prosperity, and welfare; to secure the national defense; and for other purposes." NSF is unique in carrying out its mission by supporting fundamental research across all fields of science, technology, engineering and mathematics (STEM) and all levels of STEM education. NSF is also committed to the development of a future-focused science and engineering workforce that draws on the talents of all Americans. NSF accounts for approximately 25 percent of the total Federal budget for basic research conducted at U.S. colleges and universities and has been vital to many discoveries that impact our daily lives and drive the economy. NSF is and will continue to be a respected steward of taxpayer dollars, operating with integrity, openness, and transparency.

A vibrant scientific workforce and breakthrough discoveries enabled in part by NSF investments sustain, accelerate, and transform America's globally preeminent innovation ecosystem. A long-term vision, belief in the promise of fundamental research, and commitment to pursuing risky, yet potentially extraordinary discoveries are the hallmarks of NSF. NSF's investments empower discoverers to ask the questions and develop the technologies that lead to the next big breakthroughs.

NSF Leadership in Artificial Intelligence Research

The landscape of jobs and work is changing at unprecedented speed, enabled by advances in computer and information science and engineering, including data analytics, artificial intelligence (AI), and robotics, together with new conceptions of work and workplaces. This scientific and technological revolution presents a historical opportunity to the Nation through the creation of new industries and occupations, enhanced productivity and quality of life, and the potential for more people to participate in the workforce. However, these changes also bring challenges, such as the possibility of jobs lost to automation and increased demand for workers with higher skills. Other equally important challenges include new security threats, potential for algorithmic biases, and workplace policies and practices that have not kept up with rapid changes in the nature of work.

NSF has a long and rich history of supporting transformative research in AI, machine learning, robotics and data science. NSF also plays an important role in both measuring the STEM workforce through the National Center for Science and Engineering Statistics, as well as growing it through investing in human capital. NSF leadership is helping to drive and coordinate AI research and development efforts across the federal government. The NSF Director co-chairs the National Science and Technology Council's (NSTC) Select Committee on AI, which advises the White House on interagency AI Research and Development (R&D) priorities and establishes structures to improve government planning and coordination. In addition, the NSF Assistant Director for Computer & Information Science & Engineering co-chairs the NSTC Machine Learning and AI Subcommittee and also co-chairs the NSTC Networking and Information Technology Research and Development Subcommittee, both of which serve to coordinate federal R&D investments in AI as well as other related information technology areas. For example, NSF was a key contributor to the *National Artificial Intelligence Research and Development Strategic Plan: 2019 Update* published in June of this year.

NSF also invests significant resources, nearly $450 million in Fiscal Year 2019, in fundamental research, workforce development, and advanced, scalable computing resources that collectively advance AI. Indeed, many of the transformative uses of AI that we are witnessing today are founded in Federal government investments in fundamental AI research that reach back over decades. For example, NSF-funded researchers began working on what is now known as collaborative filtering, pairing AI research with the growth of the Internet in the 1990s. This work fuels the recommender engines on popular websites like Netflix and Amazon and propel a significant proportion of e-commerce activity.

NSF has also launched several special-emphasis programs through various public-private partnerships. The NSF Program on Fairness in Artificial Intelligence in Collaboration with Amazon, will explore building trustworthy AI systems that are readily accepted and deployed to tackle grand challenges facing society. Specific topics of interest include transparency, explainability, accountability, bias, mitigation strategies, validation, and inclusivity. NSF has also joined with the Partnership on AI to understand the social challenges arising from AI technology and enable scientific contributions to overcome them. Within the Federal government, NSF and the Defense Advanced Research Projects Agency have teamed up to explore high-performance, energy-efficient hardware and machine learning architectures that can learn from a continuous stream of new data in real time.

Building the foundations of tomorrow's AI innovations will require new interdisciplinary collaborations, resources, and strategic visions — principles that NSF has championed in its support of fundamental AI research. NSF's ability to bring together numerous fields—including computer and information science and engineering, along with cognitive science and psychology, economics and game theory, knowledge of the physical world, engineering and control theory, ethics, linguistics, mathematics, philosophy—gives the agency a unique role in expanding the frontiers of AI and addressing the challenges of the future.

The Future of Work at the Human Technology Frontier (FW-HTF)

In 2016, the National Science Foundation unveiled a set of "Big Ideas," 10 bold, long-term ideas that identify areas for future investment at the frontiers of science and engineering. The Big Ideas represent opportunities to position our Nation at the cutting edge of global science and engineering leadership by bringing together diverse disciplinary perspectives to support convergence research.

The Future of Work at the Human-Technology Frontier (FW-HTF) Big Idea is one mechanism by which NSF is responding to the challenges and opportunities for the future of jobs and work. The overarching vision is to support convergent research to understand and develop the human-technology partnership, design new technologies to augment human performance, illuminate the emerging socio-technological landscape, understand the risks and benefits of new technologies, understand and influence the impact of artificial intelligence on workers and work, and foster lifelong and pervasive learning.

Specifically, the FW-HTF Big Idea will advance our understanding of how technology and people interact, distribute tasks, cooperate, and complement each other in different specific work contexts. Researchers will advance the knowledge base related to worker education and training and formal and informal learning to enable all potential workers to adapt to changing work environments. We will also advance our understanding of the links between the future of work at the human-technology frontier and the surrounding society, including the intended potential of new technologies and the unintended consequences for workers and the well-being of society.

Achieving these goals requires integration and convergence of disciplines across computer science, engineering, learning sciences, research on education and workforce training, and social, behavioral, and economic sciences. A convergent perspective is essential to understand and shape long-term social and economic drivers, so that advanced technology can empower individuals and strengthen the social fabric. A convergent perspective also informs our Nation about how to develop education and re-skilling opportunities that can confer technology's benefits to all citizens.

In FY 2019, NSF began making the first awards under the FW-HTF Big Idea. One such award at the University of Michigan is investigating how humans and robots work together in construction environments. Despite recent advances in robot functionality, many fundamental questions in human-robot interaction remain unanswered. Another award supports a collaboration among

Purdue University, Indiana University and the Massachusetts Institute of Technology to develop simulations that can help manufacturers design factories where workers thrive.

NSF is also funding research in learning technologies that prepare learners for new opportunities ahead. Our Cyberlearning for Work at the Human-Technology Frontier program examines new ways to help learners of all ages gain the STEM skills that will give them new opportunities in tomorrow's workplaces. As an example, researchers at the University of Washington are working on improving the educational tools available to learners of all ages who are studying coding. By leveraging recent advances in computer science and machine learning, the project will create a new online learning technology that automatically generates more personalized practice content for learners with different backgrounds. These activities can create critical tools to support the gender, racial, ethnic, regional and intellectual diversity of our computing workforce.

The Convergence Accelerator

The NSF Convergence Accelerator is designed to identify areas of research where investment in convergent approaches – those bringing together people from across disciplines, united to solve problems – has the potential to rapidly translate to high-benefit results and advance ideas from concept to deliverables. The Convergence Accelerator complements NSF's basic research support by creating dynamic partnerships that can include stakeholders from industry, foundations, government, nonprofits and other sectors.

On September 10th, NSF announced the first awards through its Convergence Accelerator pilot. Forty-three awards totaling $39 million will support projects across the country that will find new ways to leverage advances from across the sciences and engineering to enhance the lives of American workers. Roughly half those awards are focused on the Future of Work and will address subjects such as predictive AI tools and the educational technologies needed for adult learning.

The Convergence Accelerator awards span a wide range of industries, populations, and partnerships. One award to the University of Central Florida will combine the most recent advances in deep learning, semi-structured interviews, surveys, and work-life journal data analysis in building a hybrid framework to predict the multi-dimensional impact of AI on future jobs in the human resources industry.

These 43 awards are just the first step in funding through the Convergence Accelerator. Over the next six months, teams of researchers will participate in an "Innovation Curriculum" that will help them improve their initial ideas, augment their teams through new partnerships, improve communications, and deliver groundbreaking new advances.

The Role of Social Science Research

Understanding the human and social aspects of changing workplaces and technologies give us the opportunity to use these technologies to improve the quality of work and quality of life for all Americans. From neurons to neighborhoods, and from farms to factories, social and behavioral scientists offer a distinct and valuable form of service to help us understand the human component of the changing nature of work.

In recent years, NSF's Social, Behavioral, and Economic Sciences (SBE) Directorate has led NSF's Future of Work effort and supported related research. A few examples include:

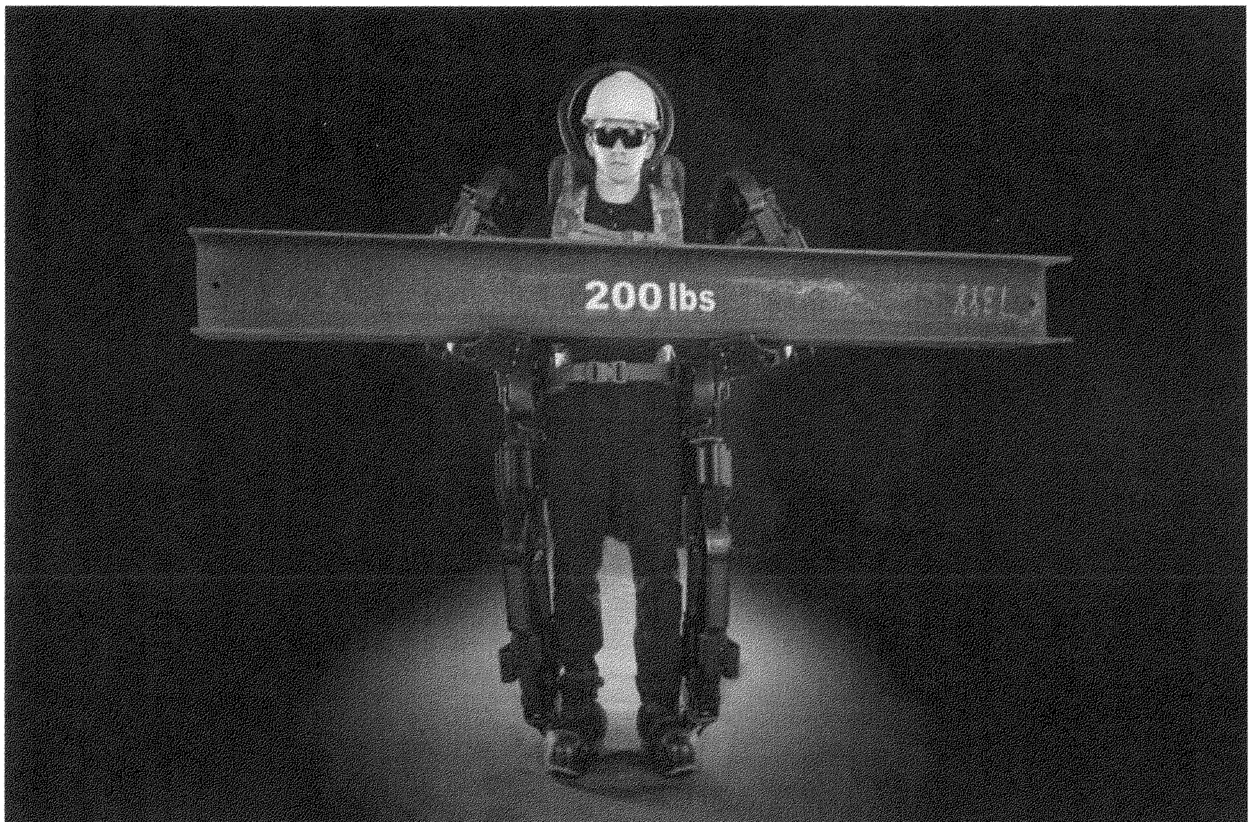
- Researchers at Carnegie-Mellon University in Pittsburgh are examining the effects of current and emerging technologies on labor outcomes with a precision that will provide meaningful insights for training programs. This work can help worker education and reskilling programs serve more people more effectively in less time.
- Vanderbilt University's Center for Autism and Innovation is working to improve opportunity and quality of life for people with neuro diverse conditions such as autism, ADHD, and dyslexia by investigating approaches to enhance retention, engagement, and productivity in STEM jobs, and specifically to harness unique capabilities accommodate for individual needs.
- Investigators at Michigan State University are examining the impact of widespread automated vehicle adoption on ride-hailing and truck hauling. Being able to predict changes will allow us to better prepare and retrain drivers, helping both industry and American workers.
- A team at the University of California-Irvine is using real time assessment to develop fair and accurate AI systems that will guide interventions to improve team cohesion, performance, workload, and collaboration and reduce interruptions, to help teams of the future work smarter, better, and happier

Concepts such as lifelong learning and values-based design are key elements of these efforts. Both concepts encourage researchers and entrepreneurs to consider the social consequences of technological change in early developmental stages – rather than after unintended consequences occur. Looking forward, social and behavioral scientists are working with their fellow scientists, engineers, and innovators from across the country to empower America's workers and help America's next generation of job creators better manage the challenges and opportunities of the future of work.

Conclusion

The discoveries and innovations funded by NSF have a long record of improving lives and meeting national needs. With the support of this Committee and the Congress, NSF will continue to invest in the fundamental research and the talented people who improve our daily lives and transform our future. As we look to the Future of Work, we are committed to supporting interdisciplinary research through the Big Ideas, the Convergence Accelerator and our core research programs that bring together all fields of science to ensure that our workers, researchers, students, innovators and industries are best positioned to take advantage of the major technological advancements we see today and will see in the future.

Thank you for the opportunity to testify today and for your continued support of NSF. I will be pleased to answer any questions you may have.



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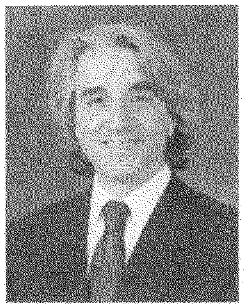

Dr. Arthur Lupia

Assistant Director

Social, Behavioral, and Economic Sciences

National Science Foundation

Dr. Arthur Lupia is Assistant Director of the National Science Foundation. In that capacity, he serves as head of the National Science Foundation (NSF) Directorate for Social, Behavioral, and Economic Sciences (SBE). He also serves the Hal R. Varian Collegiate Professor of Political Science at the University of Michigan and as co-chair of the Office of Science and Technology Policy's Subcommittee on Open Science. Prior to arriving at NSF, he served as Chairperson of the Board for the Center for Open Science, as chair of the National Academies Roundtable on the Communication and Use of Social and Behavioral Sciences, and as a leader of many scientific advisory boards.

Dr. Lupia's research and related public work examines processes, principles, and factors that guide decision-making and learning. His efforts clarify how people make decisions, and choose what to believe, when they lack information or face adverse circumstances. Lupia draws from mixes of mathematics, statistics, neuroscience, economics, psychology and other scientific disciplines to advance these topics. His work on civic competence, information processing, how voters learn and science communication has influenced scholarly practice, public policy, and classroom teaching in many countries.

Dr. Lupia has been a John Simon Guggenheim Fellow, a Andrew Carnegie Fellow, and is a recipient of the National Academy of Sciences Award for Initiatives in Research. He earned his bachelor's degree in economics at the University of Rochester and his social science PhD at the California Institute of Technology.

Chairwoman STEVENS. Dr. Brynjolfsson? Yes.

TESTIMONY OF DR. ERIK BRYNJOLFSSON, SCHUSSEL FAMILY PROFESSOR OF MANAGEMENT SCIENCE AND DIRECTOR, THE MIT INITIATIVE ON THE DIGITAL ECONOMY, MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Dr. BRYNJOLFSSON. Good afternoon, Chairwoman Stevens, Representative Marshall, and Members of the Committee. Thank you so much for inviting me to share some of the research my team and I have been doing. Addressing the opportunities created by AI is one of the most important challenges for government in the coming decade. Thanks to AI, some weird and wonderful things are beginning to happen. Cars are learning to drive themselves. Machines can now recognize your friends' faces. When you see people walking down the street talking on their phones, you don't know if they're talking to another human or to a machine, and expecting the machine to answer. Just last week Siri tried to join into a conversation I was having about interest rates.

However, it's also critical to understand that we are very far from what we call artificial general intelligence, the kind of AI that spans the full range of human intelligence. While machine learning is now superhuman in many tasks that involve mapping a particular set of inputs into outputs, humans outperform machines in most other cognitive tasks. Therefore, we are not facing the imminent end of work, but we are facing a major restructuring of work. In research that I've been doing with my colleagues, we find that few, if any, occupations will be fully automated by this new wave of technologies, but at the same time, few, if any, will be unaffected. Instead, most will be transformed. For instance, the job of a typical radiologist consists of 27 distinct tasks. While machine learning has made impressive advances in some of them, like reading medical images, it is of little use in most of the other tasks, like counseling patients.

So massive unemployment is not the challenge of our era. Instead, we face challenges in two other areas. One is delivering productivity growth, and the other is reducing inequality. To date, despite impressive improvements in AI, productivity growth has actually slowed down. Between 1995 and 2004 it averaged 2.8 percent per year, but since 2005 productivity has been just 1.3 percent per year. That's less than half the growth rate previously. So why is that? Well, the bottleneck is actually not the technology, but rather the lack of complementary process innovations, workforce reskilling, and business dynamism.

The second challenge is inequality. There's no economic law that says that everyone will benefit from technological advances. As the economic pie grows, it's possible for some people to be left behind, even as others benefit disproportionately. Indeed, over the past several decades the benefits of economic growth have been very unequal. Not only has the median income barely grown since the late 1990s, but other social indicators have actually worsened. For the first time in history, average life expectancy of Americans has begun to fall, driven by worse mortality of less educated Americans. It's no coincidence that these are exactly the Americans who haven't shared in our economic growth.

So my policy recommendations can be grouped into five key areas. The first one is to reinvent education. We need to recommit ourselves to investment in education. It's a field that the U.S. has once led the world. We also need to reinvent it so that we focus more on the kinds of skills that machines cannot match. These include creativity and interpersonal skills.

Second, we need to rebalance capital and labor. As noted in a recent research report by the MIT Work of the Future Initiative, our tax code and other policies are heavily skewed toward helping capital, rather than labor. We need a more-level playing field, particularly as AI starts to affect more and more of the labor force. This means taxing capital at comparable rates, encouraging investments in human capital, just as we do for physical capital, and updating corporate governance to recognize workers as stakeholders alongside stockholders. We can also expand the Earned Income Tax Credit to boost incomes for the working poor, and use revenues from things like carbon taxes to lower taxes on work.

Third, we need to invest in U.S. technological leadership. U.S. leadership in AI and other technologies is at serious risk because we have cut Federal investment in R&D (research and development), even as other nations have boosted theirs. Federal science agencies, like the NSF, working with our leading universities and private industry, have a central role in maintaining and extending America's science and technology leadership in AI and other areas.

Fourth, we need to welcome high skill immigrants. A vastly disproportionate number of America's leaders in science and business are immigrants, or the children of immigrants. When I ask my students at MIT what was the most important message I should convey to you here in Washington regarding AI policy, they unanimously advised me to push for less restrictive immigration policies.

And fifth, we need to work hard to support entrepreneurship. Boosting entrepreneurship can help reverse the stagnation of wages for the bottom half of the income distribution, particularly those who have been most adverse affected by automation. Among the policies that can help with this is decoupling healthcare from employment, reforming occupational licensing, and direct investments in teaching and entrepreneurship, and boosting new business formation.

With the right policies, AI can be harnessed to make the next decade the best decade in U.S. history.

[The prepared statement of Dr. Brynjolfsson follows:]

Artificial Intelligence and the Future of Work
Congressional Testimony of Erik Brynjolfsson
September 24, 2019

Good afternoon, Chairwoman Johnson, Ranking Member Lucas, Chairwoman Stevens, Ranking Member Baird, and members of the Committee. Thank you for giving me this opportunity to summarize and share some of my research on the implications of AI for the economy. Addressing the opportunities created by AI is one of the most important challenges for the government, for business and for individuals over the coming decade. I'm gratified that this Committee is taking this challenge seriously. While I primarily focus on my own research for this testimony, I will also draw on work by my team at MIT IDE, work by the MIT Work of the Future initiative, the AI Index, many other researchers. These are my own views. I am not speaking for anyone else.

1776 was a remarkable year. The United States declared its independence, creating a new kind of nation. Adam Smith wrote the *Wealth of Nations*, laying the foundations for free enterprise, and James Watt introduced a superior steam engine, igniting the industrial revolution. Our nation, and the world, are immensely freer and wealthier than our ancestors because of these three milestones and the subsequent changes they set in motion.

Today, we are also at a crossroads of history. The people in this room will help us choose the path forward. I will begin my testimony by summarizing some key changes in the underlying technologies, then discuss the implications for work, productivity and the broader economy, and conclude with five policy recommendations.

The biggest drivers of economic growth are advances in technology, specifically general purpose technologies like the steam engine, electricity and computers. These technologies not only have important direct effects, but also enable myriad complementary innovations in technology, business processes and economic organization. The most important general purpose technology of our era is AI. Indeed, it may be the most general of all general purpose technologies because if we can create intelligent machines, we can use that intelligence to solve many other problems.

The most important advances in AI have been in the area called machine learning called deep neural networks or deep learning. Because of insights by researchers like Geoffrey Hinton, Yann LeCun and Yoshua Bengio, these techniques enable machines to learn from data dramatically more effectively than ever before. For instance, in 2010, the best algorithms could recognize and label images on the large Imagenet dataset with barely 70% accuracy. Today, using deep learning techniques, they are about 98% accurate, surpassing human level performance on the same dataset. Similarly, deep learning techniques enable voice recognition systems to understand spoken language well-enough to respond to simple questions or instructions. While they are far from perfect, we are in the midst of the remarkable 10-year period of history where we went from machines not understanding human speech, to machines and humans routinely talking to each other in natural language. Machines now outperform humans in a wide variety of tasks that only humans could do before, from choosing which ads to show when we read an article on the web, to recommending who to hire or lend money to, to reading our medical images and diagnosing our diseases.

The recent advances in machine learning are breath-taking and important. However, it is critical to understand that we are very far from *artificial general intelligence* that is, the kind of AI than spans the full range of human intelligence. Machines learning is now superhuman in many tasks that involving mapping a set of inputs into a set of outputs (e.g. images -> labels, voice recordings -> transcripts; clickstream data -> advertising recommendations; medical data -> diagnoses) but humans outperform machines in most other tasks and we will almost surely continue to do so for decades.

In particular, humans have a big edge in tasks involving creativity, interpersonal skills and emotional intelligence, and physical dexterity. This means we are not in danger of mass unemployment anytime soon. There is no shortage of work that needs to be done in our society that only humans can do. In work I've been doing with Tom Mitchell and Daniel Rock, we've mapped out, in some cases literally, where machine learning technologies will have the biggest impacts. The typical occupation consists of 20-30 distinct task, some of which are much easier for machine learning systems to do than others. Our research shows that few, if any, occupations will be fully automated by the new wave of technologies. At the same time, few, if any, will be unaffected. Instead, most will be transformed. For instance, the job of a typical radiologist consists of 26 distinct tasks, from reading medical images, to consulting with other physicians and experts, to advising and counselling patients. While machine learning has made impressive advances in reading medical images, it is of little use in most of the other tasks done by radiologists. We have used our techniques to predict which occupations will be most affected, as well as which industries, which geographic regions and even which individual firms.

Our research tells us that we face two urgent economic challenges: a lack of productivity growth and too much inequality.

Productivity is what determines the wealth of nations, the success of companies and the living standards of individuals. While advances in technology are the catalyst of productivity growth, that growth is not realized unless and until a cascade of complementary innovations are implemented. For instance, when American factories first electrified, there was negligible productivity growth for the first 30 years. It was only after the first generation of managers retired and a new generation replaced the old "group drive" organization of machinery, which was optimized for steam engines, with the new "unit drive" approach that enable assembly lines that we saw a doubling of productivity. Today, despite impressive improvements in AI, not to mention many other technologies, productivity growth has actually slowed down, from an average of over 2.4% per year between 1995-2005 to less than 1.3% per year since then. The bottleneck is not the technology – though faster advances certainly wouldn't hurt – but rather a lack of complementary process innovation, workforce reskilling and business dynamism. Simply plugging in new technologies without changing business organization and workforce skills is like paving the cow paths. It leaves the real benefits largely untapped. However, by making complementary investments, we can speed up productivity growth. In this way, the economic pie will be bigger, giving us trillions of dollars of additional resources to address challenges in healthcare, the environment, poverty, national security and overall economic well-being.

While productivity is important, it isn't everything. There is no economic law that says that everyone will benefit from technological advances or productivity growth. As the economic pie grows, it is possible for some people to be left behind, even as others benefit disproportionately. For the first two centuries since 1776, that was not the case. Most

Americans benefitted as we created an economic system that generated shared prosperity. But over the past several decades, the benefits of economic growth have been much more unequal. Not only has median income barely grown since the late 1990s, but other social indictors, have worsened. Deaths from despair, namely suicide, drug addiction and suicide, are skyrocketing, particularly among Americans with a high school education or less. And for the first time in history, average life expectance of Americans has begun to fall, again driving by worse mortality of less educated Americans. It's no coincidence that these are exactly the Americans who haven't shared in our economic growth, as technologies automate many of the tasks they once did. As a society, we haven't helped them develop the new skills needed to thrive in an increasingly technological economy, or updated our organizations to put their skills to effective use.

What does the future hold? That depends almost entirely on our choices, including the choices made in Congress.

My policy recommendations can be grouped into five key areas.

1. Reinvent education.
   This is not the first time America has faced a challenge from powerful new general purpose technologies. In the early 1800s, nearly 90% of Americans worked in agriculture, by the end of that century it was only 42%. The former farmers didn't simply become unemployed. Instead they were redeployed. They went into manufacturing and services, driving productivity and growth. A big reason that transition was successful was that America led the world in education, first via primary schools and later high schools. This created not only world-leading prosperity, but also one of most equal societies on the planet, with extensive upward mobility.

   Today, we need a similar commitment to education. It won't be enough to simply invest more in human capital, although we should surely do that. We must also reinvent education to focus on the types of skills that machines can't match. As noted above, these include creativity (in science, the arts, entrepreneurship and beyond) as well as interpersonal skills (leadership, teamwork, persuasion, caring, coaching, etc.). The skills needed are not just hard skills, like software coding and STEM, but also the softer skills, from the arts, to social work, to entrepreneurship. My experience is that both hard skills and soft skills can be nurtured by the right environment and curricula.

   This transformation can and must be done not only in K-12 schools, but also through an expanded commitment to vocational education, our colleges and universities, graduate education and life-long learning. Online education is also part of the solution, not simply via MOOCs, but also via embracing the "experiment and test" philosophy that enables so many technology firms to rapidly iterate and improve their offerings. The same philosophy needs to be brought to education.

2. Rebalance capital and labor
   As noted in the recent report by the MIT Work of the Future initiative, of which I'm a member, our tax code and other policies are heavily skewed toward capital at the

expense of labor. As the share of GDP that goes to labor continues to fall, we must create a more level playing field, particularly as AI starts to affect more and more of the labor force. This means taxing capital and labor at comparable rates, encouraging investments in human capital just as we do for physical capital, and updating corporate governance to recognized workers as stakeholders alongside stockholders. We can also expand the earned income tax credit to boost incomes for the working poor and use revenues from carbon taxes and other Pigouvian taxes to lower taxes on work and create a carbon dividend.

3. Invest in US technology leadership
   The US has long been a leader not just in AI, but in a broad swath of technologies. That technological leadership is at serious risk because even as we have cut federal investment in R&D, other nations have boosted theirs. Data from the AI Index, where I serve on the steering committee, documents a host of metrics that show the falling share of research being done in the US. Federal science agencies, working with our leading universities and private industry, have a central role in maintaining and extending America's science and technology leadership in AI. In particular, my MIT colleagues Jon Gruber and Simon Johnson have put forth a compelling plan for *Jumpstarting America* that not only extends our pre-eminence but also shares the benefits from innovation more widely.

4. Welcome High Skill Immigrants
   A vastly disproportionate of America's leaders in science and business are immigrants or the children of immigrants. This reflect the fact that the US has long been a magnet for talent and a place where that talent could flourish. Sadly, that strength is being severely undercut by our recent immigration policies. When I asked my students at MIT what was the most important message I should being to Washington regarding AI policy, they unanimously advised me to push for less restrictive immigration policies. Every international student I spoke to, whether undergraduate, graduate or post-doc, as well as most of my foreign-born faculty colleagues, had harrowing stories to tell of difficulties they have add with our immigration and visa process. These have prevented them from attending conferences, participating in research projects and in far too many cases, led them to move to Canada, Europe, India, China or other nations to continue their research, rather than the US. A more welcoming immigration policy, especially for top talent, would not only be a huge boost for the US, but also good for the world, since it would make it easier for the best minds to work together.

5. Support Entrepreneurship
   While stories of technology-driven entrepreneurship are common in the media, the data tell a different story: as documented by John Haltiwanger, Steven Davis and many others, new business formation is down, fewer people are working in young firms, economic and geographic mobility is down and almost every measure of business dynamism has declined over the past 20 years. This has hindered new technologies from being translated into new products and service that benefit the economy. Boosting entrepreneurship will help reverse the stagnation of wages for the bottom half of the income distribution, particularly those groups who have been

most adversely affected by automation. This is not because everyone should become an entrepreneur or gig worker but because it's the core function of entrepreneurs to invent the new goods, services, companies and jobs that supplant the previous types of work that are being automated. Among the policies that can help with this is a reform of occupational licensing, decoupling of healthcare from employment, and direct investments in teaching entrepreneurship and boosting new business formation.

Artificial Intelligence is the most transformative technology of our era. It has begun to affect many specific tasks, but its biggest impacts are still ahead. AI creates enormous opportunities for boosting productivity. But the key to unlocking these benefits is not merely more or better technology investment, but also investment in the intangible complements, including new skills, new organizational processes and new business models. As powerful and pervasive as AI will be, we are not facing the imminent end of work or mass unemployment. Instead, we are witnessing a growing inequality and disruption as many tasks, disproportionately those done by lower wage workers, are affected by the technology.

With the right policies, we can harness the power of AI. With the right policies, particularly in reinventing education, rebalancing capital and labor, investing in US technological leadership, welcoming immigrants and boosting entrepreneurship we can create a economy that creates not only prosperity but shared prosperity. With the right polices, the next decade can be the best decade in US history since 1776.

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TECHNOLOGY AND THE ECONOMY

What can machine learning do? Workforce implications

Profound change is coming, but roles for humans remain

By **Erik Brynjolfsson**[1,2] *and* **Tom Mitchell**[3]

Digital computers have transformed work in almost every sector of the economy over the past several decades (*1*). We are now at the beginning of an even larger and more rapid transformation due to recent advances in machine learning (ML), which is capable of accelerating the pace of automation itself. However, although it is clear that ML is a "general purpose technology," like the steam engine and electricity, which spawns a plethora of additional innovations and capabilities (*2*), there is no widely shared agreement on the tasks where ML systems excel, and thus little agreement on the specific expected impacts on the workforce and on the economy more broadly. We discuss what we see to be key implications for the workforce, drawing on our rubric of what the current generation of ML systems can and cannot do [see the supplementary materials (SM)]. Although parts of many jobs may be "suitable for ML" (SML), other tasks within these same jobs do not fit the criteria for ML well; hence, effects on employment are more complex than the simple replacement and substitution story emphasized by some. Although economic effects of ML are relatively limited today, and we are not facing the imminent "end of work" as is sometimes proclaimed, the implications for the economy and the workforce going forward are profound.

Any discussion of what ML can and cannot do, and how this might affect the economy, should first recognize two broad, underlying considerations. We remain very far from artificial general intelligence (*3*). Machines cannot do the full range of tasks that humans can do (*4*). In addition, although innovations

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generally have been important for overall improvements in income and living standards, and the first wave of pre-ML information technology (IT) systems in particular has created trillions of dollars of economic value. "The case that technological advances have contributed to wage inequality is strong" [see (*1*), a report from a committee we recently cochaired for the U.S. National Academies of Science, Engineering and Medicine]. Although there are many forces contributing to inequality, such as increased globalization, the potential for large and rapid changes due to ML, in many cases within a decade, suggests that the economic effects may be highly disruptive, creating both winners and losers. This will require considerable attention among policy-makers, business leaders, technologists, and researchers.

As machines automate some of the tasks that are SML in a particular job or process, the remaining tasks that are non-SML may become more valuable. In other cases, machines will augment human capabilities and make possible entirely new products, services, and processes. Therefore, the net effect on the demand for labor, even within jobs that are partially automated, can be either negative or positive. Although broader economic effects can be complex, labor demand is more likely to fall for tasks that are close substitutes for capabilities of ML, whereas it is more likely to increase for tasks that are complements for these systems. Each time an ML system crosses the threshold where it becomes more cost-effective than humans on a task, profit-maximizing entrepreneurs and managers will increasingly seek to substitute machines for people. This can have effects throughout the economy, boosting productivity, lowering prices, shifting labor demand, and restructuring industries.

WE KNOW MORE THAN WE CAN TELL

As the philosopher Polanyi observed, we know more than we can tell (*5*). Recognizing a face, riding a bike, and understanding speech are tasks humans know very well how to do, but our ability to reflect on how we perform them is poor. We cannot codify many tasks easily, or perhaps at all, into a set of formal rules. Thus, prior to ML, Polanyi's paradox limited the set of tasks that could be automated by programming computers (*6*). But today, in many cases, ML algorithms have made it possible to train computer systems to be more accurate and more capable than those that we can manually program.

Until recently, creating a new computer program involved a labor-intensive process of manual coding. But this expensive process is increasingly being augmented or replaced by a more automated process of running an existing ML algorithm on appropriate training data. The importance of this shift is twofold. In a growing subset of applications, this paradigm can produce more accurate and reliable programs than human programmers (e.g., face recognition and credit card fraud detection). Second, this paradigm can dramatically lower costs for creating and maintaining new software. This lowered cost reduces the barrier to experiment with and explore potential computerization of tasks, and encourages development of computer systems that will automatically automate many types of routine workflows with little or no human intervention.

Such progress in ML has been particularly rapid in the past 6 to 8 years due in large part to the sheer volume of training data available for some tasks, which may be large enough to capture highly valuable and previously unnoticed regularities—perhaps impossibly large for a person to examine or comprehend, yet within the processing ability of ML algorithms. When large enough training data sets are available, ML can sometimes produce computer programs that outperform the best humans at the task (e.g., dermatology diagnosis, the game of Go, detecting potential credit card fraud).

Also critical to ML progress has been the combination of improved algorithms, including deep neural networks (DNNs) and considerably faster computer hardware. For example, Facebook switched from phrase-based machine translation models to DNNs for more than 4.5 billion language translations each day. DNNs for image recognition have driven error rates on ImageNet, a large data set of more than 10,000 labeled images (*7*), down from more than 30% in 2010 to less than 3% today. Similarly, DNNs have helped improve error rates from 8.4% to 4.9% in voice recognition since July 2016. The 5% threshold for image recognition and speech is important because that is roughly the error rate of humans when given similar data.

AUTOMATING AUTOMATION

To produce a well-defined learning task to which we can apply a ML algorithm, one must fully specify the task, performance metric, and training experience. In most practical applications, the task to be learned corresponds to some target function, such as a function from input medical patient health records to output patient diagnoses, or a function from the current sensor inputs of a self-driving car to the correct next steering command. The most common type of training experience is data consisting of input-output pairs for the target function (e.g., medical records paired with the correct diagnoses). Obtaining ground-truth training data can be difficult in many domains, such as psychiatric diagnosis, hiring decisions, and legal cases.

Key steps in a successful commercial application typically include efforts to identify precisely the function to be learned; collect and cleanse data to render it useable for training the ML algorithm; engineer data features to choose which are likely to be helpful in predicting the target output, and perhaps to collect new data to make up for shortfalls in the original features collected; experiment with different algorithms and parameter settings to optimize the accuracy of learned classifiers; and embed the resulting learned system into routine business operations in a way that improves productivity and, if possible, in a way that captures additional training examples on an ongoing basis.

One approach that is particularly relevant to gauging the rate of future automation is the "learning apprentice" (sometimes called the "human in the loop") approach (*8*), in which the artificial intelligence (AI) program acts as an apprentice to assist the human worker, while also learning by observing the human's decisions and capturing these as additional training examples. This approach has led to new kinds of business models.

Training a learning apprentice to mimic human-generated decisions offers the potential for machines to learn from the combined data of multiple people it assists, perhaps leading to outperforming each individual on the team that trains it. Still, its learned expertise may be limited by the skill level of the human team and by the online availability of relevant decision variables. However, in cases where the computer can also access independent data to determine the optimal decision (ground truth), it may be possible to improve on human decisions and then to help the human improve their own performance. For example, in medical diagnosis of skin cancer from dermatological images, using the results of subsequent biopsies as a gold standard for training can produce computer programs with even higher diagnostic accuracies than human doctors (*9*).

MOST SUITABLE TASKS

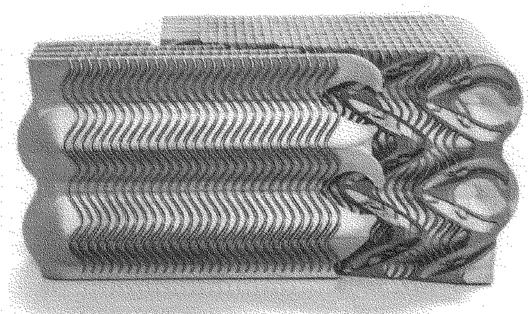
Although recent advances in the capabilities of ML systems are impressive, they are not equally suitable for all tasks. The current wave of successes draw particularly heavily on a paradigm known as supervised learning, typically using DNNs. They can be immensely powerful in domains that are well suited for such use. However, their competence is also dramatically narrower and more fragile than human decision-making, and there are many tasks for which this approach is completely ineffective. Of course, advances in ML continue, and other approaches are likely to be better suited for different types of tasks. We identify eight key criteria that help distinguish SML tasks from tasks where ML is less likely to be successful, at least when using the currently dominant ML paradigm (see the SM for a more detailed, 21-item rubric).

1. Learning a function that maps well-defined inputs to well-defined outputs

Among others, these include classification (e.g., labeling images of dog breeds or labeling medical records according to the likelihood of cancer) and prediction (e.g., analyzing a loan application to predict the likelihood of future default). Although ML may learn to predict the Y value associated with any given input X, this is a learned statistical correlation that might not capture causal effects.

2. Large (digital) data sets exist or can be created containing input-output pairs

The more training examples are available, the more accurate the learning. One of the remarkable characteristics of DNNs is that performance in many domains does not seem to asymptote after a certain number of examples (*10*). It is especially important that all of the relevant input features be captured in the training data. Although in principle any arbitrary function can be represented by a DNN (*11*), computers are vulnerable to mimicking and perpetuating unwanted biases present in the training data and to missing regularities that involve variables that they cannot observe. Digital data can often be created by monitoring existing processes and customer interactions, by hiring humans to explicitly tag or label portions of the data or create entirely new data sets, or by simulating the relevant problem setting.



A heat exchanger was designed by a machine using generative design.

PHOTO: AUTODESK

3. The task provides clear feedback with clearly definable goals and metrics

ML works well when we can clearly describe the goals, even if we cannot necessarily define the best process for achieving those goals. This contrasts with earlier approaches to automation. The ability to capture input-output decisions of individuals, although it might allow learning to mimic those individuals, might not lead to optimal system-wide performance because the humans themselves might make imperfect decisions. Therefore, having clearly defined system-wide metrics for performance (e.g., to optimize traffic flow throughout a city rather than at a particular intersection) provides a gold standard for the ML system. ML is particularly powerful when training data are labeled according to such gold standards, thereby defining the desired goals.

4. No long chains of logic or reasoning that depend on diverse background knowledge or common sense

ML systems are very strong at learning empirical associations in data but are less effective when the task requires long chains of reasoning or complex planning that rely on common sense or background knowledge unknown to the computer. Ng's "one-second rule" (*4*) suggests that ML will do well on video games that require quick reaction and provide instantaneous feedback but less well on games where choosing the optimal action depends on remembering previous events distant in time and on unknown background knowledge about the world (e.g., knowing where in the room a newly introduced item is likely to be found) (*12*). Exceptions to this are games such as Go and chess, because these nonphysical games can be rapidly simulated with perfect accuracy, so that millions of perfectly self-labeled training examples can be automatically collected. However, in most real-world domains, we lack such perfect simulations.

5. No need for detailed explanation of how the decision was made

Large neural nets learn to make decisions by subtly adjusting up to hundreds of millions of numerical weights that interconnect their artificial neurons. Explaining the reasoning for such decisions to humans can be difficult because DNNs often do not make use of the same intermediate abstractions that humans do. While work is under way on explainable AI systems (*13*), current systems are relatively weak in this area. For example, whereas computers can diagnose certain types of cancer or pneumonia as well as or better than expert doctors, their ability to explain why or how they came up with the diagnosis is poor when compared with human doctors. For many perceptual tasks, humans are also poor at explaining, for example, how they recognize words from the sounds they hear.

6. **A tolerance for error and no need for provably correct or optimal solutions**
Nearly all ML algorithms derive their solutions statistically and probabilistically. As a result, it is rarely possible to train them to 100% accuracy. Even the best speech, object recognition, and clinical diagnosis computer systems make errors (as do the best humans). Therefore, tolerance to errors of the learned system is an important criterion constraining adoption.

7. **The phenomenon or function being learned should not change rapidly over time**
In general, ML algorithms work well only when the distribution of future test examples is similar to the distribution of training examples. If these distributions change over time, then retraining is typically required, and success therefore depends on the rate of change, relative to the rate of acquisition of new training data (e.g., email spam filters do a good job of keeping up with adversarial spammers, partly because the rate of acquisition of new emails is high compared to the rate at which spam changes).

8. **No specialized dexterity, physical skills, or mobility required**
Robots are still quite clumsy compared with humans when dealing with physical manipulation in unstructured environments and tasks. This is not so much a shortcoming of ML but instead a consequence of the state of the art in general physical mechanical manipulators for robots.

WORKFORCE IMPLICATIONS

The main effects of pre-ML IT have been on a relatively narrow swath of routine, highly structured and repetitive tasks (*14*). This has been a key reason that labor demand has fallen for jobs in the middle of the skill and wage spectrum, like clerks and factory workers, whereas demand at the bottom (e.g., janitor or home health aide) and top (e.g., physicians) has held up in most advanced countries (*15*). But a much broader set of tasks will be automated or augmented by machines over the coming years. This includes tasks for which humans are unable to articulate a strategy but where statistics in data reveal regularities that entail a strategy. Although the framework of routine versus nonroutine tasks did a very effective job of describing tasks suitable for the last wave of automation (*14*), the set of SML tasks is often very different. Thus, simply extrapolating past trends will be misleading, and a new framework is needed.

Jobs typically consist of a number of distinct but interrelated tasks. In most cases, only some of these tasks are likely to be suitable for ML, and they are not necessarily the ones that were easy to automate with previous technologies. For instance, when we apply our 21-question SML rubric to various occupations, we find that a ML system can be trained to help lawyers classify potentially relevant documents for a case but would have a much harder time interviewing potential witnesses or developing a winning legal strategy (*16*). Similarly, ML systems have made rapid advances in reading medical images, outperforming humans in some applications (*17*). However, the more unstructured task of interacting with other doctors, and the potentially emotionally fraught task of communicating with and comforting patients, are much less suitable for ML approaches, at least as they exist today.

That is not to say that all tasks requiring emotional intelligence are beyond the reach of ML systems. One of the surprising implications of our rubric is that some aspects of sales and customer interaction are potentially a very good fit. For instance, transcripts from large sets of online chats between salespeople and potential customers can be used as training data for a simple chatbot that recognizes which answers to certain common queries are most likely to lead to sales (*18*). Companies are also using ML to identify subtle emotions from videos of people.

Another area where the SML rubric departs from the conventional framework is in tasks that may involve creativity. In the old computing paradigm, each step of a process needed to be specified in advance with great precision. There was no room for the machine to be "creative" or figure out on its own how to solve a particular problem. But ML systems are specifically designed to allow the machine to figure out solutions on its own, at least for SML tasks. What is required is not that the process be defined in great detail in advance but that the properties of the desired solution be well specified and that a suitable simulator exists so that the ML system can explore the space of available alternatives and evaluate their properties accurately. For instance, designing a complex new device has historically been a task where humans are more capable than machines. But generative design software can come up with new designs for objects like the heat exchanger (see photo) that meet all the requirements (e.g., weight, strength, and cooling rate) more effectively than anything designed by a human, and with a very different look and feel (*18*).

Is it "creative"? That depends on what definition one uses. But some "creative" tasks that were previously reserved for humans will be increasingly automatable in the coming years. This approach works well when the final goal can be well specified and the solutions can be automatically evaluated as clearly right or wrong, or at least better or worse. As a result, we can expect such tasks to be increasingly subject to automation. At the same time, the role of humans in more clearly defining goals will become more important, suggesting an increased role for scientists, entrepreneurs, and those making a contribution by asking the right questions, even if the machines are often better able to find the solutions to those questions once they are clearly defined.

SIX ECONOMIC FACTORS

There are many nontechnological factors that will affect the implications of ML for the workforce. Specifically, the total effect of ML on labor demand and wages can be written as a function of six distinct economic factors:

1. **Substitution**
Computer systems created by ML will directly substitute for some tasks, replacing the human and reducing labor demand for any given level of output

2. **Price elasticity**
Automation via machine learning may lower prices for tasks. This can lead to lower or higher total spending, depending on the price elasticity of demand. For instance, if elasticity is less than –1, then a decrease in price leads to a more than proportional increase in quantity purchased, and total spending (price times quantity) will increase. By analogy, as technology reduced the price of air travel after 1903, total spending on this type of travel increased, as did employment in this industry.

3. **Complementarities**
Task B may be an important, or even indispensable, complement to another task A that is automated. As the price of A falls, the demand for B will increase. By analogy, as calculation became automated, the demand for human programmers increased. Skills can also be complementary to other skills. For instance, interpersonal skills are increasingly complementary to analytical skills (*19*).

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4. **Income elasticity**
   Automation may change the total income for some individuals or the broader population. If income elasticity for a good is nonzero, this will in turn change demand for some types of goods and the derived demand for the tasks needed to produce those goods. By analogy, as total income has increased, Americans have spent more of their income on restaurant meals.

5. **Elasticity of labor supply**
   As wages change, the number of people working on the task will respond. If there are many people who already have the requisite skills (for example, driving a car for a ride-hailing service), then supply will be fairly elastic and wages will not rise (or fall) much, if at all, even if demand increases (or falls) a lot. In contrast, if skills are more difficult to acquire, such as becoming a data scientist, then changes in demand will mainly be reflected in wages, not employment.

6. **Business process redesign**
   The production function that relates any given set of different types and quantities of labor, capital, and other inputs to output is not fixed. Entrepreneurs, managers, and workers constantly work to reinvent the relevant processes. When faced with new technologies, they will change the production process, by design or through luck, and find more efficient ways to produce output (*20*). These changes can take time and will often economize on the most expensive inputs, increasing demand elasticity. Similarly, over time, individuals can make a choice to respond to higher wages in some occupations or places by investing in developing the new skills required for work or moving to a new location, increasing the relevant supply elasticity. Thus, according to Le Chatelier's principle (*21*), both demand and supply elasticities will tend to be greater in the long run than in the short run as quasi-fixed factors adjust.

Adoption and diffusion of technologies often take years or decades because of the need for changes in production processes, organizational design, business models, supply chains, legal constraints, and even cultural expectations. Such complementarities are as ubiquitous in modern organizations and economies as they are subtle and difficult to identify, and they can create considerable inertia, slowing the implementation of even—or especially—radical new technologies (*22*). Applications that require complementary changes on many dimensions will tend to take longer to affect the economy and workforce than those that require less redesign of existing systems. For instance, integration of autonomous trucks onto city streets might require changes in traffic laws, liability rules, insurance regulations, traffic flow, and the like, whereas the switch from talking to a human assistant to a virtual assistant in a call center might require relatively little redesign of other aspects of the business process or customer experience.

Over time, another factor becomes increasingly important: New goods, services, tasks, and processes are always being invented. These inventions can lead to the creation of altogether new tasks and jobs (*23*) and thus can change the magnitudes and signs of the above relationships. Historically, as some tasks have been automated, the freed-up labor has been redeployed to producing new goods and services or new, more effective production processes. Such innovations have been more important than increased capital, labor, or resource inputs as a force for raising overall incomes and living standards. ML systems may accelerate this process for many

"Applications that require... changes on many dimensions will tend to take longer to affect the economy..."

of the tasks that fit the criteria above by partially automating automation itself.

As more data come online and are pooled and as we discover which tasks should be automated by ML, we will collect data even more rapidly to create even more capable systems. Unlike solutions to tasks mastered by humans, many solutions to tasks automated by ML can be disseminated almost instantly worldwide. There is every reason to expect that future enterprise software systems will be written to embed ML in every online decision task, so that the cost of attempting to automate will come down even further.

The recent wave of supervised learning systems have already had considerable economic impact. The ultimate scope and scale of further advances in ML may rival or exceed that of earlier general-purpose technologies like the internal combustion engine or electricity. These advances not only increased productivity directly but, more important, triggered waves of complementary innovations in machines, business organization, and even the broader economy. Individuals, businesses, and societies that made the right complementary investments—for instance, in skills, resources, and infrastructure—thrived as a result, whereas others not only failed to participate in the full benefits but in some cases were made worse off. Thus, a better understanding of the precise applicability of each type of ML and its implications for specific tasks is critical for understanding its likely economic impact. ■

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ACKNOWLEDGMENTS

The authors acknowledge helpful discussions and comments from D. Acemoglu, D. Autor, S. Benzell, Y. LeCun, F. Levy, A. Ng, T. Poggio, D. Rus, G. Saint-Jacques, Y. Shavit, C. Syverson, S. Thrun, and especially D. Rock. E.B. acknowledges funding from the MIT Initiative on the Digital Economy for this research. T.M. acknowledges support from the U.S. Air Force Office of Scientific Research.

SUPPLEMENTARY MATERIALS

www.sciencemag.org/content/358/6370/1530/suppl/DC1

10.1126/science.aap8062

Science

What can machine learning do? Workforce implications

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Science **358** (6370), 1530-1534.
DOI: 10.1126/science.aap8062

Erik Brynjolfsson is Director of the MIT Initiative on the Digital Economy, Schussel Family Professor at the MIT Sloan School, and Research Associate at NBER. His research examines the effects of information technologies on business strategy, productivity and performance, digital commerce, and intangible assets. At MIT, he teaches courses on the Economics of Information and the Analytics Lab.

Professor Brynjolfsson was among the first researchers to measure the productivity contributions of IT and the complementary role of organizational capital and other intangibles. His research also provided the first quantification of the value of online product variety, often known as the "Long Tail," and developed pricing and bundling models for information goods. His research has appeared in leading economics, management, and science journals and has been recognized with ten Best Paper awards and five patents.

Author of several books including, with co-author Andrew McAfee, *NYTimes* best-seller *The Second Machine Age: Work, Progress and Prosperity in a Time of Brilliant Technologies* (2014) and *Machine, Platform, Crowd: Harnessing Our Digital Future* (June 2017), Brynjolfsson is editor of SSRN's Information System Network and has served on the editorial boards of numerous academic journals. Holding Bachelors and Masters degrees from Harvard University in Applied Mathematics and Decision Sciences and a PhD from MIT in Managerial Economics, he has also taught at Harvard and Stanford.

TESTIMONY OF REBEKAH KOWALSKI, VICE PRESIDENT, MANUFACTURING SERVICES, MANPOWERGROUP

Ms. KOWALSKI. Chairwoman Stevens, Ranking Member Dr. Baird, and Representative Marshall, on behalf of ManpowerGroup, thanks for the invitation to speak today on such an incredibly important topic. ManpowerGroup is the world leader in innovative workforce solutions. Every day we connect more than 600,000 people to work around the world in a wide range of skills and industries. One of our most predominant industry sectors is the manufacturing sector, and I oversee our manufacturing solutions practice. I've worked with a lot of companies as they are struggling to deal with the twin challenge of finding enough rightly skilled talent, and figuring out how they're going to navigate the bright new future that digital offers.

Manufacturers are reporting talent shortages as they struggle to find the right blend of technical and soft skills. Our perspective is that AI, machine learning, and other digital technologies produce new jobs that require new skills. Some of those we can't even imagine yet. Our research shows that over 90 percent of employers expect to be impacted by digitization over the next 2 years. Eighty-seven percent of them plan to maintain or increase head count. Four percent say they don't know. And yes, there is a small number, 9 percent of them, that say that they anticipate a reduction. Fully 75 percent say this is going to require new skills, skills that we do not currently have in our workforce, and skills that we can't actually even anticipate.

In 2017 we released a study with MXD, which was formerly known as the Digital, Manufacturing, and Design Innovation Institute, on how digital technologies, including AI and machine learning, would impact manufacturing jobs. The study was accomplished in partnership with academia and industry, and identified 165 new or significantly evolved roles. Today the majority of manufacturing roles are in the general entry level population, by count. That is—those are roles like picker/packer, assembler, operator, helper, laborer. And the manufacturing sector, the backdrop here, is that we are going to produce 3.5 million new jobs over the next decade, while at the same time 2.7 manufacturing workers are set to retire. Many of the new jobs will be in these more specialized areas, like technicians, testers, analysts, specialists, and that's a significant shift for us.

We have the following concerns. First, employers are uncertain about how digitization will impact roles and skills, and over what period of time. Second, the ability of employers of all sizes to invest in upscaling falls far short of what is required to produce the workforce they need, both from a time and resource perspective. Third, the talent shortage impacts all types of talent, from entry level to leadership, meaning employers have to determine the best way to allocate precious dollars. That disproportionately impacts small and mid-sized manufacturers.

There are several obstacles to being resourceful around talent attraction and upscaling. One, it's difficult for organizations to predict workforce needs more than a year in advance. Strategic workforce planning does not have as long of a horizon as it needs. Without enough exact match talent, we need to shift to hiring on potential and learnability, but H.R. (human resources) systems and processes are still geared toward finding an exact match. Third, job descriptions need to be less stationary, and more evolutionary, so that individuals can actually anticipate the need for ongoing learning and adaptation. And four, organizations lack sufficient funding for workforce training.

An example of improved training processes is what we do with Rockwell Automation in our Academy of Advanced Manufacturing, where we take veterans and we put them through a 12-week embedded program, and we graduate them as Certified Automation Technicians. They walk away with a job that, on average, is double what they were making when they came in, and the employer walks away with the talent that they need. With 12 million manufacturing workers in the U.S., we need those kinds of nimble programs, many, many more of them, in order to ensure that people have a path to sustainable prosperity, and we need to start now. Don't count the humans out.

Talent is, in fact, the most renewable resource we have on the planet. It is ready to learn, adapt, and thrive in new environments, and we need to work collectively now across educators, employers, and individuals to become proactive builders of talent to develop a workforce with the skills employers and individuals need to remain competitive, both now and in the future.

Thank you again to the Subcommittee for the opportunity to share my testimony.

[The prepared statement of Ms. Kowalski follows:]

Prepared Statement of Rebekah Kowalski
Vice President, Manpower Manufacturing

U.S. House of Representatives Committee on Science, Space, & Technology,

Subcommittee on Research and Technology

Hearing on "Artificial Intelligence and the Future of Work"

September 24, 2019

Chairwoman Stevens, Ranking member Baird, and members of the Subcommittee -

On behalf of ManpowerGroup, thank you for the invitation to speak today on the impact of machine learning and artificial intelligence on the workforce.

ManpowerGroup is a world leader in innovative workforce solutions. Every day, we connect more than 600,000 people to meaningful work across a wide range of skills and industries. We are a $21 billion company that operates in 80 countries with nearly 30,000 employees.

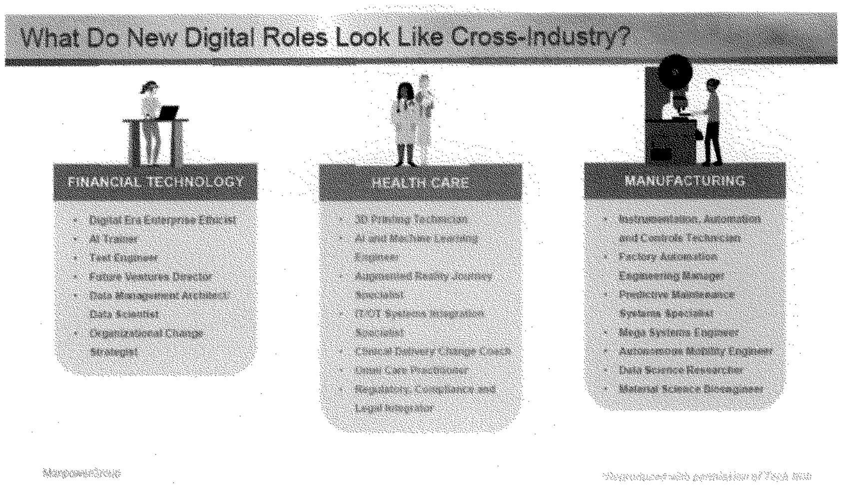
Context of the Manufacturing Labor Market

In 2017, we released a study with MxD (formerly the Digital Manufacturing Design & Innovation Institute "DMDII") on how digital technologies, including Artificial Intelligence and Machine Learning would impact manufacturing jobs. The study identified 165 roles that would either be new or evolved.[1]

This evolution of roles is impacting all sectors as artificial intelligence, robotics, machine learning, and automation hasten innovation cycles creating new products and services. See ***Figure 1*** below for an example of the roles that are evolving or emerging as these technologies are applied to the traditional sectors of Healthcare, FinTech, and Manufacturing:

[1] https://www.uilabs.org/innovation-platforms/manufacturing/taxonomy/ and https://workforce-resources.manpowergroup.com/home/the-future-factory

Figure 1: What Do New Digital Roles Look Like Cross-Industry?



New jobs and skill requirements are emerging at the same time as employers are having almost unprecedented difficulty in getting access to talent.

A hot jobs market with 107 consecutive months of job growth, 3.7% unemployment rate, and population growth that has hit an 80-year low are all key contributors. Our latest quarter of the ManpowerGroup Employment Outlook Survey shows a strong hiring intent across all sectors.[2] The bottom line is that today, there is <1 person for each open job, including individuals who are on the sidelines and unemployed. And with the highest quit rate since 2001, the squeeze on employers is getting tighter. The future outlook is not much brighter. In Manufacturing specifically, the sector is set to produce 3.5 million new jobs over the next decade, but 2.5 million are on pace to retire, leaving US manufacturers with a 6 million shortfall in available talent for jobs that are evolving rapidly – a double squeeze.[3]

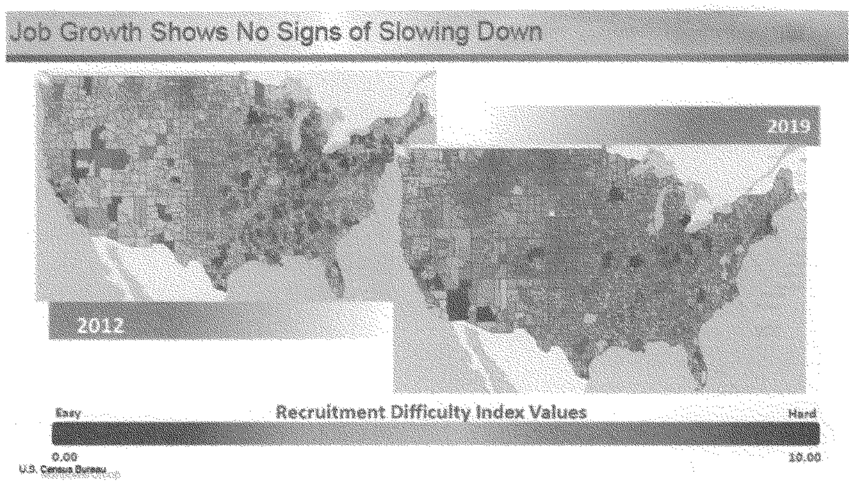
ManpowerGroup's annual Talent Shortage Survey measures the difficulty employers are having in hiring talent. In 2018, 46% of US employers reported difficulty in finding the talent they were looking for, this is compared to 14% just 8 years prior.[4] Of the Top 10 toughest jobs to fill, 3 are particularly relevant to Manufacturing: Skilled Trades leads the list at #1; Technicians are at #7; and Production & Machine Operators are at #10.[5] Employers say the top three reasons they have difficulty in finding talent:

[2] https://manpowergroup.us/meos/public/pdf/employment-outlook-forecast.pdf
[3] https://manpowergroup.us/meos/public/pdf/employment-outlook-forecast.pdf
[4] https://go.manpowergroup.com/talent-shortage-2018#shortagebycountry
[5] https://go.manpowergroup.com/talent-shortage-2018#shortagebycountry

- 26% said lack of applicants
- 21% said lack of experience
- 14% said applicants lack required hard skills (technical competencies)[6]

ManpowerGroup's Recruitment Difficulty Index aggregates across all sectors and roles. We believe the double squeeze of available workforce and rapid evolution of roles & skills is reflected in the difficulty we are having in recruiting individuals for our thousands of customers across the U.S. ***Figure 2*** shows the 'heat map' comparing recruiting difficulty in 2012 to 2019. As you can see, the market context for preparing the workforce for rapidly evolving roles & skills is one of scarcity. This climate will require employers to be resourceful and creative in evaluating and selecting talent. We advocate for hiring on potential (vs. 'exact match' of skills and experience), and then investing in upskilling and reskilling that talent to take them into the future. There is simply no 'fresh' resource of talent coming into the US either through an increase in population or significant populations of untapped potential. Digital technologies will certainly help close the gap, but it will also create new jobs and opportunities for which we are fundamentally unprepared.

Figure 2: Job Growth Shows No Signs of Slowing Down



[6] https://go.manpowergroup.com/talent-shortage-2018#shortagebycountry

Impacts of AI and Machine Learning on Manufacturing Workforce

ManpowerGroup's perspective is that the Digital Era will rush in new jobs that require new skills. Our research shows that 90%+ of employers expect to be impacted by digitization in the next two years, 75% believe that this will require new skills in their workforce. 87% of employers plan to increase or maintain headcount as these new technologies evolve their products and services, 4% are unsure of the impact and only 9% plan to decrease their workforce.

In the Manufacturing sector, the majority of roles are in the general, entry level production workforce that consists of roles such as picker/packer, assembler, operator, and helper/laborer. Our research with DMDII shows that as US manufacturing transitions to an increasingly digital model there will be an increase in higher skilled roles such as: analyst, specialist, tester and technician. It could take 1-2 years to train the *skilled* manufacturing workforce for roles of the future, and much longer to train the unskilled population. (For additional detail on this, please review pages 49-52 of the DMDII & ManpowerGroup Report, *The Digital Workforce Succession in Manufacturing*). Individuals will move from the direct operation of tasks to using technology to facilitate those tasks, and in some cases, operating bundled technology to complete many more operations than they could if they were completing the tasks manually.

The speed at which evolved roles and skills are required is highly dependent on the speed of the uptake of technology inside of organizations. ***Figure 3*** shows the general progression of technological generations in the Manufacturing sector. There is no crystal ball on timing, as organizations make the decision to make capital investments in new technology based on what they believe their return on investment (ROI) will be and over what timeline it will be achieved. This ROI can be measured in terms of increased productivity (faster time to market, lowered costs, etc), an evolved product offering that opens up new consumer markets and thus drives up revenue growth, or a complete reinvention of their playing field, and many points in between. See ***Figure 4*** for a breakdown of what percentage of roles in manufacturing organizations are shifting, evolving and being redefined. 28% of evolving roles are on the production floor. Many organizations are on the sidelines, waiting to jump in as the price of technology drops, others are first adopters, and many more are operating legacy technologies in one plant and the newest, cutting-edge technologies at another. In general, those production facilities tied to food and pharma or a Tier 1 defense contractor, will tend to take up new technologies faster than, say, a small manufacturer who makes cutting tools and is a Tier 4 or 5 supplier. That said, a tipping point will be reached in terms of the percent of labor tied to manual and transactional tasks and the percentage of workers with the skills to operate and cooperate with the newest digital technologies. That tipping point will likely come sooner than the pace at which we are preparing our workforce.

Figure 3: Generations of Manufacturing

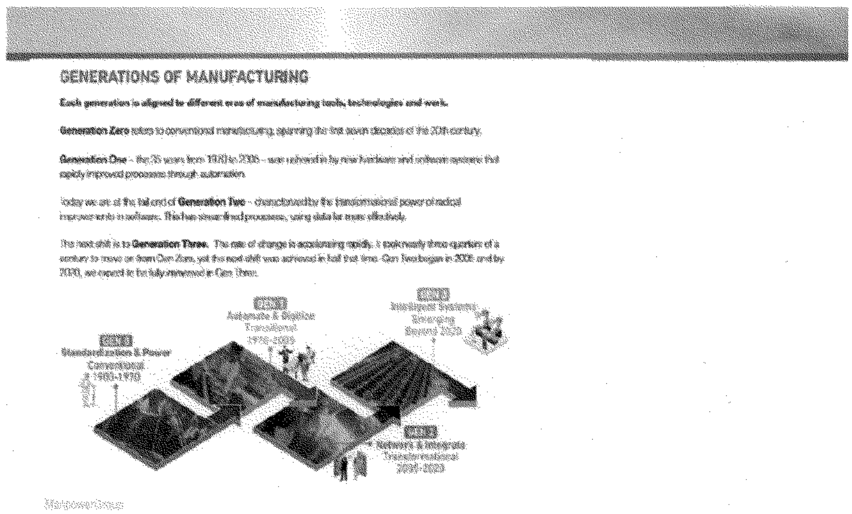
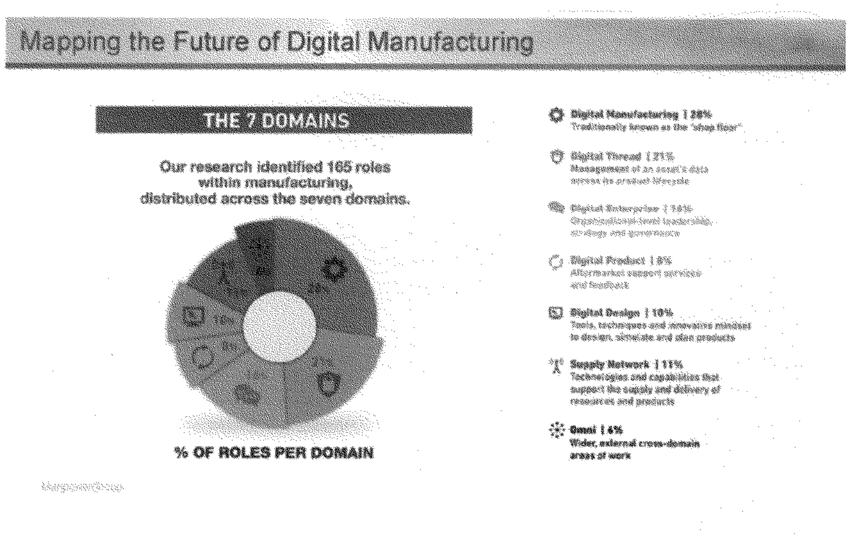


Figure 4: Mapping the Future of Digital Manufacturing



This last point out is born out in some key data. ***Figure 5*** shows the shift in both percentage of jobs and skills that employers are requiring as they increasingly digitize their operations, including an increased uptake in automation and AI technologies. ***Figure 6*** shows the increased investment that employers are making in training their employees. Much of this investment is driven by employers' understanding that the skills required to do jobs today are not the ones that will be required with tomorrow's technology. That said, based on our conversations with employers, ManpowerGroup has the following concerns:

- *First*: employers are uncertain about how digitization will impact roles and skills and over what time. As mentioned earlier, 75% of employers believe that digitization will require an evolution in skills, but they are less clear on the specifics of that evolution.

- *Second*: we hear regularly from employers across the spectrum of enterprise size that their ability to invest in upskilling falls short of what is required to produce the workforce they will need over time. Put simply, they need either more money or more time. Increasingly, the lack of skilled workforce is impeding their ability to invest in new technologies. A 2017 study by MAPI showed that for 60% of manufacturers surveyed, the number one impediment to investing in technology was a rightly skilled workforce.

- *Third*: the talent shortage is impacting employers across all types of talent: the transactional, entry-level talent on the production floor today; the transitional talent that will bridge their legacy and newly digital operations; and the transformational talent that will take them forward. This means that employers are having to determine the best way to allocate precious training and development dollars, what they will do themselves, and where they will need to invest in partnerships. This pain is felt across all sizes of employers, but there is a disproportional impact on the small and mid-size employers who not only have fewer resources, but also compete with large and mega-size employers who have established brands, richer benefits, and more varied career opportunities for employees.

Figure 5: Functions Anticipating the Largest Increase and Decrease in Headcount in the Next Two Years

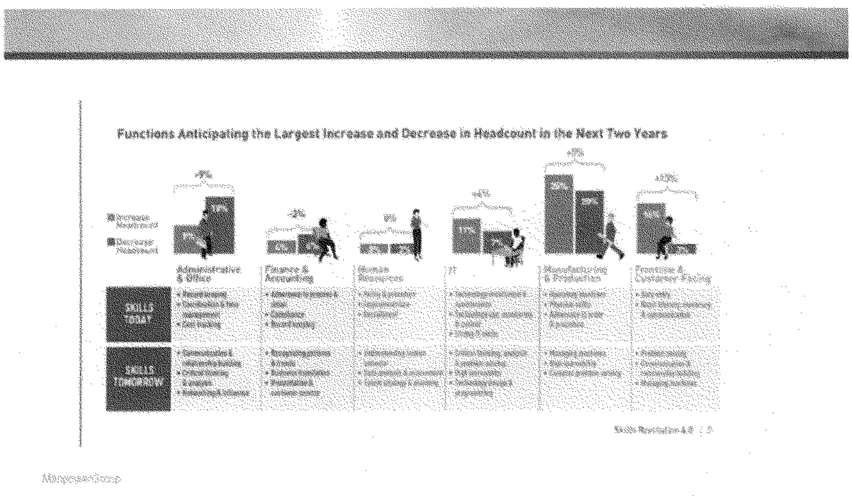
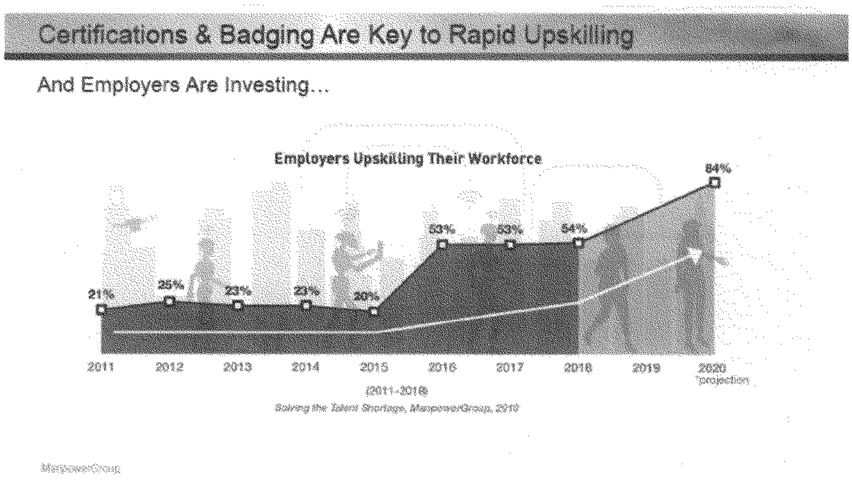


Figure 6: Certifications and Badging are Key to Rapid Upskilling



Worker displacement is a risk in jobs that are heavily routinized (picker/packer, helper/laborer, and certain assembly and operator roles). The potential for displacement in terms of size and timing is, as indicated above, variable, but it is coming. It is helpful to think of this in terms of ladders and pipelines. Today, the bottom rung of the ladder in production is represented by the heavily routinized roles that require little in the way of qualifications to perform. As digital technologies are increasingly adopted, the bottom rung of the ladder is redefined. It is crucial that those individuals currently qualified for only entry-level work get on the ladder and move up with intent. It is also crucial that talent that cannot progress to certain new roles be pipelined into other roles that are created or redefined that may not be on the production floors.

Doing this will require organizations to be resourceful in terms of what is most important in hiring talent. From ManpowerGroup's perspective, the most important thing to measure for will be what we call Learnability, that is the ability to learn and acquire new skills and adapt to changing circumstances. This will help employers and employees weather ongoing cycles of adaptation with resilience.

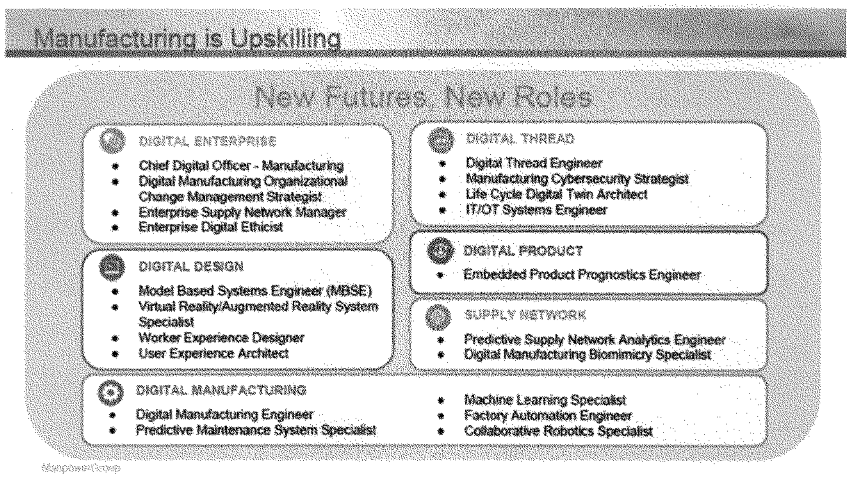
New technology adoption will create many benefits for employees and employers, not limited to the following:

Employees	Employers
• Improved worker safety through digital safeguards and predictive maintenance • Lower 'wear and tear' on workforce as robots take on repetitive motion and weight bearing tasks • Lowered barrier to workforce entry – examples: increased use of digital simulations for training and work process guidance • Enriched career paths that take individuals from entry level production to higher paying analyst, specialist, and technician roles or pipeline into newly created roles in other parts of the organization • More flexibility in how individuals work (at a distance, shift flexibility, etc.)	• Increased productivity • More rapid cycles of innovation improving overall US competitiveness in global manufacturing • Decreased waste as modeling evolves to increased use of digital twins for processes, products, services, and analytics for predicting behavior • Technology offsets some of the worker shortage, but this is offset by the need for talent to learn new skills to operate technologies in all domains of the modern manufacturing enterprise

It is worth noting that ManpowerGroup also anticipates significant growth in the professional segment. See ***Figure 7*** for a representative listing of roles that we see emerging. We anticipate a continuing surge of cybersecurity related roles as "more digital" and "more data" becomes the mantra of modern manufacturing organization. The security of data moving across production floors and through the supply chain, not to mention how data is being used to drive new IP in the US or how assets that are tied to consumer safety and data are secured means an explosion in workforce tied to managing security at all levels and in all domains of manufacturing. ManpowerGroup's real-time analysis shows a shortage of 500,000 IT workers today.[7]

This shortage will compound very quickly as malicious attacks grow in both number and sophistication and goes beyond the IT domain into process and policy work, risk mitigation, data quality, and threat awareness. Additionally, we anticipate growth in the number of individuals who are responsible to train AI, determine strategic direction on product and process opportunities that emerge from the increased use of AI, provide guardrails and checkpoints on those strategies, and translate strategic direction into tactical execution. We also anticipate that in a more digital era, a premium will be placed on human connection, driving a surge in roles related to customer experience. These represent real opportunities for career path progression from all areas of the manufacturing organization.

Figure 7: Manufacturing is Upskilling



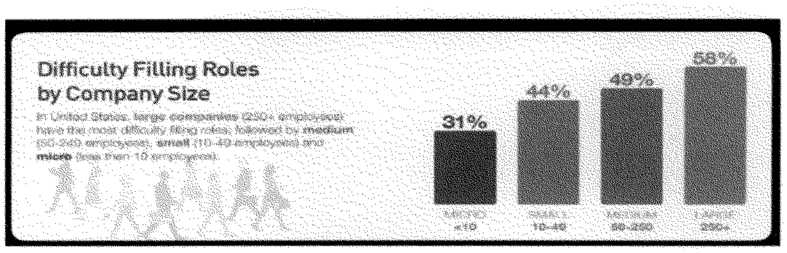
[7] Data is ManpowerGroup Solutions proprietary analysis and the data is aggregated across multiple platforms including but not limited to ManpowerGroup's Recruitment Difficulty Index, ManpowerGroup Solutions TAPFIN IntelliReach platform, Gartner Talent Neuron and Bureau of Labor Statistics

Unique Challenges for Small and Medium-Sized Manufacturer's

Most manufacturing firms in the United States are quite small. In 2016, there were 249,962 firms in the manufacturing sector, with all but 3,837 firms considered to be small (i.e., having fewer than 500 employees). In fact, three-quarters of these firms have fewer than 20 employees.[8] These organizations face unique challenges in the digital era, yet also have unique opportunity to benefit from it. Small and Medium-Sized Manufacturer's (SMM's) must invest in digital technologies that will help them grow and evolve their products and services that align with shifting market demand. They must invest in technology, however, any investment in tech is wasted if they aren't also investing in talent that have the skills to use it.

The double squeeze outlined earlier is also impacting SMM's. We hear regularly from SMM's that they are having difficulty in finding, hiring, training, re-training, and retaining talent. ManpowerGroup's 2018 Talent Shortage Survey reveals that small and mid-size companies have a bit of an edge. ***Figure 8*** shows that though micro and small companies across all sectors are having difficulty finding talent, the largest companies experience the highest level of difficulty.

Figure 8: Difficulty Filling Roles by Company Size



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- Opportunity: Generally, SMM's have more flexibility to take risks and be creative when tapping under-leveraged populations as there are fewer and less complex processes and systems for them to navigate in the talent acquisition and retention process. They can also be more creative in creating career, equity stake and owner pathways.

- Challenge: Traditional career paths are limited relative to their larger peers and in many cases are competing with larger organizations with richer benefits packages with greater leverage in pay and incentive plans and more varied career opportunities. Many SMM's have felt the sting of investing in creative recruiting and

[8] U.S. Census Bureau, Statistics of U.S. Businesses

training programs just to see the talent siphoned off by larger corporations. Though SMM's can be nimbler and more creative, they have fewer resources to invest in talent acquisition, and learning & development and more inherent risk if the bets they have made on building talent don't pay off.

- Distinct Challenge: SMM's have higher risk when it comes to cybersecurity as many of them do not have the resources to invest in specialized talent. In many cases, a single individual wears many hats (for example, an engineer doing the work of engineer, IT, and safety). As the costs associated with these risks escalate, there needs to be strong consideration around what talent pool SMM's can tap into to better secure the supply network.

SMM's will need to be incredibly resourceful in how they navigate acute talent shortages and evolving roles and skills in the digital era. The good news is that their size lowers barriers to creativity and agility; however, they will need more support from public and private entities such as the MEP network to guide their short- and long-term talent strategies and market their unique career opportunities. SMM's will need to seek out ways in their communities to work with each other and their customers to create talent channels to create effective change. Shared platforms - or coopetition - that maximize their investments on talent acquisition, learning & development, employee transportation, and talent sharing will be important especially as they increasingly consider non-traditional pools of talent that can help them out of their talent crisis.

Retraining and Professional Development of Current Workforce

With less than one person available for each job opening in the U.S. today[9] finding rightly skilled talent for the manufacturing workforce has never been more challenging. The manufacturing sector in the U.S. is estimated to produce up to 2 million new jobs over the next decade. At the same time, almost 2.7 million manufacturing workers are set to retire by 2025 (taking their knowledge and skills with them).[10]

Against the demographic backdrop outlined in the first section, we know new workers will not be enough to close the gap. Technological evolutions will be able to close some of the gap, but we must become far more resourceful in how we look at our current workforce and workforce re-training programs.

This is not just about worker training specific to production roles, but also the entire ecosystem of manufacturing as well as pipelining individuals into jobs where they have *adjacent skills* (as noted earlier, ManpowerGroup believes there will be growth in cyber, quality, customer service, analyst, specialist, and technician roles). There are several obstacles to ensuring mobility of talent inside of organizations:

- Strategic workforce planning – organizations struggle to balance the long-term and short-term of their workforce planning. It is difficult for them to predict needs more

[9] Bureau of Labor Statistics. September 2019, https://www.bls.gov/news.release/empsit.nr0.htm

[10] Skills Gap and Future of Work Study, Deloitte Insights and The Manufacturing Institute, 2018

than one year into the future.

- Systems and processes – talent acquisition and management systems have been fine-tuned to assumptions around abundance. Systems and processes are geared toward getting the highest possible fit and systematically weeding out talent that is not an exact match. As hiring on potential becomes increasingly important, systems need to be re-programmed and re-trained (many are increasingly AI driven) and processes need to be re-thought.
  - Our analysis showed that in September 2019 there were over 500,000 open IT jobs in the U.S. – that's roughly the population of Minneapolis. Almost half of these jobs are for software engineers and a quarter are IT project managers. Employers are demanding more specific skills for these positions today than they did two years ago, such as expertise in Amazon Web Services rather than just Cloud. In two more years, it will be different again. This rapid evolution is having tremendous ripple effects on all industries, especially manufacturing. Therefore, processes that govern workforce eligibility need to be revisited to determine if they are unnecessarily restrictive and artificially limiting the available talent pool. Similarly, talent management systems that support the existing population need to be re-set to make talent mobility options more transparent to hiring managers.

- Evolved job descriptions – job descriptions are created and often stay stagnant, long after technology has impacted the jobs and evolved the skills required to do them. Modern HR Information Systems do not currently allow for rapid evolution of job descriptions nor is there a general culture and mindset that supports continuous evolution of skills in an organization. This is predominantly because, from a historical perspective, evolution of tasks to create outputs was seen as something that needs to be aligned with payrate increases. Today the tasks are the same, but they are done differently, which does not always require a revision in the compensation plan.

- Sufficient funding for worker training – Learning & Development organizations have been downsized and more worker training is being accomplished through partnerships and cooperative agreements. Organizations are in the tough position of determining which roles need training first and how to deliver it at speed and scale. Navigating funding options for worker training at the state and federal level is complex and the requirements from incentives for specific pools of talent, types, of training to measurements of success can be drastically different. In some instances, funding programs are aligned to outdated definitions (such as multi-year and 2,000-hour requirements on certain apprenticeships) and do not align with organizations' willingness to experiment and take risks. The net impact is that an organization's pilot program on worker training may be limited in its scale and benefit only a relatively small percentage of workers.

The critical blend for the workforce now and in the future is soft, technical, and digital skills as shown in ***Figures 9 and 10.***

Figure 9: Most Valued Soft Skills by Function; Hardest to Find Soft Skills by Function

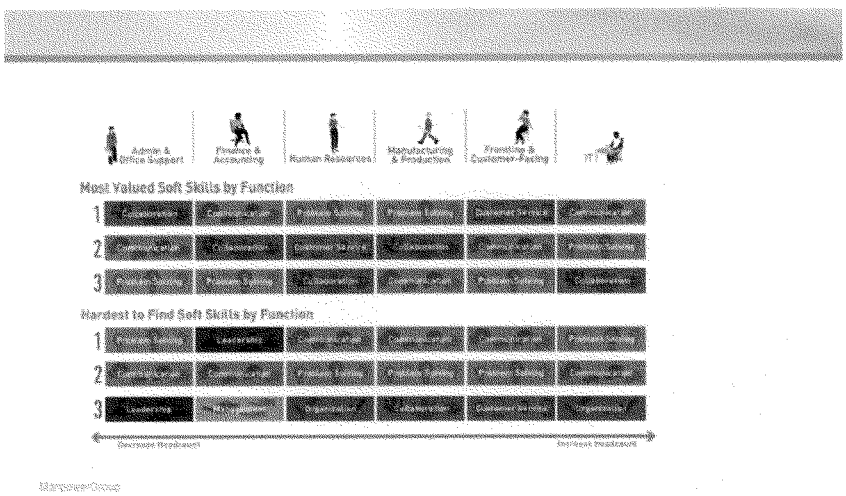
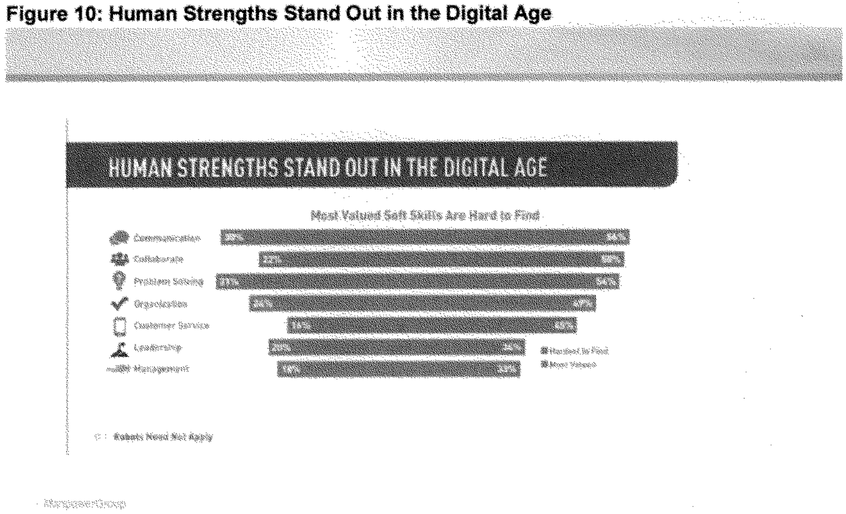


Figure 10: Human Strengths Stand Out in the Digital Age



Improved Training & Recruitment to Develop Skilled Technical Workforce

While much of the training and recruitment needs are addressed above there are additional points to consider.

An example of improved training for a skilled technical workforce can be found in our work with Veterans. Veterans share many technical and soft skills that are critical in the digital economy, but often have difficulty representing their skills in terms employers understand. This is increasingly prevalent in high tech manufacturing jobs where electro-mechanical skills are at a premium and where large numbers of military personnel are working on industrial computer systems. We looked at skills adjacencies and the concept of learnability using in-depth assessments and identified veterans who'd benefit from the Academy of Advanced Manufacturing. In partnership with Rockwell Automation, we invested in an academy to upskill and reskill veterans for higher-paying, in-demand jobs within the digital manufacturing industry. The program continues to be a win-win. We're helping service men and women earn more – the majority of academy graduates have doubled; some even tripled their previous salaries - and stay employable for the long term while helping employers address their skills gap.

In recruiting, we need to be more resourceful in working with under-leveraged populations such as formerly incarcerated, limited eligibility (no HS diploma or GED), women, individuals with physical and cognitive disabilities. It would take 243,934 people with Disabilities to connect to jobs and match their respective unemployment rate to the 3.7% national rate. There are also over 400,000 military spouses in the U.S. and only half are participating in the labor market with double the national unemployment rate.[11] These represent excellent talent pools to tap into and digital technologies decrease the amount of time to train, onboard and provide ongoing reinforcement.

We need to reimagine partnership between individuals, education and employers and become systems thinkers. Talent strategy has evolved from a historical high-growth, highly stable environment, where companies had time and resources to be builders of talent. Individuals joined organizations for life and stayed long enough to provide a strong return on investment.

Globalization brought shrinking margins and cost-cutting. Companies responded by labor cost reduction and just-in-time recruitment. Wages, once set by the enterprise, are now set by the market, and the bifurcation of the workforce began. Higher skilled people enjoyed pay increases, lower skilled people did not. Companies became consumers of talent and minimizers of overall labor costs.

Now, companies need to quickly adjust to what is happening in the marketplace to get a quicker return on investment and grow. Talent cycles are shorter, so people need to upskill in short bursts. Training has to impact more quickly and present a faster time to value. Even with low unemployment, wages are rising for people with in-demand skills.

To win in the digital age an effective talent strategy should have four parts: build, buy, borrow and bridge. See ***Figure 11.*** Build your talent pipeline by identifying future potential, driving a

[11] Bureau of Labor Statistics. September 2019. https://www.bls.gov/jlt/

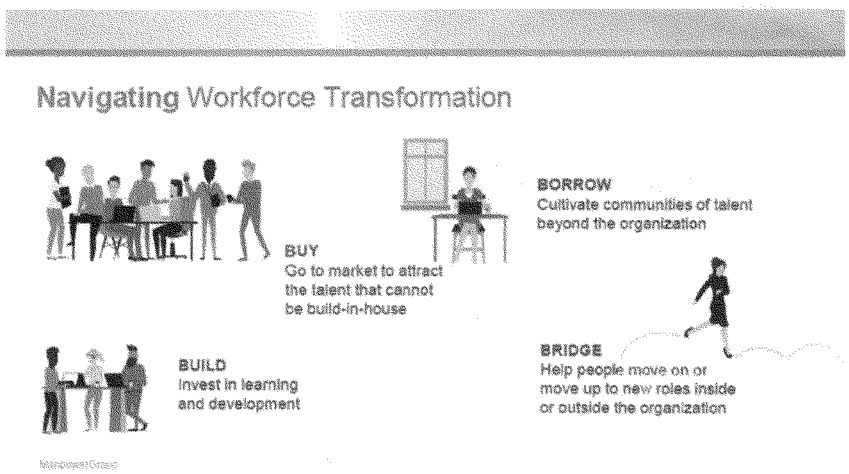
culture of learnability through the organization and providing accelerated training programs will be critical to success in the digital age.

Buy skills where necessary. Employers need to understand that candidates are consumers too; in order to attract and engage the best and brightest, HR needs to be a master marketer. we need to continue to evolve the narrative around manufacturing. The word manufacturing connotes 'dark, dirty, and dangerous.' Better messaging needs to align with words that attract talent: makers, maker spaces, innovation, high tech, etc. Manufacturing is where innovation and high tech go hand in hand.

Borrow from external talent sources. Organizations must learn to cultivate communities of workers inside and outside of the company.

Bridge people with adjacent skills from one role to another to complement existing skills. Leaders have a critical job to optimize the skills they have and find alternative pathways so those whose skills no longer fit can bridge to changing or emerging roles.

Figure 11: Navigating Workforce Transformation



Conclusion

Digitization, automation and transformation are impacting every industry, disrupting skills and creating new jobs. Manufacturing is the vanguard, with new roles appearing as fast as others become obsolete.

Manufacturers are reporting growing talent shortages as they struggle to find the right blend of technical and soft skills to fill new positions. The catalyst for the early stages of this skills shift was automation – machine strength. Now sector wide transformation has been turbocharged by the Internet of Things, the digitally connected enterprise, the relentless expansion of data and Artificial Intelligence (AI) to handle the scope of the challenge – machine thinking.

The potential for manufacturing to transform industries and drive economic growth has never been greater, thanks to the rapid advancement of new technologies. Against the backdrop of an existing skills shortage and with skills needs evolving so rapidly, we can only reach this potential with new and evolving skills for the current and future workforce. Talent is the most renewable resource on our planet: ready to learn, adapt and thrive in new environments. Employers can no longer go to market to buy new skills when they want them. We need to all become builders of talent to develop a workforce with the skills employers and individuals need to remain competitive.

ManpowerGroup™

Rebekah Kowalski

Vice President, Manpower Manufacturing

Rebekah Kowalski was appointed Vice President of Manpower Manufacturing in January 2019. She leads a matrixed team of sales, marketing, delivery, service, and consulting professionals across Manpower's Enterprise (national) and Convenience (branch-based) teams to drive break-through growth in the sector in the US and Canada and to upskill Manpower's thousands of North American-based associates.

Rebekah's work focuses on developing solutions that help organizations and leaders deal with the implications of both the shortage of rightly skilled workers, and the evolution of roles and skills. Rebekah led the team that worked with MxD to identify how roles and skills will evolve as manufacturing transforms with the introduction of more digital technologies.

Previously, Rebekah served as Vice President, Client Workforce Solutions - ManpowerGroup, North America, driving business growth through cross-brand solution development that supported clients and their workforce by creating sustainable pipelines of future-focused talent through new models and partnerships.

Rebekah is a recognized expert in innovative workforce solutions in the Manufacturing sector. She co-created and leads with Rockwell Automation the design, development, and management of the Academy of Advanced Manufacturing, a partnership between ManpowerGroup and Rockwell Automation to develop future-focused talent.

Rebekah is passionate about education leading into a sustainable career and has served on both the Board of the Wisconsin Education Business Roundtable and the Executive Committee of Competitive Wisconsin. She is currently an active member of the University of Wisconsin System Business Council and the Advisory Board of i.c.stars, an immersive technology workforce training and placement program for promising young adults.

TESTIMONY OF DR. SUE ELLSPERMANN, PRESIDENT, IVY TECH COMMUNITY COLLEGE

Dr. ELLSPERMANN. Thank you, Chairwoman Stevens, Ranking Member Baird, welcome, and Representative Marshall. It's really a privilege to be here representing community colleges today, and Ivy Tech Community College specifically, as we talk through machine learning, artificial intelligence, and particularly how that's affecting community colleges, and how we're working with industry and businesses to establish an ecosystem to address the changing demands. I also will speak at the end about what the Federal Government could do to assist in this work.

So remember that community colleges are the most common type of U.S. college, with Ivy Tech being one of those, established in 1963 as a vocational/technical college, now the largest in the Nation Statewide system, singly accredited, with 150,000 students and 18 campuses, 40 locations. But think about our student, who is now—the traditional student is that community college-like student, who is part time. Average age is probably 27 years old, Pell eligible, and a quarter of those students have dependents, children, that is, and you can see more in our report.

But how will that impact us as we look at AI and machine learning? And what you heard from several of my colleagues here is that there will be some displacement, but with that displacement will become very good opportunities, and it's up to our community colleges to prepare those students, those employees, for the wide spectrum of industries and opportunities that are out there. So let me talk about just a few of the very concrete things that we've done, and I thank Ms. Kowalski for sharing some of those as well in the manufacturing space, but one that I'm sure she'd be interested in is the partnership that Ivy Tech's done with the Smart Automation Certification Alliance as they've developed the first certifications in industry 4.0, which we know will be factories of the future, and the kind of credentials we'll need in that very connected manufacturing environment.

But at the community college level, we work with many partners, for instance, Sales Force, through their Pathfinders Program to earn Sales Force developer and administrator certifications. We have many certificates in informatics and software development at the Associate level. We work with Apple in their iOS systems applications. We work with Cisco, as they overhaul their certifications, to embed those right into our IT programs. With Amazon Web Services, we are developing cloud computing certificates, and soon to be an Applied Associate in Cloud Computing. All of those are staying with those industries and particular businesses to make sure that we're providing our students with the kind of skills that they will need.

I'm going to speak to a partnership we have with industry, particularly our Achieve Your Degree Program, which is a redesign of the tuition reimbursement program, where industries actually pay for, at the end of that cycle, the tuition that that employee of theirs pursues, but we, concierge-style, come to the industry, that business, to enroll, to do financial aid eligibility, and then to ensure that the programs align with what the business has. In doing that, we've had a great partnership with our Indiana Chamber of Commerce, Statewide, more than 200 companies doing that. I'll just share one, with Cook Group in Bloomington, Indiana, where 500 of their employees are being skilled up, have already earned 100 credentials in the last 3 years.

Now, in design, we put everything, from an economist standpoint, into quadrants to make sure that the highest demand areas with the smallest supply of employees are being built up into those particular quadrants. We'll describe those quadrants more in our full report, but in doing that, we make sure that we are putting our focused energy in the high-demand areas, that we're shrinking problems that need to shrink, and that we are seeking equilibrium in this highly changing environment. And it's working. In IT we, just last year, increased our completions by 75 percent in a single year, and we see that across our programs.

I'm going to spend my last moments talking about what we could do with some Federal support. You know, employers hate to have to pay Unemployment Insurance (UI) into that trust fund. Several years ago, most of our States were in a deficit. We were in Indiana. Congressman Baird remembers that. Today we are at $900 million in the black. Those funds could be deployed toward this work rescaling earlier than when that person is displaced, but when you decide on that technology, and we're hopeful that there will be some willingness of this Congress to look at making that available to a State and a community college system to experiment with how we could deploy a portion of those UI funds in these ways. We look for all kinds of support in reducing regulation so that we can change at the speed of the technologies that we're working with to ensure that all of our workers have those opportunities. And with that, I'll just thank you for the opportunity for appearing before the Subcommittee, and the opportunity to share the work of Ivy Tech Community College.

[The prepared statement of Dr. Ellspermann follows:]

Written Statement of Dr. Sue Ellspermann, Ph.D.
Ivy Tech Community College of Indiana
Before the Research and Technology Subcommittee
Of the Committee on Science, Space, and Technology
Hearing Title: *Artificial Intelligence and the Future of Work*
United States House of Representatives
September 24, 2019

Chairwoman Stevens, Ranking Member Baird, and Members of the Subcommittee, thank you for the opportunity to appear before you today to represent Ivy Tech Community College of Indiana and share with you the work that we, and other community colleges across the country, are doing to develop a skilled technical workforce of the future.

Today, I will discuss how machine learning and artificial intelligence are affecting how community colleges and vocational schools educate and train the workforce; how Ivy Tech Community College is working with industry, government, and academia to establish an ecosystem to address the changing demands for the skilled technical workforce; how Ivy Tech is using its Career Coaching and Employer Connections program to assist students in developing a career plan for the jobs of the future; and how the Federal government can work with community colleges and vocational schools to address future research and education needs.

Community colleges are the most common type of U.S. two-year colleges, and they offer millions of students a better way to reach their goals, whether their goal is to get a good career in a shorter period of time, or to get a better, more affordable start to a bachelor's degree by transferring credits on to a four-year school.

For its part, Ivy Tech was founded in 1963 as Indiana Vocational Technical College. Back then, we focused primarily on technical and vocational education. Now, we are Indiana's only community college, a statewide entity with 18 campuses and more than 40 locations. We are accredited by the Higher Learning Commission and offer programs in advanced manufacturing, engineering, and applied science; information technology; nursing and health sciences; business, logistics, and supply chain; public affairs and social sciences; and arts, sciences, and education. Additionally, we offer more than 100 transfer programs with in-state and out-of-state schools and provide students with hands-on experience in some of the state's most advanced technologies and training facilities. While we are the largest singly-accredited statewide community college system in the nation, we shape our curriculum with the needs of local communities in mind and keep higher education accessible for those communities' residents, which results in over 97% of our graduates staying in Indiana.

Our students typically attend on a part-time basis, and the average age of our students is 27 years old. Half of our students are Pell-Eligible and 24% have dependents.

Ivy Tech Student Demographics	
White	73%
Black/ African-American	11%
Hispanic/ Latino	4%
Multiracial	4%
Asian	2%
Other / Not Available	5%

How machine learning and artificial intelligence are affecting how community colleges and vocational schools educate and train the workforce.

Most conversations about the impacts of artificial intelligence (AI) and machine learning in the workplace end with one word: displacement. It is true. Research by The Center for Technology at Brookings states that 14% to 54% of jobs will be eliminated due to automation over the next 20 years. In addition, more than half of CEO's suggest they will be reducing jobs while only 16% plan on increasing jobs. Low-skilled workers in industries such as manufacturing, logistics, and customer service call centers will indeed be displaced, but that does not mean they will be unemployed or unemployable. According to Forbes, where the evolution of technology threatens jobs, it also creates new jobs. Because community colleges were created to be responsive to workforce and student needs in particular communities, AI and machine learning challenge community college and vocational school leaders to prepare a wide spectrum of students for industries that are changing faster than higher education has been able to move in the past. As such, community colleges are forming new partnerships with businesses to provide employers with exactly what they need out of their employees by developing new certifications and nimble programs to address the demand and changes that will inevitably arise from the implementation of AI and machine learning. At the community college level, programs of study have become more flexible in delivery methods by adding more online coursework and through restructuring traditional timing of course work through accelerated programs and shorter course offerings like eight-week courses.

How Ivy Tech Community College is working with industry, government and academia to establish an ecosystem to address the changing demands for the skilled technical workforce;

Ivy Tech is addressing the changing demands for the skilled technical workforce in many ways by partnering with industry leaders to develop flexible degrees that are interdisciplinary in nature, changing our delivery models for class offerings and receipt of payments to best meet student and employer needs, and establishing a comprehensive data-driven program and workforce demand review process to ensure we are keeping our fingers on the pulse of changes in our communities.

Partnerships with industry leaders enable Ivy Tech to address the changing demands. For example, the College has partnered with the Smart Automation Certification Alliance (SACA), other community colleges, and businesses across the country to develop certifications demonstrating competencies in Industry 4.0 skills. We are embedding those certifications in our current programs and training faculty to teach the content. These credentials can be stand alone in the form of digital credentials.

The College's partnership with Salesforce, called Pathfinder, provides students with technical and business skills training to earn a Salesforce Developer or Administrator certification. This qualifies them to fill more than 300,000 positions at Salesforce partner employers. In 2020, the School will introduce two certificates into the Informatics and Software Development associate degree programs allowing the certifications to crosswalk into new College credit-bearing certificates. We have partnered with Apple to build its Swift curriculum – the program language for development of the iOS applications – into our software development degrees, enabling students to earn certifications and giving them access to Apple partner employers. Ivy Tech is also working closely with Cisco as they overhaul their certifications, which will also be embedded within our School of IT programs. The rising amount of data via the Internet of Things (IoT) requires technical solutions to both manage data and perform data analytics – data stored in the cloud. Via a partnership with Amazon Web Services, the School of Information Technology has created a framework for the creation of "Emerging Technology" certificates, including a Cloud Computing certificate with courses from the Amazon Web Academy. Ivy Tech foresees the creation of an Associate of Applied Science in Cloud Computing as well.

Through each of these partnerships, the College acknowledges that the future of education is through life-long learning that allows students to advance in their careers while they continue to earn valuable credentials that build on one another.

We know that in the future we will need to develop new degrees that support careers not in existence today. The model we have now will allow us to develop those quickly and align them with the needs of our employers in all areas of the state.

The College is also working to address demands by changing our delivery models for class offerings and receipt of payments to best meet student and employer needs. One change is through eight-week course format offerings, which allow students to focus on fewer courses at a time and to complete their degrees more rapidly. National data showed that eight-week course offerings support increased student success over the traditional 16-week sessions, and the results at Ivy Tech have been similar. We have found that our course success rates are higher and drop rates lower for students in 8-week courses than in traditional 16-week courses, and this is especially good for students who are working while attending school, allowing us to address the requirements of employers who continue to have business needs while wanting to encourage employee development.

Additionally, Ivy Tech has created an accelerated Cyber Academy in partnership with the Indiana National Guard at the Muscatatuck Urban Training Complex, the Department of Defense's largest urban training center. Students earn a Cyber Security/Information Assurance Associate of Applied Science degree in an 11-month, 60 credit hour program, which includes flexibility to modify up to 20 percent of the course curriculum to meet emerging military requirements and needs for cyber-military occupational specialties.

Most notably is our Achieve Your Degree (AYD) program, a proven construct for collaboration between Ivy Tech and employers marketed through the Indiana Chamber of Commerce to offer employees the opportunity to earn a community college education at minimal cost aligned with employer professional development goals and business outcomes.

All degree programs and pathways are approved by the employer with the intention of supporting internal professional development and training opportunities to reduce turnover, foster loyalty and career advancement within the company. These employer approved program offerings include stackable credentials, cohort course offerings, individual academic plans aligned with employer professional development, and dedicated Ivy Tech courses.

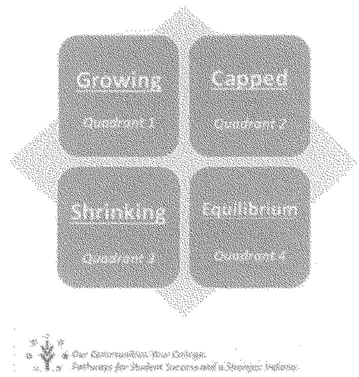
Through AYD, the College identifies financial aid, if available, and uses tuition deferral, coupled with a company's tuition reimbursement policies, which serves to eliminate or greatly minimize student upfront costs. This is achieved through the use of tuition deferral, in-state tuition, scholarships, and gap funding by employers or community organizations.

Bloomington, Indiana-based Cook Group is one of 200 College partners in this effort and has been one of the biggest with nearly 500 Cook employees enrolled and 100 credentials earned within the last three years. Through Cook's agreement, participants can earn a certificate stackable through associate degree in seven programs including biotechnology, business administration, hospitality, and various computing and informatics tracks aligned to their business needs.

To ensure the College remains focused on the occupational demands in each area, in 2017, the College began classifying programs into one of four quadrants, developing campus-level and statewide metrics to measure annual progress toward the goal of producing graduates in high-demand fields, meeting the current and future needs of Indiana employers.

Those classification are as follows:

- Growing: High-Demand from Employers/Low Supply Completions (Quad 1)
- Capped: High-Demand from Employers/Limited-Enrollment Completions (Quad 2)
- Shrinking: Low-Demand from Employers/High Supply Completions (Quad 3)
- Equilibrium: Demand/Supply Equilibrium (Quad 4)



Ivy Tech campuses analyze local supply and demand data annually as part of their program review process, which guides decisions to grow or suspend programs. The program review process requires campuses to evaluate program offerings that do not meet enrollment and completion thresholds, taking market demand into consideration. Examples of programs suspended based on market demand data and employer feedback include: Criminal Justice and General Studies programs in South Bend and Anderson. Suspending programs that are not aligned to local demand allows campuses to reallocate faculty and resources to grow high-demand programs. For example, several campuses added faculty to the Supply Chain Management program, and every campus now has Information Technology programs aligned to their employer needs. Supply Chain enrollment grew 21.8% from fall 2017 to fall 2018, and this growth will accelerate due to the addition of faculty and active marketing and recruiting.

Ivy Tech's School of Information Technology focused on the continued growth of IT programs, reflective of the ever-increasing demand for IT talent statewide. Due to the strong marketability of skills attained by Ivy Tech students as well as the local, state, and national demand within the

Information Technology sector, the number of course enrollments in IT classes increased by 21.1% from spring 2017 to spring 2018. Moreover, the highest percentage increase in completions for the entire college came from the School of Information Technology over both recent one-year and two-year periods at 74.8% and 162.4%, respectively.

Responding to Indiana's tremendous demand for registered nurses and licensed practical nurses, Ivy Tech's School of Nursing optimized faculty loading, hired additional faculty where needed, more efficiently utilized campus resources, and took advantage of state legislation that allows the College to hire faculty with Bachelor of Science credentials who are currently pursuing a Master's degree or Nurse Educator certificate. These efforts resulted in increased enrollment in nursing programs, with 2,946 students enrolled in Associate of Science and Practical Nursing programs at 18 campuses in fall 2018. The school graduated 1,564 students from the Associate of Science and Practical Nursing programs in the 2017-18 academic year, with an on-time completion rate of 83%. Campuses continue to work toward the expansion of nursing programs, including building or re-modeling in Muncie and Kokomo. Parkview Health in Fort Wayne entered into a shared staff/faculty memorandum of understanding (MOU) with the College that allows a Parkview nurse to work as a full-time Ivy Tech faculty member for two years at the College's Fort Wayne campus. Ball Memorial Hospital in Muncie signed a MOU allowing for a "Dedicated Education Unit" that allows one unit of the hospital to be solely dedicated to Ivy Tech nursing students. All will allow for increased enrollment as long as the number of nursing and health sciences faculty also increases.

The College now integrates analyses of workforce supply and demand data into considerations of physical plant investments, equipment funding, and personnel decisions. In the area of physical plant investment, each campus is now required to tie labor market supply and demand analysis to their capital project requests. That analysis serves to illustrate current and future needs of employers in the service area. This results in renovations and other changes to campus facilities being tied directly to determinants such as the needs to grow, sustain, minimize, or eliminate programs. Coupled with this approach around capital projects and physical plant, all requests related to equipment, including annual Perkins Grants requests, are required by the College to be tied directly to the supply and demand analysis.

Overall, this strategic approach of leveraging supply and demand data has created more robust discussions for campus, employers, community, state, and College systems office leaders around the importance of thoughtfully utilizing scarce resources and their appropriate allocation.

How Ivy Tech is using its Career Coaching and Employer Connections program to assist students in developing a career plan for the jobs of the future

Over the past year, the College has worked to integrate career outcomes as a vital part of a student's academic journey from application through employment. The college's new Office of Career Coaching & Employer Connections (CCEC) will engage with students early, often, and proactively to provide career support and track completion of indicators. At the beginning of their Ivy Tech experience, students will utilize career exploration and clarity tools as well as labor market data to select a program aligned with their interests, skill sets, and desired wage and employment goals. As students make more informed choices about their fields of study, they will switch programs less frequently and be more likely to choose a higher wage, high-demand career path. Students will develop a Career Action Plan (CAP), completing tasks strategically designed to lead to work-and-learn experiences, which in turn will make students twice as likely to secure employment. The CAP includes resume development, ongoing interview preparation, regular engagement with employers, and employability skill development. Employers will have defined points of contact to assist them in navigating the engagement and recruitment processes to connect with students, developing work-and-learn experiences, and securing talent.

Ivy Tech's new approach to career services emphasizes career readiness practices alongside academics throughout the duration of the student experience. Implementation of these strategies will result in a clear and meaningful pathway for students to and through Ivy Tech that equips them with the knowledge and skills needed to thrive in the workforce. Skilled graduates will leave Ivy Tech prepared to attain meaningful careers, which will ultimately enhance the Hoosier workforce and economy and strengthen communities across the state. Further, Ivy Tech's goal is for students to report earnings at or above Indiana's median wage by one year post-graduation. CCEC will measure its success in achieving meaningful employment outcomes through rigorous data collection. Students will share their post-graduation status, including job placement and wages, through Ivy Tech's First Destination survey. Ivy Tech will validate data utilizing its existing partnership with the State of Indiana Department of Revenue and the Department of Workforce Development.

Recommendations for how the Federal government can work with community colleges and vocational schools to address future research and education needs.

Going forward industry and government need to work together to identify those workers whose jobs will be eliminated and begin skilling up immediately. One way to do this is to rethink federal unemployment insurance (UI) allowing employers to deploy a portion of the funds they are required to pay towards skilling up employees they know will be displaced by technology within the next two years. Indiana currently has a nearly $900 million surplus in UI and 50,000 open jobs that require a post-secondary credential. Federal regulations currently determine the number of days' notice employers must give to employees, so changes would need to be made to incentivize employers to give more advance notice, their ability to deploy UI funds towards upskilling, and enable employees to retrain before losing their job. Those jobs identified as more at-risk of being lost due to automation and digitization could receive a higher level of priority, and employees in those jobs, if given additional time, could spend a portion of the day on their existing job and portion of their day attending classes or training at a community college. While it is important to have funds to address needs during a recession, allowing a willing state and community college to serve as an experimental site would leverage the lowest cost training for individuals who will be most affected and reduce the amount of UI deployed as these individuals remain employed. The impact of unemployment is far more than loss of a paycheck; it has psychological, family, and financial impacts. Solutions that proactively upskill individuals whose jobs will be replaced with technology should be a top priority of the federal government.

The federal government can also work with community colleges to modify regulations that hamper schools' ability to be nimble and meet business needs. Many regulations, while intended to protect against harm, do not serve the intended purpose and slow down approval processes needed to ensure that programs are financial aid eligible, and, on the student side, create additional obstacles for students. Programmatic reviews that are required for a simple name or course change can take months to receive approval, and students enrolling in short-term courses are still not eligible for financial aid because of program length. Additionally, student financial aid verification requirements result in lost aid to students who need it most.

States also need continued support of funding opportunities to support faculty training and equipment upgrades. Because technology so rapidly changes, it is important that students can train on current equipment. Use of virtual reality trainers can help some, but support of models like apprenticeships in nontraditional industries can advance work-based learning that is essential in developing the skills and experience employers require. Technology is constantly evolving and skills formerly required only by technicians and engineers like design, data analytics, and innovation are increasingly required by more entry-level positions.

Finally, the federal government can work in tandem with community colleges to reach underrepresented groups to encourage the attainment of post-secondary credentials in high wage technology intensive careers. Many of these potential students need wrap-around services like child care, transportation, healthcare, food, and even addiction services to successfully complete the credential that could help them improve their lives. Forward-thinking partnerships between community colleges and the federal government to develop holistic programs can help meet and anticipate the demand for skilled workers in an ever more AI, digitized, automated workplace.

Thank you again for the opportunity to appear before this Subcommittee and share the work of Ivy Tech Community College. I applaud and appreciate your leadership and service to our country.

ACHIEVE YOUR DEGREE™
IVY TECH COMMUNITY COLLEGE

INDIANA CHAMBER

Ivy Tech Community College and the Indiana Chamber are pleased to offer Chamber members a unique and innovative solution to meet current and future workforce needs. Achieve Your Degree allows employees the opportunity to earn a credential through a combination of online and on-campus coursework and defer the tuition payment until the end of the semester. Chamber members enrolled in the Achieve Your Degree program are eligible for a 5% rebate on paid employee tuition.

WHAT ARE THE BENEFITS TO MY ORGANIZATION?

The talent currently housed in your organization will be cultivated and developed; this talent will then become more involved in the community and will stay company-loyal due to your support.

WHAT DOES THE PROGRAM COST MY EMPLOYEES AND ME AS AN EMPLOYER?

You are responsible for anything the student's financial aid package does not cover, but Ivy Tech will help you design a tuition-reimbursement policy to cover these costs. The tuition payments for students will also be deferred until the end of the semester, ensuring students take advantage of financial aid opportunities. All employees will receive in-state tuition.

HOW DOES THE APPLICATION PROCESS WORK?

Ivy Tech staff will come on-site to assist employees with online applications for both the College and financial aid.

WHAT SUPPORT IS AVAILABLE TO MY EMPLOYEES?

Ivy Tech offers individualized advising, financial aid, admissions assistance, and tutoring to assist employees with their courses and help foster success. Ivy Prep, a program designed to develop skills to best prepare your employees for college math and English, is also available.

WHAT SUPPORT IS AVAILABLE TO ME?

Ivy Tech will provide you with all necessary collateral needed to advertise the program, as well as a point person to help coordinate everything for your employees.

Learn more at **indianachamber.com/achieve**
or call (800) 824-6885.

IVY TECH
COMMUNITY COLLEGE

ACHIEVE YOUR DEGREE™
IVY TECH COMMUNITY COLLEGE

INDIANA CHAMBER

NEXT STEPS:

1. Complete the Memorandum of Understanding
2. Work with Ivy Tech to determine a date for an on-site information and enrollment session
3. Determine your point person for the Achieve Your Degree program
4. Identify academic programs to fund
5. Market Achieve Your Degree program to your employees

BENEFITS OF ACHIEVE YOUR DEGREE AS A MEMBER OF THE INDIANA CHAMBER

Your organization:

- Chamber members enrolled in the Achieve Your Degree program are eligible for a 5% rebate on paid employee tuition
- State funding through Next Level Jobs grant opportunities
- Ivy Tech will help design a custom program tailored to your company's employees

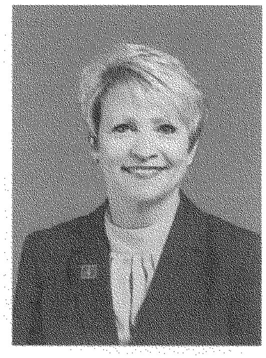
Your employees:

- Many class options, both in-person and online, available at multiple locations across Indiana
- Multiple start dates throughout the year
- Classes in 16-week and 8-week formats
- Expanded skillsets to become more valuable employees

Learn more at **indianachamber.com/achieve** or call **(800) 824-6885**.

IVY TECH COMMUNITY COLLEGE

Dr. Sue Ellspermann, Ph.D.



Dr. Sue Ellspermann has more than 30 years of experience in higher education, economic and workforce development, and public service.

In May 2016, Dr. Ellspermann was selected to serve as President of Ivy Tech Community College of Indiana, its first female president.

In January 2018, Ivy Tech launched its new five-year Strategic Plan, "Our Communities. Your College. Pathways for Student Success and a Stronger Indiana." The plan's vision is for Ivy Tech students to earn 50,000 high-quality certifications, certificates, and degrees per year aligned with workforce needs. The plan aligns with Indiana's goal to equip 60 percent of the workforce with a high-value, post-secondary degree or credential by 2025. Through achievement of this goal, the College will help increase Hoosier per capita income and support the transformation of the state's advanced industries economy. The plan development covered 18 months, including a restructure of the College, comprehensive fact finding conducted internally and externally, including thousands of faculty, staff, students and statewide stakeholders.

Dr. Ellspermann most recently served as Indiana's 50th Lieutenant Governor from 2013 until March of 2016. As the vice chair of the Indiana Career Council she led efforts to align Indiana's education and workforce development system to meet the needs of employers which is her continued focus at Ivy Tech. Her public service began in 2010 when she was elected as the State Representative for District 74.

Ellspermann formerly served as the founding Director of the Center of Applied Research and Economic Development at the University of Southern Indiana and also owned and operated Ellspermann and Associates, Inc., an independent consulting firm licensed in the training and facilitation of Simplex Creative Problem Solving.

Early in her career she spent time with Frito-Lay and Michelin Tire Corporation. Ellspermann holds a Ph.D. and M.S. from the University of Louisville in Industrial Engineering and a B.S. from Purdue University also in Industrial Engineering.

She is married to James Mehling, a former high school principal. She has a blended family of four daughters, three sons-in-law, two grandsons and two granddaughters.

Chairwoman STEVENS. Well, thank you all, and at this time the Chair would like to recognize Ranking Member Dr. Baird for his opening remarks. Thank you.

Mr. BAIRD. Thank you, Madam Chairwoman. I apologize for being late, but I do admire you for going on without me. Thank you.

Chairwoman STEVENS. We're a team, you know.

Mr. BAIRD. So I appreciate this opportunity. I appreciate you waiting on me, and I'd like to make this opening statement, and thank you for holding this "Artificial Intelligence and the Future of Work" Committee hearing. Since the term AI was introduced in the 1950s, we have made some huge advances in the field, and thanks to critical investments by government and industry, universities and the United States, in leading global AI research and development.

Today AI systems have been deployed in every sector of the U.S. economy. These technologies have already delivered significant benefits for the U.S. economic prosperity, for the environmental stewardship, and the national security. AI has long been a subject of interest of the House Science Committee, and we have held several important and productive hearings on this topic. In the past we have discussed how to define AI, the science of AI technologies, and the needs for standards to address ethics and potential bias. Now, this afternoon, we will examine AI from the prospective of the American worker.

In order to remain a leader in AI, I believe we must prepare our workforce for the next generation of opportunities in this technology, and for our future, defined by a lifelong learning experience. In order to grow our economy, I also believe we must acknowledge and understand how AI is changing, and will continue to change, the jobs and lives of hard-working Americans. This is a large scale effort that is going to require cooperation between industry that was already mentioned here, industry, academia, and the Federal agencies, so I'm pleased to see that the Trump Administration is making this issue a priority, and recently established the National Science Council for the American Worker and the American Workforce Policy Advisory Board. American industry has responded well to the Administration's initiatives. Over 300 companies and organizations have pledged to study and expand education, training, re-skilling opportunities for American workers to gain AI-relevant skills.

We also need to re-think how we educate future workers, and reskill the workers of today, all the way from K through 12 schools to the community colleges, the vocational schools, and the 4-year universities. Some leaders in the U.S. education system are already finding innovative ways to develop a highly skilled AI workforce, one of the future. We have heard about some of those efforts from my friend, Dr. Sue Ellspermann, President of the Ivy Tech Community College system in our home State of Indiana. Sue, so glad to have you here today. At Ivy Tech, Dr. Ellspermann works to address the changing demands of employers in the Hoosier State by providing strategic support and career planning for students at community colleges and vocational schools, and working closely with local industry. I look forward to hearing more about her important work in our community, and how it will be applied across the country.

Over the next few months, this Committee will be working toward bipartisan legislation to support a national strategy on artificial intelligence. The challenges we must address are how industry, academia, and the government can work together on AI challenges, including today's critical workforce questions, and what role the Federal Government should play in supporting industry as it drives innovation. I want to thank our accomplished panel of witnesses for their testimony today, and I appreciate the opportunity to hear how this Committee and the Federal Government can support innovation and education to ensure a bright future for America's workers, our students, and maintain our leadership in AI. So thank you.

[The prepared statement of Mr. Baird follows:]

Chairwoman Stevens, thank you for holding today's hearing on "Artificial intelligence (AI) and the Future of Work."

Since the term AI was first coined in the 1950s, we have made huge advances in the field. And thanks to critical investments by government, industry, and universities, the United States is leading in global AI Research & Development.

Today, AI systems have been deployed in every sector of the U.S. economy. These technologies have already delivered significant benefits for U.S. economic prosperity, environmental stewardship, and national security.

AI has long been a subject of interest for the House Science Committee and we have held several important and productive hearings on this topic.

In the past, we have discussed how to define AI, the science of AI technologies, and the needs for standards to address ethics and potential bias.

Now, this afternoon, we will examine AI from the perspective of the American worker.

In order to remain a leader in AI, I believe we must prepare our workforce for next generation opportunities in this technology and for a future defined by lifelong learning.

In order to grow our economy, I also believe we must acknowledge and understand how AI is changing and will continue to change the jobs and lives of hard-working Americans.

This is a large-scale effort that is going to require cooperation between industry, academia and federal agencies.

So I am pleased to see that The Trump Administration is making this issue a priority and recently established the National Council for the American Worker and the American Workforce Policy Advisory Board.

American industry has responded well to the Administration's initiatives. Over 300 companies and organizations have pledged to study and expand education, training, and reskilling opportunities for American workers to gain AI-relevant skills.

We also need to rethink how we educate future workers and reskill the works of today, all the way from K-12 schools to community colleges and vocational schools, to 4-year universities.

Some leaders in the U.S. education system are already finding innovative ways to develop a highly-skilled AI workforce of the future.

We will learn more about some of those efforts from one of our witnesses today, my good friend, Dr. Sue Ellspermann, President of the Ivy Tech Community College system in our home state of Indiana.

At Ivy Tech, Dr. Ellspermann works to address the changing demands of employers in the Hoosier State by providing strategic support and career planning for students at community colleges and vocational schools and working closely with local industry.

I look forward to hearing more about her important work in our community, and how it can be applied across the country.

Over the next few months, this Committee will be working towards bipartisan legislation to support a national strategy on Artificial Intelligence.

The challenges we must address are how industry, academia, and the government can work together on AI challenges, including today's critical workforce questions, and what role the federal government should play in supporting industry as it drives innovation.

I want to thank our accomplished panel of witnesses for their testimony today. I look forward to hearing how we can support innovation and education, to ensure a bright future for America's workers and students and maintain our leadership in AI.

Chairman STEVENS. If there are Members who wish to submit additional opening statements, your statements will be added to the record at this point.

[The prepared statement of Chairwoman Johnson follows:]

Thank you, Chairwoman Stevens and Ranking Member Baird, for holding this hearing. I would also like to welcome this esteemed panel of witnesses and thank each of you for accommodating the rescheduling of today's hearing. We are here today to discuss an urgent challenge facing the country. Artificial intelligence is a rapidly advancing, sophisticated technology that promises to transform the way we live and work.

As Chairwoman, I take seriously the responsibility entrusted to this Committee to support the nation's research and innovation enterprise for the benefit of society. We are increasingly feeling pressure from our global competitors, particularly in the case of AI. As countries like the United Kingdom, Germany, and China invest heavily in this technology, there is a strong sense of urgency to race headlong toward technological maturity and widespread adoption.

I want to urge caution. We must take the time to draw upon lessons learned from past technological disruptions, assess the opportunities and potential risks, and implement a coordinated national strategy to ensure the benefits of AI are enjoyed by everyone. We are here to explore one of the primary concerns associated with AI - its potential impact on the workforce. Many Americans are understandably worried that AI-driven automation and robots will make their jobs obsolete.

Research has a critical role to play in informing how AI is integrated into the American workforce. Research can help employers understand the benefits and risks of this technology. Just because it seems like a task can be performed by an AI system, does not mean it can or should be, at least not without a human still in the loop. Research can also improve our understanding of the human-technology relationship. This can inform decisions regarding how best to integrate AI into the workflow so it can both complement and enhance the value of the worker. Research can advance the development of effective practices for retraining the current workforce and for ensuring workers have the flexibility to be lifelong learners. Research can provide students and those pursuing a career change with a clear understanding of emerging industries and occupations, so they can chart an education path best suited to their goals.

Artificial intelligence holds immense promise to spur economic growth and make our lives easier. We are at a critical point in the development of this technology, and we must ensure we have the research knowledge base necessary to maximize these benefits for everyone.

I look forward to today's testimony and discussion and I yield back.

Chairwoman STEVENS. Fabulous. At this time we're going to begin the 5-minutes of questioning, and the Chair will recognize herself for 5 minutes.

Dr. Lupia, in your testimony, you discuss a recent award made to the University of Michigan to support research on how humans and robots are working together in construction environments, and you stated that, despite recent advances in robot functionality, many fundamental questions in robot interaction remain unanswered. Do you mind elaborating on that a little bit further, and also, could you touch on some of the major social science research questions regarding human/robot interaction, and where we need to go from here?

Dr. LUPIA. Thank you for that question. As discussed in the opening statements, there are things right now that AI and robots can do that humans can't do, but there are many things that humans can do that robots can't do. And when we're thinking about the workplace of the future, particularly its impact on workers and workplaces, you know, there are these fundamental questions about what the two groups know now, and what can we expect them to know in the future, to empower workers.

So I think about farms, for example, right? So I grew up on a farm, and so, when I was a kid, people milked cows. And, if you've ever done that, it's not the most fun thing. But now they have robots that can milk cows, so if you think about how—just—a farm that's pretty simple, there are things that people can do that robots can't do, and things that robots can do that people can't do. And so, through a number of grants, we're trying to help factories, farmers, offices, and so forth think through, "How do you make workplaces more efficient?" "How do you make them more effective, with this set of evolving skills?"

Some of it requires trust, right? So if we're going to automate a manufacturing process, the worker has to trust the robot, or the machine. And trust is a great thing, unless the robot's about to do the wrong thing. And so you've always got to have an override capacity. What we're trying to do at NSF is bring large groups of people together to understand, at a pretty fundamental level, when is the trust relationship going to work, when is it going to fail, and as robots get better at things, how does that change how we should organize the workplace? So that's the fundamental question.

It takes understanding humans, because if you press the override button at the wrong time, you can disrupt the process. If you wait too long, unintended consequences can happen. So understanding the human/robot interaction is really critical to all of the progress we want, from manufacturing, to farms, to offices of the future.

Chairwoman STEVENS. To be successful. And, Ms. Kowalski, you might have given us the line of the day, which is don't count the humans out. And you also, in your testimony, discussed the rapid change in skills being sought by employers. And, you know, in terms of how we think about job descriptions to account for this rapidly changing marketplace for skills, and also promote a mindset of supportive, continuous skill development, how do we do it all? How do we bring that together?

Ms. KOWALSKI. So I think there's a few things. One is just determining that this is what we have to do, right? It's a decision that we have to make, that we cannot allow the workforce to stay still, that there is no grassy plateau on which we'll all be able to stretch out when transformation is done. It will be an unending climb, and evolution and adaptation, which we're very good at as human beings, right? But the way that we approached education and employment was we educated to the job. People came into an exact match environment, and then they made progressions up the ladder based on merit. We haven't seen something come in that acts so rapidly.

Think about automation, and the—it was about 15 years playing out in the last cycle. We're talking about something that's going to play out, by this research, in 3 to 5 years that's unfolding now. And it will get faster, and the peaks and troughs will get steeper, and so how we get people attenuated to that shift, that starts all the way back in K–12, and moves all the way through—and in employment. And the hardest thing is going to be taking the people that are currently employed and helping them understand they haven't done anything wrong. They are hardworking, they've been doing a great job, and these are the new set of skills that they have to assimilate, and there has to be a new contract, right? And that contract is one of you put in for continuous adaptation and evolution, we'll be right there to meet you with the resources.

You know when we were good at doing that? Was in the 1950s and 1960s, when we hired on potential. We built whole companies hiring on potential for jobs we didn't even know what they were going to look like, and people got used to making the progression, and having a partnership with employment and educators in order to do that. And it's going to take a system to do it.

Chairwoman STEVENS. Well, I am just at time, so—you can tell we're in a rich topic area. So I'm going to yield back the remainder of my time, and I am going to recognize Dr. Baird for 5 minutes of questioning. You've got this, Dr. Baird.

Mr. BAIRD. Thank you, Madam Chair. And, Dr. Ellspermann, I'm sure that you recognized I was probably going to start with you.

Dr. ELLSPERMANN. Thank you.

Mr. BAIRD. The thing that, and I know you spent a lot of time in this area, and thinking about it, but the needs of the industry today, compared to the future, and this technology that we're discussing today, is changing so fast because of quantum computing, and that sort of thing. So I guess, in other words, how do you feel, or how do you see Ivy Tech balancing that need for today, and then in the future? Kind of give us some feel what you think that might look——

Dr. ELLSPERMANN. Very good. So, actually, 3 years ago, the General Assembly in Indiana understood how important it would be that we would be work-forced aligned as a system, and actually required that, in addition to having a provost I have a Chief Workforce Officer, which makes sure this alignment happened.

So I alluded in my comments to this way that we classify all of our programs, because we know it's a moving target, we know that there is BLS (Bureau of Labor Statistics), and Emsi, and other good data out there, economically, to project the future. We know that broadly, but it's not accurate at the local level, so we take that, and we let the local industry work with us to look at what's coming, what is the real demand, and then we size our programs on every campus, every program, to be that right size.

And that's where our quadrants, that quadrant one of—quadrant one is where we focus. It is those high-demand, low-supply, not enough students to fill that work, and making sure we're building those programs. We have limited enrollment programs that we have to push on. We have programs that have to shrink so that they are the right size, or maybe discontinue, and then finally equilibrium. That work is working. It is working across our State. We can take the local data to understand that maybe the economic data is not quite accurate to what the local needs are, and we could shore up, and we could shrink, and we do that in a very rapid way.

What becomes challenging is the support at the Federal level to get those kind of programs, when you need new programs stood up, to quickly stand those up in 3 to 6 months so that an employer gets the kind of skill set that they need. And so we look to any support we can get with our U.S. DOE (Department of Education) to quickly approve programs. But, as I shared, looking at new ways to anticipate, when we know these changes are coming, and we know there's a higher demand, how do we identify that employee at risk early, even if it is just a year, or a year and a half in advance? We can then begin skilling before that individual is out of a job, unemployed, which is, for many, much more than just about being out of a job. It is psychological impact. It is a feeling that a trust has been broken with that employer, so how do we proactively work with them?

And whether we use Unemployment Insurance as a part of that trigger, we need to change that mindset to create that contract again between employer and employee. And I believe the community colleges, at least Ivy Tech, is working very hard to get there, but I know we will be the front lines for most of employers as they look to scale up their employees, and it's our job to be as rapid as we can.

Mr. BAIRD. Thank you. Dr. Lupia, I'm glad to hear you came from a farm, and I couldn't help but say—several of you mentioned the importance of the human factor. I think you mentioned that. But I just want you to know that those old cows have a vested interest in how well these—but anyway, I thought maybe you might want to elaborate—I've been fascinated by NSF's convergence accelerators since Director Córdova spoke about them in this Committee in May. Would you mind elaborating on how this new approach to research will improve our understanding of the future of work, and enhance the lives of American workers?

Dr. LUPIA. Absolutely, sir. Thank you for asking that question. The convergence accelerators really build on the traditional NSF approach. So in NSF, we fund all of science, but the idea with the Convergence Accelerators is, from the beginning, you bring in other partners, people in the room, who, if great ideas emerge, they can bring them to market. So the Convergence Accelerators have really been an exciting way to think about how to take amazing collaborations and bring them to market.

So I'll give you one example, because we just started funding these things. One has to do with re-skilling the workforce, and it is funded, coincidentally, at Purdue University, and it focuses on apprenticeships. So both of my grandparents were in the trades, and the way that you've learned a trade for 100 years is through an apprenticeship. So that takes a number of months, and you follow somebody around, and you learn the trade. But for a small company it's really expensive to take one of your workers and have them do an apprenticeship for 6 months. So one of the Convergence Accelerators is a project built around using technology to do apprenticeships at scale.

So imagine we could take what a master plumber knows, or a master technician, or someone who runs a computer, and we can follow them around, and then create scalable, low-cost ways to distribute this information to everybody. And one of the ways you can do that is through having simulations. So instead of one person shadowing the expert, you can build a simulation where 50 people can have a virtual reality experience of shadowing the expert. And so it has a lot of the benefits of the traditional apprenticeship, and of course you still need the one-to-one contact, but this is a way to really make that happen at scale. And, again, if you're a small company, if you can go to a community college, or somewhere else, and get this type of training, it's a real game changer.

So the idea here is apprenticeship, lower costs, improve speed and reliability, minimize errors, and this is something that the Converge Accelerator, I think, can really do to help companies across the country.

Mr. BAIRD. Thank you.

Chairwoman STEVENS. At this time the Chair would like to recognize Dr. Marshall for 5 minutes of questioning.

Mr. MARSHALL. All right. Thank you, Chairwoman. Dr. Ellspermann, I'm a community college graduate, my wife, community college graduate, huge fans of my community colleges. The technical colleges can quickly pivot to the job needs of my community, and I think that's where the rubber meets the road. How do you measure success? What are you measuring to say, we're being successful in our technical college that you run?

Dr. ELLSPERMANN. We measure success the way most Americans do, by wages. We actually measure the wages of our graduates 1 year out to see what they're making. Our goal is that 80 percent of all of our graduates will make above median wage 1 year after completion. We're at 45 percent today, we were at 38 percent 2 years ago, and we're marching our way—but we think that is one fair way to do that. In addition, too, we also hold ourselves accountable to those four quadrants. We want 80 percent of our programs to be in equilibrium, meaning we're roughly producing the number of graduates needed for our community.

Mr. MARSHALL. And are you measuring their debt when they're leaving too?

Dr. ELLSPERMANN. We have minimal, you know, community college debt is kind of the best kind of debt. It's, like, under $10,000. It's the way to do college. But we do measure debt, and we do measure what those students have, and always are looking for ways to continue to reduce that.

Mr. MARSHALL. I'm not sure how long you've been at Ivy Tech, but what are you doing differently today than 1 year ago, than 3 years ago, or 5 years ago?

Dr. ELLSPERMANN. We have reinvented how we're delivering. So we've gone from traditional 16-week courses to 8-week courses because, guess what, adults do better in that format. There's higher pass rates, lower drop rates. We've just redesigned our online education. We're one of the largest online educators in the country. We know we have to do that better because, guess what, single moms need to be able to take courses online, and they have to be as good as the face-to-face delivery. So in that redesign, we are looking at all of the way we do our work to align better to industry, and to deliver in the best way for our students. And there's much more to do, Congressman.

Mr. MARSHALL. So certainly, as an obstetrician, you're hitting on exactly who I'm thinking of, that single mom who maybe could get her auntie, or her sister, to come in and help with the kids for 6 weeks or 8 weeks, but it's hard to get them to commit to 18 weeks. One of the things that we're certainly looking at is using Pell Grants in a non-traditional situation, what you're describing. Hopefully we can make some progress there at some point in time.

Dr. ELLSPERMANN. Thank you.

Mr. MARSHALL. So we have the NSF person here, Dr. Lupia, as well. What would you tell him? How could NSF work better with community colleges and technical colleges? What ideas out there are outside the box that you wish we could get better engaged with NSF?

Dr. ELLSPERMANN. I would say certainly in helping us to adopt that technology early. We are not funded at the levels of research institutions, as you might guess, so keeping our labs up to date with that front-edge technology at the same time industry's getting it, not a generation later. We really need to have it early. Certainly Perkins helps on that front, but that cycle of rapid change is so much quicker than it was generations ago that we have to be able to refresh our equipment every year, two, or three, which there's probably a partnership to be built there.

Mr. MARSHALL. OK. Dr. Lupia, any return thoughts, or comments?

Dr. LUPIA. We are so grateful for the work that your organization does, and part of our Future of Work Project is really to try and make this information and these collaborations happen a lot earlier. So the scientific approach is, there's a relationship between jobs and skills. Most jobs take a whole bunch of skills, and as jobs evolve, some of the skills that we have now will still be relevant, but there will be these other new skills that you can use.

So we are working with government, industry, and a whole range of researchers to try and project, "How are skills and jobs likely to evolve?" If we can figure that out, and put that into data bases, and match it to jobs as they're evolving, then our partners can make that data available to everyone—because that's the idea, right? We have projects in several States—Georgia, West Virginia now—where we're collecting data from them, and then trying to push out real-time and usable data about how jobs are likely to change. This can produce really great efficiencies, because now we can tell community colleges and others these are the skills that employers need now, these are the skills they're likely to need 6 months from now, 12 months from now, 24 months from now.

And with that type of data you not only get these efficiencies, now you have this possibility someone can go to a college and not just get the next job, but be able to be given the skills that can help them build a career, that can take the next two or three steps in their life. So we want to be a tailwind to them, and very supportive.

Mr. MARSHALL. Sounds good. I'm going to start my Community College Caucus here someday. I need to do that. Thank you so much for being here, and I yield back.

Chairwoman STEVENS. Great, thank you. And at this time we're going to begin a second round of questions.

Dr. Brynjolfsson, as you've kind of defined the two urgent economic challenges around lack of productivity growth and too much inequality, and then gave us a list of pretty cogent and solid recommendations on how to address those, do you mind weighing in a little bit around some of the ethical considerations that come up on this topic, and how those either might be urgent right now, or might become more urgent as we move forward?

Dr. BRYNJOLFSSON. Absolutely. I think those are some of the most urgent challenges. They're a little outside some of the economics, but some of them also have an economic implication as well. Machine learning systems have been remarkable at helping us make all sorts of decisions, but one of the things we've also discovered is that they're only as good as the data that go into them, and oftentimes machine learning systems that are trained on decisions that humans made end up perpetuating, or even amplifying, the biases that we often have. So when it comes to hiring, or making credit loan decisions, or who gets parole, if the humans who are making those decisions have a set of biases, those are going to be captured by the systems and repeated. So there have been a number of academic studies that—these are one of the challenges.

There's both a challenge and an opportunity there. Part of the challenge with machine learning systems, particularly when they're using deep neural net technology, is that it is difficult to understand what's going on inside the black box. They capture data, sometimes from thousands or millions of examples, and they spew out a recommendation, and it's hard to know exactly why, and that makes it challenging to second guess it and say, wait a minute, this may not be right.

But the opportunity is that we can use techniques like one called a Turing Box, where you have repeated sets of inputs, with different characteristics going in, and sets of outputs coming out, and you start learning what kinds of biases the machine may have inadvertently picked up, and you can correct those in a way that may actually, ultimately, I think, be easier to correct than our own human biases. Because, after all, it's not like humans are perfect either.

So I wouldn't necessarily rule out using machine learning systems for some of these challenges, even when they are imperfect, but we should put very high on the agenda better understanding of some of the ethical and other biases that they can create.

Chairwoman STEVENS. And, Ms. Kowalski, coming out of your taxonomy that you helped to lead with MXD, do you mind just chiming in on some of the job roles that you identified that might be pertinent to some of the points that Dr. Brynjolfsson just talked about?

Ms. KOWALSKI. Yes. It's a great question. There are five that I think really, really pop out of the work. One is what we call the digital era enterprise ethicist, and that's a conceptual title, of course, no one puts that out there, but it was, you know, an individual success profile of a role of who gets to make those decisions. Who makes the call? Who says how far is too far?

Traditionally these decisions have been kind of bandied about, maybe IT owns this, or Risk owns it, or Legal owns it. Well, now, the way organizations are built in the digital era, it does not land neatly in one of those silos, it spreads across. And so where the buck stops actually is in a place where no one ever imagined it. And so there are—you made a comment earlier about how processes haven't caught up, so that's decisionmaking processes, that's organizational structures. It's a recognition that there's distributed decisionmaking more and more now in organizations, and we still have an end-of-year code-of-conduct compliance, you know, mindnumbing 2-hours of training that we take that don't actually get to can you identify the decisionmaking framework that your organization uses for developing new products, solutions, or making decisions around human beings? That's a fundamental issue that has to be dealt with now.

A couple other things, in terms of just roles that you're going to see popping up, obviously an organization only has one ethicist like that, but does have to establish the framework that supports it, but some of those specialist roles, like the machine learning specialist, the collaborative robotic specialist, the autonomous mobility engineer, right, how do you make sure that, you know, people of different ethnicities are recognized by that autonomous vehicle, right? How do you make sure that your H.R. systems are wired not to filter people out, but actually to bring people in, based on potential?

So those are some of those roles that we see coming up across all organizations, and obviously a few of those are quite specific to the manufacturing sector. And it's important that we figure these out, because what I see right now is a lot of organizations just trying to spread that responsibility out without actually recognizing that those need to be defined disciplines.

Chairwoman STEVENS. As we talk about technical talent, and the push for the hard-skilled trades, and the work that we see out of our community colleges, and the push for people to go into apprenticeship, and other training programs, we still feel the need to train for analog, but also embrace the soft skill digital. And I'm slightly over time, but with just the remainder that I'm going to steal here, I'd love for each of you to just comment on this shift here, and the balance of the soft with the hardnosed technical skills that are still required in many jobs. And, Dr. Ellspermann, if you want to start, we'd certainly——

Dr. ELLSPERMANN. I'd be happy to. We recognized 3 years ago that we weren't doing enough to prepare students to be successful in the workforce: Number one, making the right decisions in the careers, being prepared for the world of work, because not every student anymore comes to us already with some prior work experience, and that they would be successful so—building that in, so we are in the midst of rolling out what we call our Career Coaching and Employer Connections, which ensures every student, when they begin with us, begins building a career action plan, which includes work and learn experiences in industry to build some of that kind of real-world work.

We build in, certainly, soft skills throughout the curriculum, but those skills are learned best on the job, making sure every student has that experience before they get out there. But it is an early and often experience, meeting with employers being out there, interviewing, understanding what's expected. And we know there's a lot to be done that we've never been really asked to do in the past, but is required by our industry, and know that that's a part of the future.

Ms. KOWALSKI. So I'll pick up on this theme of moving from analog to digital roles. So, if you were to look at the research that we have, you'd see that 28 percent of those 165 new or highly evolved roles are sitting on the production floor, and what we estimated was about 1 to 2 years of building up that talent that would prepare them to take on progressively more digital roles.

Because at the heart of it, the shift is really from doing things physically, physical operations, to accomplishing those operations through systems and technology. So you see a lot more skills like quantitative, tech-assisted, optimization-focused, integrative, mobile, virtual, and remote. That wasn't in the lexicon, really, 5 years ago, even 3 years ago. You know, organizations that were starting to talk about it were the OEMs (original equipment manufacturers), for instance, that participated in this study. Now it's spreading throughout the supply network, and we have quite a task in front of us to gear people up, because right now they'll have to bridge from those more tactical analog roles into the transitional. So organizations have to keep a foot planted firmly where they are now, and reach for the future.

Dr. BRYNJOLFSSON. Thank you for that question. I think this is a very important issue, about the balance between hard and soft skills. I teach at the Massachusetts Institute of Technology, so certainly I have an appreciation for the importance and value of hard skills. There are a number of technical capabilities that our workforce is lacking and that we need to supplement. In some cases, they can be compensated very highly. But I also want to stress that soft skills are increasingly the ones that are less automatable, and therefore more humans will be needed to do those softer skills. They often have a longer span of relevance and usefulness.

In the science article that I included as background, we created a framework for which tasks are suitable for machine learning. And, indeed, the ones that were less likely to be automated were many of the softer skills, involving creativity and interpersonal skills, persuasion, caring, coaching, leadership, and teamwork. These are things that are very important in the workforce, and I also think that there are opportunities to teach them, not just on the job, but by reinventing and reorganizing our educational curriculum. And a research agenda to better understand the kinds of skills that are needed going forward, I think, would be a useful supplement to be able to map our strategies, both in education and workforce training, going forward.

Dr. LUPIA. I'd just like to state a principle and an example. One of the overarching principles for this problem is the idea of values-based design. So when you build a new technology, oftentimes we're thinking about the products, and we're not thinking about the people. And so you don't think about the people, and the workers, and the consumers, until the end of the process, when the unintended consequences and the inefficiencies are already built in. A lot of our recent misadventures with Big Tech, I think, are an example of not thinking about the people at the beginning.

So now, when we think about the future workforce, with values-based design, we're thinking about the people in the workplace, and how they're going to interact. If you think about that—starting at time one, when you start to build the code, when you start to write the algorithms and so forth, there are all kinds of efficiencies that you can realize later on. And one of the efficiencies, with respect to the workforce, is personalized practice. Because once we think about how the new technology, and the new workplaces are going to affect people, now we can start to understand the set of skills that are going to be needed, and we can start to design personalized education so that people can learn efficiently the skills that they will need in this new place. But if you start with values at the beginning, you get to those outcomes.

And in the point of practices, NSF is already trying to help support this through its Advanced Technological Education Program, or ATE. There are hundreds of community colleges and 48 ATE centers around the country that are really preparing students for STEM (science, technology, engineering, and mathematics) and the skilled technical workforce. We've got 17 million Americans in the skilled technical workforce now that are in the workflow. They're building the machines, and maintaining the computers, and so forth, and the ATE Program is really meant to encourage and improve the training of science and engineering technicians at both undergraduate and secondary levels. So the things we're doing right now are things like ATE, but the future benefit really comes from thinking through, you know, what are the human impacts of technology?

Chairwoman STEVENS. Thank you. And I'm lucky that my colleague likes me, because I spent some of that liking capital going slightly over, but it was really to hear from all of you, and to have your expertise. So, at this time, I'd like to recognize my good friend, Dr. Jim Baird, for 5 minutes of questions.

Mr. BAIRD. Thank you, Madam Chair, and my question now is going to be directed at all of you, at some point here. But, you know, online, you know, I have grandchildren that can use these faster than they could talk, almost, and so my question relates to that, in a way. We're using online courses for both formal and informal education, and so I guess the question is this: Do we have any research that tells us what online courses, and how to make those effective? And then also, how do online courses, and what you're doing—and AI relate to STEM education? We're carrying a bill about the STEM careers, and so on. So I'm going to start with—at your left, my right, and move that way, go ahead. Thank you.

Dr. ELLSPERMANN. Congressman Baird, let me just say that I think we realize that online education is here to stay. It's not going to take over all of education. It's not the best way for all of education. It's not the preferred learning style for many. But we know, as I shared earlier with that single mom, she's got to have that opportunity to learn. So we have to—as educators, it's our responsibility to improve it constantly. It's come through many iterations. It'll go through many more, but it'll also be hybrid, and augmented, and many things that, as technologies we're talking about here today, ever greater enables us to make that online experience more real, more virtual, more—in the way that that learner wants to learn it.

But I think we understand, as community colleges, we have to lean in, and it's not an either/or, it's an and, it's a both, and we need to continue to evolve. So we study, we know we have a gap between our face-to-face and our online learning. It's double digit right now, which is not acceptable, so our goal is to eliminate that gap. That will be one measure of quality, but we will continue to look for ways to make that experience better for the online learner.

Ms. KOWALSKI. So I would agree with my co-panelist here that it is a both/and. We have a number of occupations that employers won't accept a fully virtual experience for, so they require some sort of hands-on. I'm not going to let you touch an aircraft wing unless you have actually touched an aircraft wing before you come into my hangar, thankfully, right. And yet the promise of this is pretty profound.

So if you think back to the statistics that I shared earlier, in terms of the gap that we have facing us in manufacturing right now, the only way to close it is to become incredibly resourceful about who we bring in from the sidelines. Women are certainly one untapped resource, but what about people with physical and cognitive disabilities? Some of the greatest advancements made in digital technologies actually allows them to participate. The exoskeleton Dr. Lupia shared before is a marvelous example of how we can bring people in who, before this, have never even imagined actually having the ability to participate in workforce.

Strictly in online education, and kind of what we think of as the standard, this is part of how ManpowerGroup is helping our associates upskill. We're offering all of our associates access to free education so that they can move up, with this idea. And just to validate what you were saying earlier, 6 to 8 weeks, that's the ability of an individual who's working full time, sometimes two jobs, and raising kids. So it opens up more opportunity than we've ever seen before, but it's not going to be the only way that we can educate, because there are some things fundamentally that require hands-on.

Dr. BRYNJOLFSSON. Thank you for that question, Dr. Baird. At MIT we've been doing a lot with online education for quite a while. One of the first big courses that we did was an online circuits design course. A couple hundred thousand people took it. Anant Agarwal organized it. One of those students was actually in Mongolia, and got a perfect score on it. It turned out to be a 17-year-old boy, and it was someone who wouldn't have been reached otherwise if there weren't this kind of technology. MIT went ahead and admitted him to the regular program, and it was somebody we probably wouldn't have found otherwise.

We have put all of our regular courses online through the Open Courseware for free. People can just access and read them. In fact, you can see my syllabi, and see my lecture notes, and problem sets. There's also an online system called edX. It's a consortium of universities—it started with MITX, then Harvard and others joined—that coordinates course materials to have them in a little more structured way so that you go through a curriculum. And these are what we call MOOCs, massive online courseware. I think there was an early wave of hype and excitement about them, you know, taking over, and doing all sorts of things. It worked very well in some areas, like the Circuits Course. It didn't work so well in others.

It's certainly not a silver bullet, but I think there are four things that we've learned. One is that, for many applications, you can get enormous scale, and much lower cost, than we could've previously. Second, one of the unexpected benefits was an ability to personalize. People learn at different rates, and there's different media that work better for other people, and you can have things extremely customized, and even personalized, and we're learning how to do that better. Third, it often makes sense to do a hybrid system, where you have people meet in person, particularly for some of the softer skills we were talking about. We often combine where people physically get together, know their classmates, do things together, then work separately online, then come back together, which is actually how a lot of workforce works as well, after all.

And then last, but not least, in fact, probably most importantly, I think that the biggest lesson is that there is no one best way of doing online education. What we need to do is continually experiment and test. The success of a lot of tech companies has been this approach of A/B testing, constantly trying a new product, seeing if it works with different subsets of people, and we've very much taken that to heart with our online course offerings, and companies like Coursera, Udacity, have been very successful in trying things. And sometimes they work, sometimes they don't, but it's an attitude of experiment testing. So your question was spot on, what is the research showing what is working, and what isn't working? And there's a whole set of things that have failed miserably, another set of things that have succeeded. But I think we're still in very early days, and the digital approach allows you to gather data at a scale, and cost, and speed that just can't be matched in other ways.

Dr. LUPIA. Well, thank you for asking that question. At NSF there's a foundation-wide effort to really support basic research on how to develop, evaluate, and improve online learning structures. One common way of doing it is you collect a lot of information about the types of things people need to know, you correlate that with information about the types of tasks that they may be asked to do, you integrate that with information about curricula, and how people are doing in learning environments, and you take all that data together, and then you can really evaluate not just what does somebody remember after they take a test, but what can they do 6 months later? So there's all kinds of projects like that being funded at NSF, from trucking to farms and there's even one for veterans. So the idea is, you know, how do you structure curricula to help veterans who want to get into STEM pipelines, because veterans have special abilities, and sometimes special challenges.

I guess the biggest headline, in terms of what we've been doing recently, is—about a year ago the Boeing company gave $10 million to NSF to try and really boost activity in this field. And, within the last few weeks, we have announced five new awards to study open source learning platforms to try and train and re-skill workers at a larger scale, and these were just announced. It's going to be done at the University of Southern California, Purdue, Northeastern, Colorado School of Mines, and Oregon State University. They're all getting a couple million dollars to test some really big ideas they have in different ways. So it's, like—what is it, "coopetition," or something? They're doing it in different ways, but they're all going to be able to learn from each other.

And I think this is, you know, our approach is to fund a lot of different innovations in the hope that some of them figure out something really innovative that can be spread all over the country.

Mr. BAIRD. Well, thank every one of you, and thank you, Madam Chair, for letting us have that amount of time.

Chairwoman STEVENS. Well, before we bring this hearing to a close, it is evident that we are having a hearing with giants, in terms of the expertise of our witnesses here today. And it was not shared, but the new Dems have a Future of Work Taskforce that Congressman Bill Foster chairs, and I'm a part of. Some of our colleagues who do not sit on the House Science Committee, we will be sharing with them this testimony here today, all of your testimony, and the questions.

And certainly we find ourselves in a profound, and exciting, and sometimes perplexing moment, and so your expert testimony will guide our Committee going forward, and help us to embrace some of these challenges, turn them into opportunities, and continue to push forward in a measured and data-driven way, and in a way that really respects where our economy is heading, and can head, and how we push to continue to support the workforce of the future.

So thank you all so much for coming to Washington today, or taking some time to come to the Science Committee to join us for today's hearing. This record will remain open for 2 weeks for additional statements from Members, and for additional questions that the Committee may ask of the witnesses, and of which we are expecting. So, at this time, our witnesses are excused, and this hearing is now adjourned.

[Whereupon, at 5:22 p.m., the Subcommittee was adjourned.]

Appendix I

ANSWERS TO POST-HEARING QUESTIONS

ANSWERS TO POST-HEARING QUESTIONS

Responses by Dr. Arthur Lupia

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEE ON RESEARCH AND TECHNOLOGY

Questions for the Record to:
Dr. Arthur Lupia
Assistant Director, Directorate for Social, Behavioral and Economic Sciences
National Science Foundation
Submitted by Congressman Daniel Lipinski

1. I introduced the Growing Artificial Intelligence Through Research, or GrAITR, Act because I am concerned about the current state of AI R&D and education here in the US. My bill dedicates additional resources to AI research and education and requires interagency coordination through an interagency committee, to help ensure that America maintains its lead on technology development and our workforce develops skills necessary to effectively develop and utilize AI.

   Dr. Lupia, you described in your testimony how NSF is driving coordination with other research and development efforts across the federal government, including co-chairing NSTC subcommittees of relevance. How would NSF and the broader federal research community benefit from legislative mandate on interagency AI coordination?

   My bill also would direct the NSF to establish Multidisciplinary Centers for AI Research and Education. These centers should promote interdisciplinary AI research as well as support long-term and short-term workforce development in AI. At least one Center must have the primary purpose of integrating AI into K-12 education. Dr. Lupia, how could centers like this compliment NSF's ongoing work in building our future workforce pipeline?

   Answer: As noted in my written statement, NSF leadership is helping to drive and coordinate AI research R&D efforts across the federal government. Through active participation on, including co-chairing of, various NSTC subcommittees and working groups of relevance to AI research, education, and workforce development, NSF is engaging with other federal agencies to help ensure America maintains its lead in artificial intelligence. These interagency efforts are crucial to a coordinated and strategically sound path forward with respect to federal funding for all aspects of AI. In addition, NSF funds workshops that inform the broader federal research community's priorities, which subsequently inform funding priorities at NSF.

   NSF supports a variety of centers programs that contribute to the Foundation's mission and vision. Centers exploit opportunities in science, engineering, and technology in which the complexity of the research program or the resources needed to solve the problem require the advantages of scope, scale, duration, equipment, facilities, and students. Centers are a principal means by which NSF fosters interdisciplinary research. Earlier this month, NSF issued a solicitation for National AI Research Institutes, which aims to support multi-disciplinary, multi-institutional projects on foundational and translational aspects of AI beginning in FY 2020. Each National AI Research Institute project would receive up to $20 million over five years. One of the thematic areas emphasized in the FY 2020 funding opportunity is AI-augmented learning. The National AI Research Institutes program is joint between NSF and several other federal agencies – a concrete result of the coordination described above.

Appendix II

Additional Material for the Record

LETTER SUBMITTED BY REPRESENTATIVE HALEY STEVENS

KELLY SERVICES

September 24, 2019

The Honorable Haley Stevens
Chair
Research and Technology Subcommittee
House Science, Space, and Technology Committee
U.S. House of Representatives
Washington, DC

Dear Representative Stevens:

I was delighted to learn that Research and Technology Subcommittee of the House Science, Space, and Technology Committee is holding a hearing on "Artificial Intelligence and the Future of Work". As you know, Kelly Services embraces our role in connecting people to work in ways that enrich their lives. Our core mission balances automation based economic growth and transformation with workforce needs. We strongly believe that employment for those who may face disadvantages from many circumstances, including automation, is fundamental to quality of life and dignity.

There is a great need to learn and further explore the implications of automation on people, and possible updates needed to public policy. We urge Congress to collect information, hold hearings, and engage to develop an integrated approach to policy that will support both our nation's economic growth and leadership in artificial intelligence. As our economy modernizes our nation's leaders will need to gather information to ensure technology, economic, tax, education, and labor policy supports the American economy and its workforce.

I would like to note that the Work Opportunity Tax Credit (WOTC) is a policy (albeit not a policy under the House Science Committee jurisdiction) that provides incentives and resources to ensure training and employment of those who are disadvantaged. With a minor update, like those made in the past to address specific workforce disadvantages, WOTC could be a tax incentive used for worker retraining when technology or automation leads to upskilled positions and needs. Kelly Services has extensive experience and success with WOTC (see attachment) as an incentive that allows the company to develop and invest in the systems and recruitment required to employ those who are on the sidelines and not currently working, certainly upskill training could be another use for this credit.

Again, thank you so much for your work in raising awareness and focus on the impact of artificial intelligence on the workforce. Please do not hesitate to contact me if you have any questions or need any further information.

Sincerely,

Matt Harvill /S/

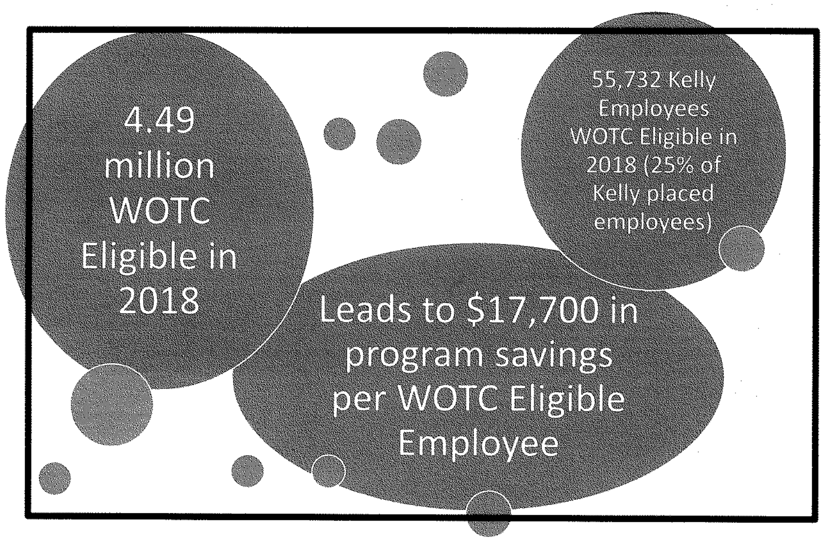
Matt Harvill
Vice President, Operations Shared Services Center

WOTC: Attachment

WOTC is a cost-effective tool to encourage the hiring of disadvantaged workers with low skills and other barriers to employment.

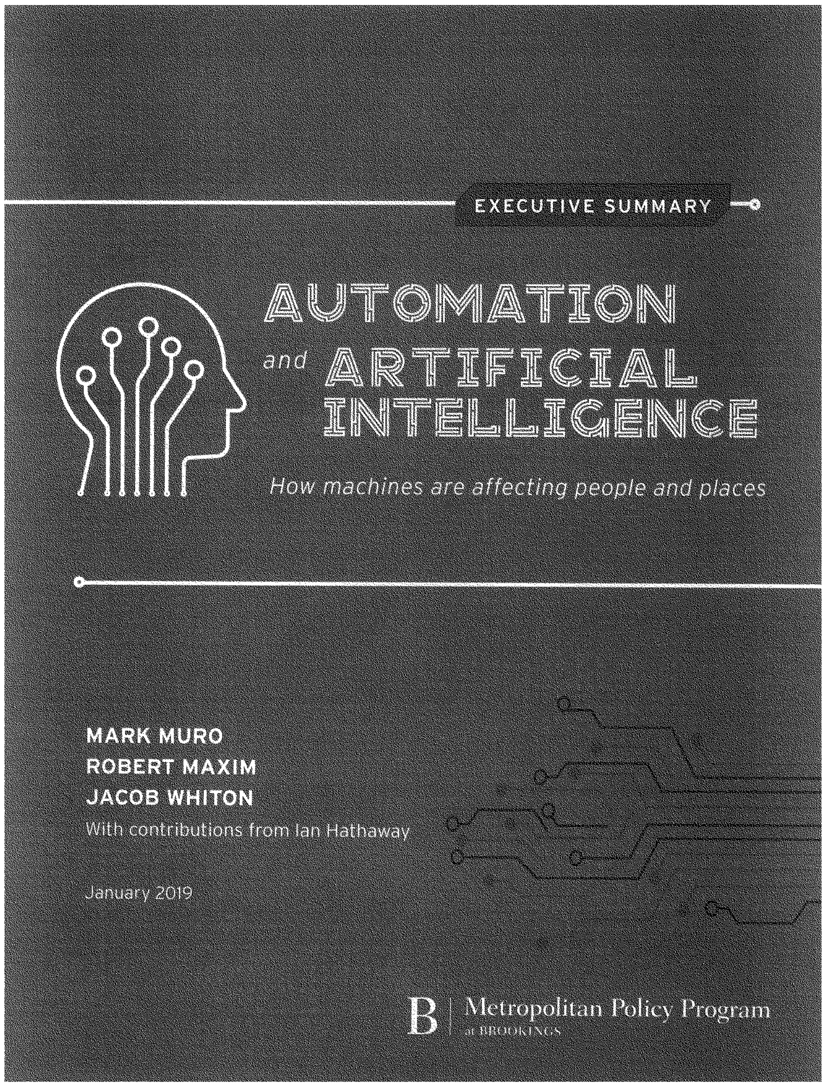
- First enacted as of October 1, 1996 as part of comprehensive welfare reform.
- The credit encourages employers to incur the additional costs of hiring and training individuals who may have never been in or succeeded in the workforce (TANF, SNAP, Unemployed Veterans, Long Term Unemployed, etc.)
- Overtime, Congress has changed categories of individuals who may qualify as WOTC eligible when employed.
- Extensive analysis of WOTC over time demonstrates it leads to long term employment of individuals who were not formerly in the work force AND it saves money by reducing federal and state government -assistance payments

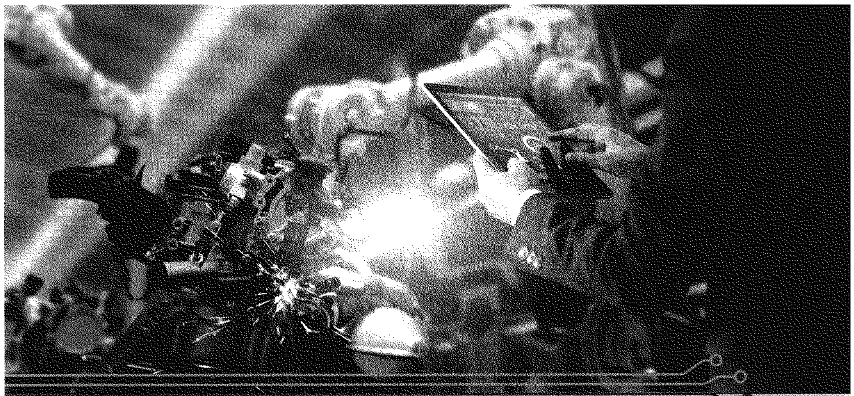
WOTC by the Numbers



Sources: US DoL WOTC Certifications, Kelly Services data, and Cappelli study at www.wotcmeansjobs.org

EXECUTIVE SUMMARY SUBMITTED BY REPRESENTATIVE HALEY STEVENS





EXECUTIVE SUMMARY

The power and prospect of automation and artificial intelligence (AI) initially alarmed technology experts for fear that machine advancements would destroy jobs. Then came a correction, with a wave of reassurances.

Now, the discourse appears to be arriving at a more complicated, mixed understanding that suggests that automation will bring neither apocalypse nor utopia, but instead both benefits and stresses alike. Such is the ambiguous and sometimes-disembodied nature of the "future of work" discussion.

Which is where the present analysis aims to help. Intended to clear up misconceptions on the subject of automation, the following report employs government and private data, including from the McKinsey Global Institute, to develop both backward- and forward-looking analyses of the impacts of automation over the years 1980 to 2016 and 2016 to 2030 across some 800 occupations. In doing so, the report assesses past and coming trends as they affect both people and communities and suggests a comprehensive response framework for national and state-local policymakers.

In terms of **current trends**, the report finds that:

1. Automation and AI will affect tasks in virtually all occupational groups in the future but the effects will be of varied intensity—and drastic for only some. The effects in this sense will be broad but variable:

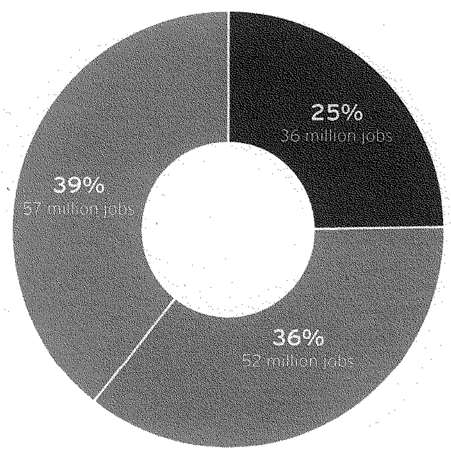
- **Almost no occupation will be unaffected by the adoption of currently available technologies.**
- **Approximately 25 percent of U.S. employment (36 million jobs in 2016) will face high exposure to automation in the coming decades (with greater than 70 percent of current task content at risk of substitution).**
- **At the same time, some 36 percent of U.S. employment (52 million jobs in 2016) will experience medium exposure to automation by 2030, while another 39 percent (57 million jobs) will experience low exposure.**

FIGURE 5

Most jobs are not highly susceptible to automation
Shares of employment by automation potential

Potential for automation
(volume of tasks within the job that are susceptible to automation)

- **High** *(70% of more)*
- **Medium** *(30% - 70%)*
- **Low** *(0% - 30%)*



Source: Brookings analysis of BLS, Census, EMSI, and McKinsey data

2. The impacts of automation and AI in the coming decades will vary especially across occupations, places, and demographic groups. Several patterns are discernable:

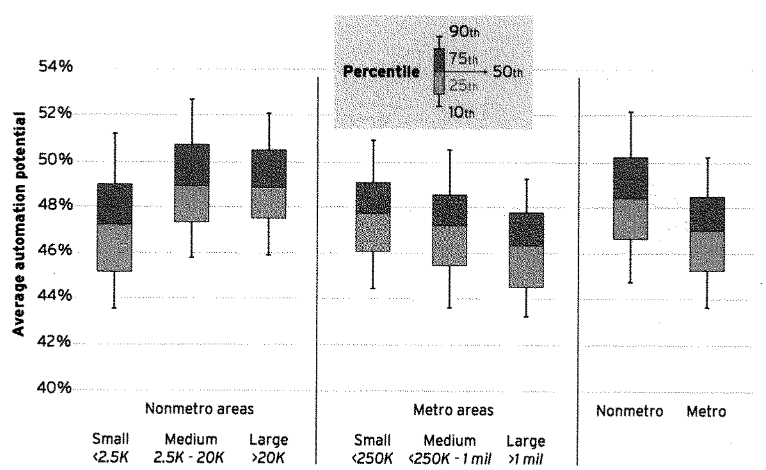
- **"Routine," predictable physical and cognitive tasks will be the most vulnerable to automation in the coming years.**

  Among the most vulnerable jobs are those in office administration, production, transportation, and food preparation. Such jobs are deemed "high risk," with over 70 percent of their tasks potentially automatable, even though they represent only one-quarter of all jobs. The remaining, more secure jobs include a broader array of occupations ranging from complex, "creative" professional and technical roles with high educational requirements, to low-paying personal care and domestic service work characterized by non-routine activities or the need for interpersonal social and emotional intelligence.

  Near-future automation potential will be highest for roles that now pay the lowest wages. Likewise, the average automation potential of occupations requiring a bachelor's degree runs to just 24 percent, less than half the 55 percent task exposure faced by roles requiring less than a bachelor's degree. Given this, better-educated, higher-paid earners for the most part will continue to face lower automation threats based on current task content—though that could change as AI begins to put pressure on some higher-wage "non-routine" jobs.

FIGURE 8

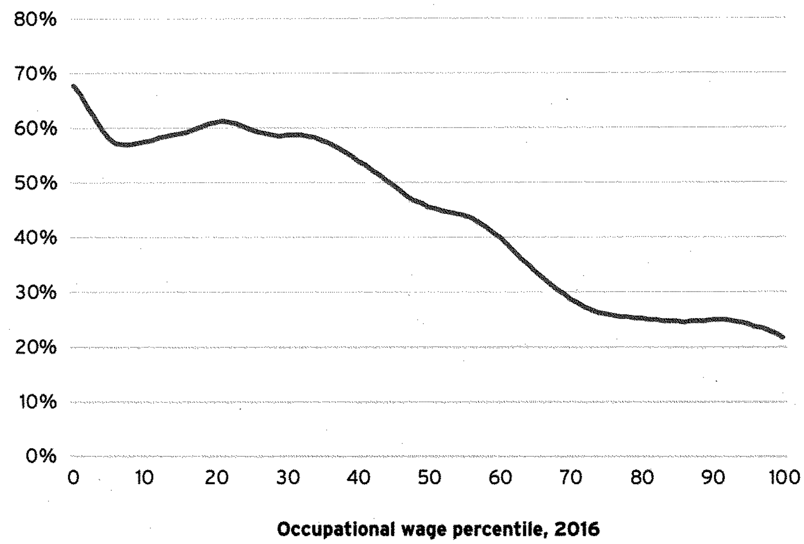
Smaller, more rural places will face heightened automation risks
County distribution by community size type, 2016



Source: Brookings analysis of BLS, Census, EMSI, Moody's, and McKinsey data

FIGURE 6

The lowest wage jobs are the most exposed to automation
Automation potential. United States, 2016



Note: Figures have been smoothed using a LOWESS regression
Source: Brookings analysis of BLS, Census, EMSI, and McKinsey data

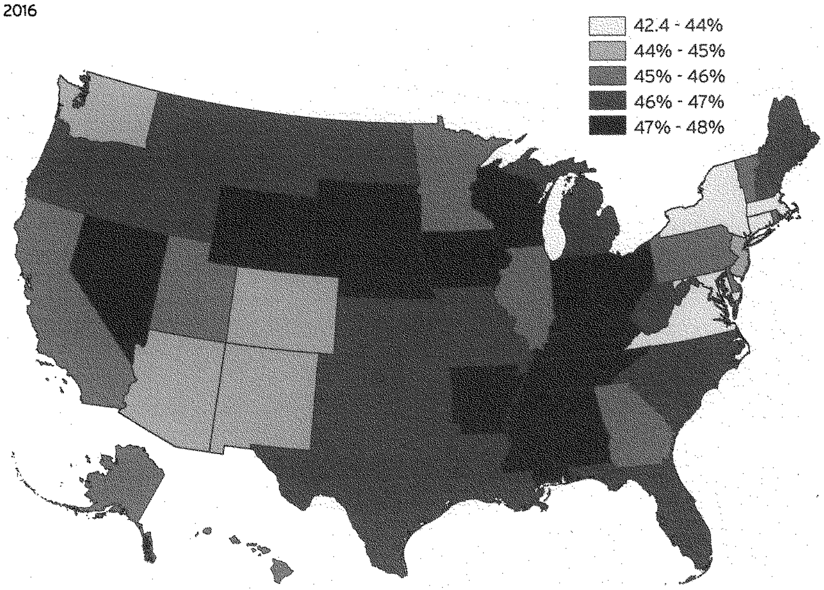
- **Automation risk varies across U.S. regions, states, and cities, but it will be most disruptive in Heartland states.** While automation will take place everywhere, its inroads will be felt differently across the country. Local risks vary with the local industry, task, and skill mix, which in turn determines local susceptibility to task automation.

Large regions and whole states—which differ less from one another in their overall industrial compositions than do smaller locales like metropolitan areas or cities—will see noticeable but not, in most cases, radical variations in task exposure to automation. Along these lines, the state-by-state variation of automation potential is relatively narrow, ranging from 48.7 and 48.4 percent of the employment-weighted task load in **Indiana** and **Kentucky** to 42.9 and 42.4 percent in **Massachusetts** and **New York**, as depicted in Map 2.

Yet, the map of state automation exposure is distinctive. Overall, the 19 states that the Walton Family Foundation labels as the **American Heartland** have an average employment-weighted automation potential of 47 percent of current tasks, compared with 45 percent in the rest of the country. Much

MAP 2

Average automation potential by state
2016



Source: Brookings analysis of BLS, Census, EMSI, Moody's, and McKinsey data

of this exposure reflects Heartland states' longstanding and continued specialization in manufacturing and agricultural industries.

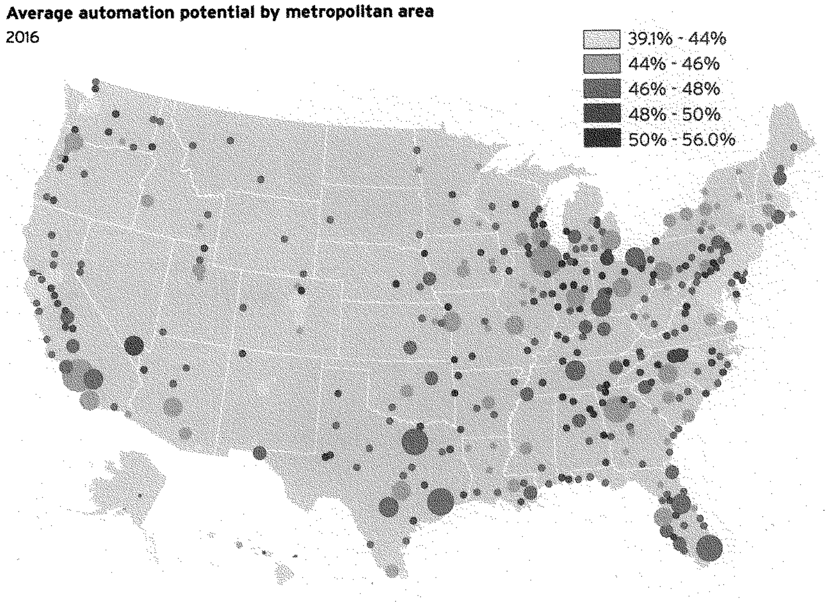
- **At the community level, the data reveal sharper variation, with smaller, more rural communities significantly more exposed to automation-driven task replacement—and smaller metros more vulnerable than larger ones.** The average worker in a small metro area with a population of less than 250,000, for example, works in a job where 48 percent of current tasks are potentially automatable. But that can rise or decline. In small, industrial metros like **Kokomo, Ind.** and **Hickory, N.C.** the automatable share of work reaches as high as 55 percent on average. By contrast, small university towns like **Charlottesville, Va.** and **Ithaca, N.Y.**, or state capitals like **Bismarck, N.D.** and **Santa Fe, N.M.**, appear relatively well-insulated.

As to the 100 largest metropolitan areas, it is also clear that while the risk of current-task automation will be widely distributed, it won't be evenly spread. Among this subset of key metro areas, educational attainment will prove decisive in shaping how local labor markets may be affected by AI-age technological developments.

Among the large metro areas, employment-weighted task risk in 2030 ranges from 50 percent and 49 percent in less well-educated

MAP 4

Average automation potential by metropolitan area
2016



Source: Brookings analysis of BLS, Census, EMSI, Moody's, and McKinsey data

locations like **Toledo, Ohio** and **Greensboro-High Point, N.C.**, to just 40 percent and 39 percent in high education attainment metros like **San Jose, Calif.** and **Washington, D.C.**

Following Washington, D.C. and San Jose among the larger metros with the lowest current-task automation risk comes a "who's who" of well-educated and technology-oriented centers including **New York**; **Durham-Chapel Hill, N.C.**; and **Boston**– all with average current-task risks below 43 percent. These metro areas relatively protected by their specializations in durable professional, business, and financial services occupations, combined with relatively large education and health enterprises.

- **Men, young workers, and underrepresented communities work in more automatable occupations.** In this respect, the sharp segmentation of the labor market by gender, age, and racial-ethnic identity ensures that AI-era automation is going to affect demographic groups unevenly.

Male workers appear noticeably more vulnerable to potential future automation than women do, given their overrepresentation in production, transportation, and construction-installation occupations–job areas that have above-average projected automation exposure. By contrast, women comprise upward of 70 percent of the labor force in relatively safe occupations, such as health care, personal services, and education occupations.

Automation exposure will vary even more sharply across age groups, meanwhile, with the young facing the most disruption. Young workers between the ages of 16 and 24 face a high average automation exposure of 49 percent, which reflects their dramatic overrepresentation in automatable jobs associated with food preparation and serving.

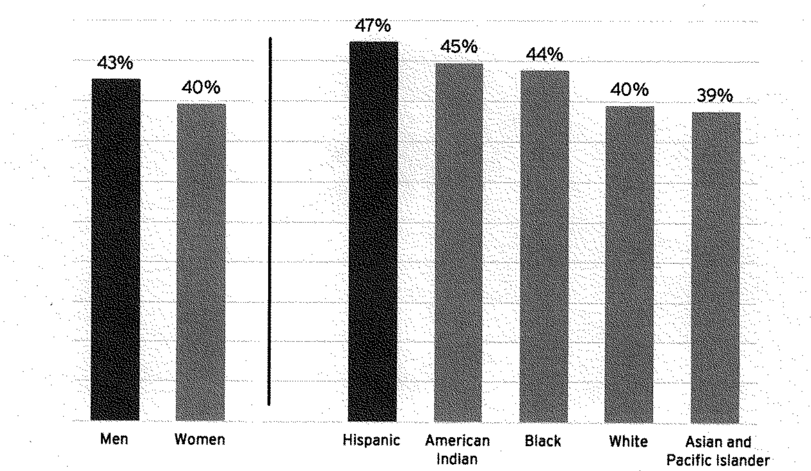
Equally sharp variation can be forecasted in the automation inroads that various racial and ethnic groups will face. Hispanic, American Indian, and black workers, for example, face average current-task automation potentials of 47 percent, 45 percent, and 44 percent for their jobs, respectively, figures well above those likely for their white (40 percent) and Asian (39 percent) counterparts.

Underlying these differences is the stark over- and underrepresentation of racial and ethnic groups in high-exposure occupations like construction and agriculture (Hispanic workers) and transportation (black workers). Black workers have a slightly lower average automation potential based on their overrepresentation in health care support and protective and personal care services, jobs which on average have lower automation susceptibility.

FIGURE 10

Automation exposure breaks sharply along demographic lines

Average automation potential by gender and race, 2016

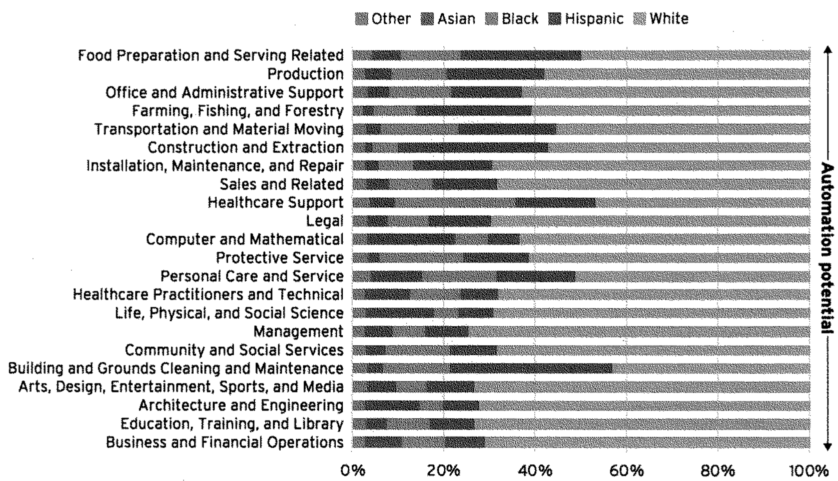


Source: Brookings analysis of 2016 American Community Survey 1-Year microdata

FIGURE 11

Black and Hispanic workers are concentrated in more automatable occupations

Shares of occupation group, 2016



Source: Brookings analysis of American Community Survey 1-year microdata

3. To manage and make the best of these changes five major agendas require attention on the part of federal, state, local, business, and civic leaders.

To start with, government must work with the private sector to **embrace growth and technology** to keep productivity and living standards high and maintain or increase hiring.

Beyond that, all parties must invest more thought and effort into ensuring that the labor market works better for people. To that end, the appropriate actors need to:

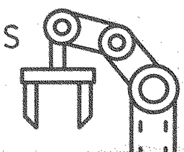
- **Promote a constant learning mindset**
  - Invest in reskilling incumbent workers
  - Expand accelerated learning and certifications
  - Make skill development more financially accessible
  - Align and expand traditional education
  - Foster uniquely human qualities
- **Facilitate smoother adjustment**
  - Create a Universal Adjustment Benefit to support all displaced workers
  - Maximize hiring through a subsidized employment program

- **Reduce hardships for workers who are struggling**
  - Reform and expand income supports for workers in low-paying jobs
  - Reduce financial volatility for workers in low-wage jobs

- **Mitigate harsh local impacts**
  - Future-proof vulnerable regional economies
  - Expand support for community adjustment

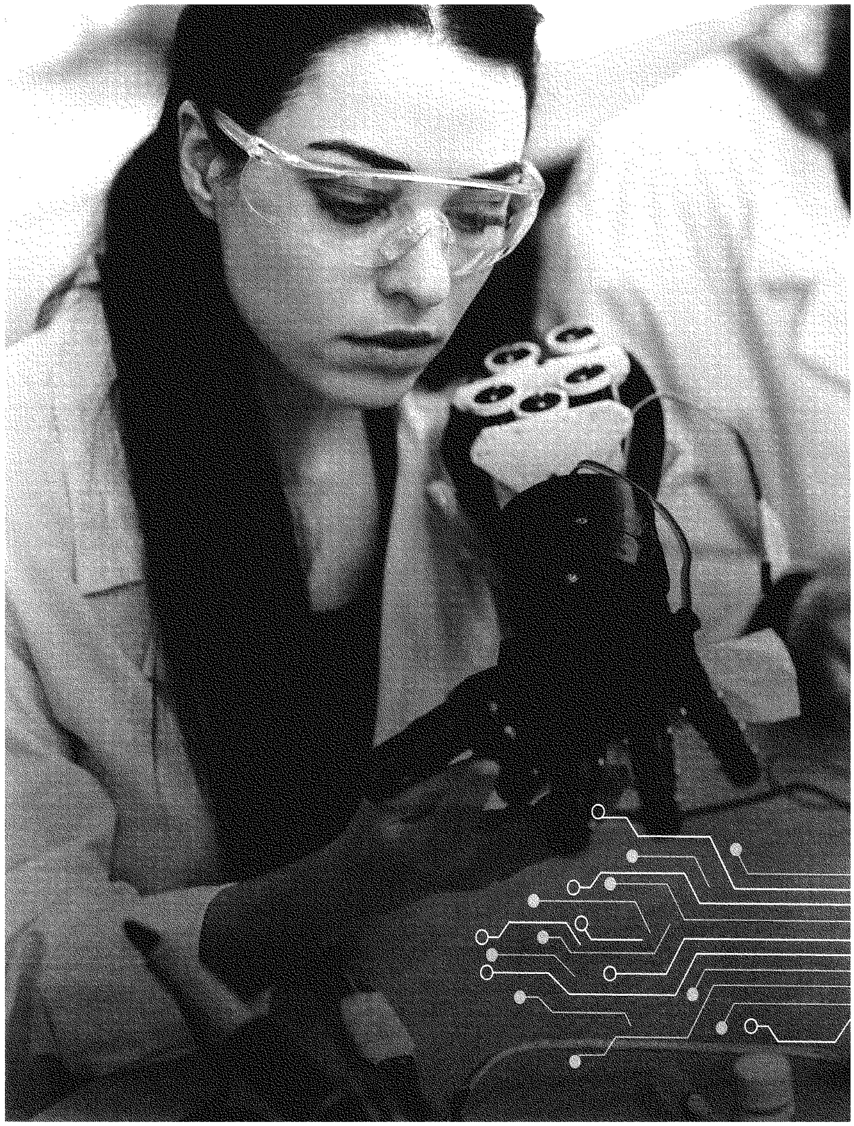
If the nation can commit to its people in these ways, an uncertain future full of machines will seem much more tolerable.

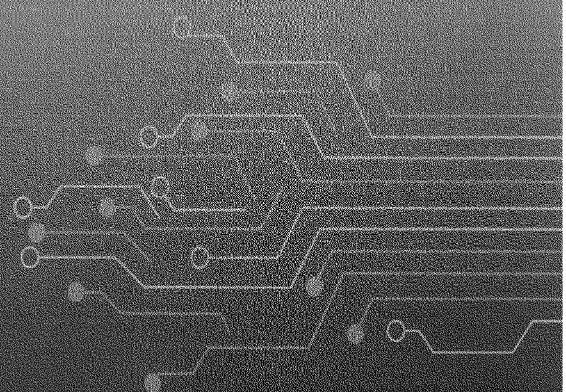
FIVE POLICY STRATEGIES FOR ADJUSTING TO AUTOMATION



Embrace growth and technology
Run a full-employment economy, both nationally and regionally
Embrace transformative technology to power growth
Promote a constant learning mindset
Invest in reskilling incumbent workers
Expand accelerated learning and certifications
Make skill development more financially accessible
Align and expand traditional education
Foster uniquely human qualities
Facilitate smoother adjustment
Create a Universal Adjustment Benefit to support all displaced workers
Maximize hiring through a subsidized employment program
Reduce hardships for workers who are struggling
Reform and expand income supports for workers in low-paying jobs
Reduce financial volatility for workers in low-wage jobs
Mitigate harsh local impacts
Future-proof vulnerable regional economies
Expand support for community adjustment

Source: Metropolitan Policy Program at Brookings





Metropolitan Policy Program
at BROOKINGS

1775 Massachusetts Avenue, NW
Washington, D.C. 20036-2188
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brookings.edu/metro

STATEMENT SUBMITTED BY REPRESENTATIVE HALEY STEVENS

Ramayya Krishnan

President, Institute for Operations Research and Management Sciences (INFORMS)

Statement Submitted to the Subcommittee on Research and Technology

Hearing on "AI and the Future of Work"

September 24, 2019

Chairwoman Stevens and Ranking Member Baird:

I appreciate the opportunity to submit this statement on behalf of the Institute for Operations Research and the Management Sciences (INFORMS) where I currently serve as President. As you may know, INFORMS is the professional society for operations research and analytics. Our 12,000 members are leveraging complex mathematical modeling to save lives, save money, and solve problems throughout academia, industry, and the federal government.

A significant amount of work within the operations research and analytics fields has been focused on the two issues this committee is reviewing today – artificial intelligence and the future of work.

In addition to my role at INFORMS, I am also the Dean of the Heinz College of Information Systems and Public Policy at Carnegie Melon University. I also serve as Director of a Carnegie Mellon Center – The Block Center for Technology and Society -- , which is focused on the study of the future of work, trust and transparency in the deployment of AI, and the solution of challenging societal problems (e.g., hunger, reskilling at scale) through technology and analytics. The center's mission is "addressing technological disruption from the perspective of economics, organizations, and public policy, the Block Center's projects will seek to ensure that the benefits of technological change are widely shared, opening new paths to prosperity for all."

There are many predictions around the impact artificial intelligence will have on the American economy and the workforce. At this point, while forecasting and speculation is fueling the discussion around AI, there is no science to show exactly what will happen in the years ahead as technologies emerge.

We do know that AI brings great opportunities in a range of sectors, from healthcare to transportation safety (and many in between). We know that these technologies will help the United States remain globally competitive and will bring advances that were unimaginable a decade ago. We shouldn't work to stall these innovations, but we should be willing to plan aggressively for them.

It is my belief that AI will certainly bring change to the workforce, but not in a manner that will result in job losses, but rather tactical changes in job responsibilities. AI, in some categories, will bring new opportunities as well. If we plan and respond appropriately, the workforce will witness AI as an addition to the workforce, not a replacement to the workforce. Much of that, however, depends on the systems we have in place to adjust for this technological reality.

I would suggest all stakeholders – government, academia, and industry – focus on three important strategies as we, together, approach the broad adoption of AI technologies: (1) evaluating the impact of AI on the future of work, (2) developing comprehensive re-skilling and re-training opportunities for workers at scale, and (3) designing teaming arrangements to ensure AI can effectively work with humans. I outline these three strategies below in some additional detail.

Evaluating the Impact of AI on the Future of Work

The first and most important step in evaluating the impacts of AI on jobs should be to map out how technology is going to affect the future of work. This comprehensive analysis will help to better understand where AI will impact the workforce and in what ways those impacts will affect employees.

There is already a significant amount of focus around the potential for job losses and I believe that is not the appropriate way to view the impact AI will have. We must focus on tasks, not jobs. Some tasks will be automated, while others will be augmented. It is important that we understand where the technological change is likely to happen – at the task level vs. at the job level. This distinction is important as we plan around these emerging technologies since jobs are a bundle of tasks. When tasks get automated or augmented, the nature of skills required to do the job changes.

Developing Comprehensive Re-Skilling and Re-Training Opportunities

Once we fully understand the sectors and tasks within them that will be augmented or automated by AI, we will need to prioritize re-skilling. This could be retraining or reskilling provided by the employer to employees or offered at societal scale to citizens seeking to acquire the skills required to find jobs. This is a fundamental change from where we are today. We don't have effective reskilling programs that can train large numbers of people (i.e., at scale) in the United States and where they exist they often do not deliver learning outcomes and skills required to acquire the jobs being produced in the economy.

Operations research can be an effective tool in determining how to deploy training and who should receive it. While AI-based educational technologies can be harnessed to deliver the training, targeting what training would deliver the most value to an individual is the province of Operations Research. This requires complex modeling to ensure that re-skilling and re-training at scale is effective for both employees/citizens and responsive to emerging job trends.

Designing Teaming Arrangements with AI

Since most jobs will not be fully replaced by AI, it is critical that AI is designed in a way to work effectively with humans. In doing so, we must develop teaming arrangements, which requires a firm understanding of and coordination with both the priorities I mentioned previously – identifying tasks within jobs that are impacted by AI and developing re-skilling and re-training opportunities.

In closing, I would like to thank the committee for the work you are doing to approach AI with a focus on the workforce. I hope you will work with academia, especially those within the operations research and analytics fields, who are aggressively leading the way on modeling the future of work as it relates to AI.

I look forward to working with the members of this committee and your staff as you think through policy decisions that relate to both AI and the future of work.

Thank you.