The Rise of the Robots

In the U.S.

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About the Editor

Michael Erbschloe has worked for over 30 years performing analysis of the economics of information technology, public policy relating to technology, and utilizing technology in reengineering organization processes. He has authored several books on social and management issues of information technology that were published by McGraw Hill and other major publishers. He has also taught at several universities and developed technology-related curriculum. His career has focused on several interrelated areas:

- Technology strategy, analysis, and forecasting
- Teaching and curriculum development
- Writing books and articles
- Publishing and editing
- Public policy analysis and program evaluation

Books by Michael Erbschloe

Social Media Warfare: Equal Weapons for All (Auerbach Publications)
Walling Out the Insiders: Controlling Access to Improve Organizational Security (Auerbach Publications)
Physical Security for IT (Elsevier Science)
Trojans, Worms, and Spyware (Butterworth-Heinemann)
Implementing Homeland Security in Enterprise IT (Digital Press)
Guide to Disaster Recovery (Course Technology)
Socially Responsible IT Management (Digital Press)
Information Warfare: How to Survive Cyber Attacks (McGraw Hill)
The Executive's Guide to Privacy Management (McGraw Hill)
Net Privacy: A Guide to Developing & Implementing an e-business Privacy Plan (McGraw Hill)

Introduction

In 1982 comments given before a House subcommittee by the General Accountability Office (GAO) presented the view that automation can be an important factor in productivity improvement, although rapid, wide-scale adoption of automation may exacerbate such problems as labor displacement, skill shortages, geographic dislocations, and labor-management bargaining. The U.S. lag in implementing automation in comparison with other industrial nations is in part reflected in the Nation's declining productivity. The barriers to more rapid implementation of automated technologies include: (1) technical barriers which are encountered in getting automated equipment to work; (2) financial barriers which arise from the necessity to invest in new capital equipment such as automated devices; and (3) social barriers which are based on human resistance to change. Published predictions have cited the potential loss of millions of jobs in the manufacturing sector because of the use of robotics. At the same time, new and existing occupations are expected to increase because of the advent and diffusion of automation. Federal efforts to encourage automation include: (1) financial incentives for private sector action; (2) research responsibilities; (3) technology transfer mechanisms; (4) support of engineering education; and (5) the development of standards to facilitate integration of diverse components of automation systems.

(Link: http://www.gao.gov/products/118784)

Welcome to the 21st Century!

One exciting element of the Advanced Manufacturing Partnership is the National Robotics Initiative. Robots are working for us every day, in countless ways. At home, at work, and on the battlefield, robots are increasingly lifting the burdens of tasks that are dull, dirty, or dangerous.

But they could do even more, and that's what the National Robotics Initiative is all about. Four agencies (the National Science Foundation, the National Institutes of Health, NASA, and the United States Department of Agriculture) issued a joint solicitation that will provide up to $70 million in research funding for next-generation robotics.

The focus of this initiative is on developing robots that work with or beside people to extend or augment human capabilities, taking advantage of the different strengths of humans and robots. In addition to investing in the core technology needed for next-generation robotics, the initiative will support applications such as robots that can:

- Increase the productivity of workers in the manufacturing sector;
- Assist astronauts in dangerous and expensive missions;
- Help scientists accelerate the discovery of new, life-saving drugs; and
- Improve food safety by rapidly sensing microbial contamination.

The initiative will also designed to accelerate progress in the field by requiring researchers to share the software and robotics operating systems they develop or contribute to, and funding the purchase of robotics platforms. The Obama Administration decided to make robotics a priority because:

- Robotics can address a broad range of national needs such as advanced manufacturing, logistics, services, transportation, homeland security, defense, medicine, healthcare, space exploration, environmental monitoring, and agriculture;
- Robotics technology is reaching a "tipping point" and is poised for explosive growth because of improvements in core technologies such as microprocessors, sensors, and algorithms;

• Robotics can play an important role in science, technology, engineering and mathematics (STEM) education because it encourages hands-on learning and the integration of science, engineering, and creative thinking; and
• Members of the research community such as the Computing Community Consortium and program managers in key sciences have developed a shared vision and an ambitious technical agenda for developing next-generation robotic systems that can safely work with humans and augment human capabilities.

(Link: https://obamawhitehouse.archives.gov/blog/2011/06/24/developing-next-generation-robots)

The goal of the National Robotics Initiative (NRI) is to support fundamental research that will accelerate the development and use of robots in the United States that work beside or cooperatively with people. The original NRI program focused on innovative robotics research that emphasized the realization of collaborative robots (co-robots) working in symbiotic relationships with human partners.

The 2.0 program significantly extends this theme to focus on issues of scalability: how teams of multiple robots and multiple humans can interact and collaborate effectively; how robots can be designed to facilitate achievement of a variety of tasks in a variety of environments, with minimal modification to the hardware and software; how robots can learn to perform more effectively and efficiently, using large pools of information from the cloud, other robots, and other people; and how the design of the robots' hardware and software can facilitate large-scale, reliable operation.

(Link: https://www.nsf.gov/funding/pgm_summ.jsp?pims_id=503641&org=CISE)

The Need for Industrial Competitiveness

In 1982 comments given before a House subcommittee by the General Accountability Office (GAO) presented the view that automation can be an important factor in productivity improvement, although rapid, wide-scale adoption of automation may exacerbate such problems as labor displacement, skill shortages, geographic dislocations, and labor-management bargaining. While the private sector may assume primary responsibility for developing and implementing automation technology, the Federal Government will probably continue to play some role by developing policies and programs to encourage continued growth in automation and to address related employment problems.

The U.S. lag in implementing automation in comparison with other industrial nations is in part reflected in the Nation's declining productivity. The barriers to more rapid implementation of automated technologies include: (1) technical barriers which are encountered in getting automated equipment to work; (2) financial barriers which arise from the necessity to invest in new capital equipment such as automated devices; and (3) social barriers which are based on human resistance to change. Despite these barriers, current national economic problems stimulate both development and use of automation technology. Published predictions had cited the potential loss of millions of jobs in the manufacturing sector because of the use of robotics. At the same time, new and existing occupations are expected to increase because of the advent and diffusion of automation. Federal efforts to encourage automation include: (1) financial incentives for private sector action; (2) research responsibilities; (3) technology transfer mechanisms; (4) support of engineering education; and (5) the development of standards to facilitate integration of diverse components of automation systems. No current Federal programs

are aimed specifically at resolving the problems of unemployment caused by automation, including training in the necessary technical skills. GAO believes that there is a need for an overall plan to guide Federal policies and programs related to automation."

(Link: http://www.gao.gov/products/118784)

In 1992 the GAO reported to Congress that: (1) aggregate performance indicators provide some evidence of a decline in the U.S. leadership position in developing and marketing technology-intensive products, particularly relative to Japan; (2) evidence on trends in the U.S. trade balance in high-technology products is mixed, with measures of high-technology trade sensitive to which products are included; (3) several indicators yield evidence that the technology gap between Japan and the United States has narrowed in recent decades; (4) measures of research output show Japanese gains; (5) the United States is the world leader in the production and consumption of telecommunications equipment; (6) the share of U.S.-owned firms in the domestic and world consumer electronics markets has declined dramatically over the last 40 years; (7) Japan is the world's largest market and producer of semiconductors; and (8) the decline in U.S. position in some industries has been strongest in the less technologically sophisticated industry segments.
(Link: http://www.gao.gov/products/NSIAD-92-236)

In 2013 the GAO reported that over the last decade, the United States lost about one-third of its manufacturing jobs, raising concerns about U.S. manufacturing competitiveness. There may be insights to glean from government policies of similarly-situated countries, which are facing some of the same challenges of increased competition in manufacturing from developing countries.

The four countries GAO analyzed--Canada, Germany, Japan, and South Korea--offer a varied mix of programs to support their manufacturing sectors. For example, Canada is shifting emphasis from its primary research and development (R&D) tax credit toward direct support to manufacturers to encourage innovation, particularly small- and medium-sized enterprises (SMEs). Germany has established applied institutes and clusters of researchers and manufacturers to conduct R&D in priority areas, as well as a national dual training system that

combines classroom study with workplace training, and develops national vocational skills standards and credentials in 350 occupations. Japan has implemented science and technology programs--with a major focus on alternative energy projects--as part of a comprehensive manufacturing strategy. South Korea has substantially expanded investments in R&D, including the development of a network of technoparks--regional innovation centers that provide R&D facilities, business incubation, and education and production assistance to industry.

When compared to the United States, the countries in GAO's study offer some key distinctions in government programs to support the manufacturing sector in the areas of innovation, trade, and training.

- While the United States and the other four countries all provide support for innovation and R&D, the foreign programs place greater emphasis on commercialization to help manufacturers bridge the gap between innovative ideas and sales. These include programs that support infrastructure as well as hands-on technical and product development services to firms, and that foster collaboration between manufacturers and researchers. In contrast, the United States relies heavily on competitive funding for R&D projects with commercial potential.

- Within trade policy, the United States and the four countries in GAO's study provide similar services, but there are several differences in how they are delivered. For example, the United States is an acknowledged leader in intellectual property protection, but the U.S. government plays a less prominent role than the Japanese government in developing technological standards on industrial products.

- A key difference related to training programs pertains to the sustained role of government in coordinating stakeholder input into a national system of vocational skills training and credentialing, which helps provide a supply of skilled workers for manufacturers. This was particularly evident in Germany. In contrast, the United States largely devolves vocational training to states and localities and does not have a national system to issue industry-recognized credentials. However, the U.S. manufacturing industry, with participation from the federal government, has recently launched an effort

to establish nationally portable, industry-recognized credentials for the manufacturing sector.

(Link: http://www.gao.gov/products/GAO-13-365)

The U.S. manufacturing sector comprises businesses that are engaged in the mechanical, physical, or chemical transformation of materials, substances, or components into new products, including sectors such as machinery, textiles, apparel, food production, and chemicals. However, U.S. policy makers have become focused on competing in high-end, or "advanced manufacturing." While no consensus definition of advanced manufacturing exists, it refers generally to the production of scientifically- and technologically-intensive products, in which the economic value derives from inputs of knowledge and design more than it reflects traditional inputs such as labor and materials. Robotics, nano-manufacturing, and electric vehicles are examples of advanced

Statistics present a mixed picture about the health of U.S. manufacturing, both relative to the rest of the U.S. economy and to other countries' manufacturing sectors. According to data from BLS, manufacturing employment has fallen from 17.6 million workers in 1998 to 11.5 million in early 2010, a decline of over one-third over a period in which total U.S. employment grew somewhat. However, the decline in U.S. manufacturing employment is not a new phenomenon, and a longer-term view shows a steady decline of manufacturing's share of all American jobs.

Since bottoming out in 2010, manufacturing employment rebounded slowly up to about 12 million workers at the end of 2012. Also, other advanced economies, such as Canada, Germany, Japan, and the United Kingdom, suffered large manufacturing job losses from 1998 to 2011, suggesting that global economic forces have affected manufacturing employment in addition to any factors that may be unique to the United States.

Not all experts agree on what role, if any, the government should play in supporting manufacturing. Economic theory generally suggests that government intervention into private sector activity is justified by "market failure"—situations in which the private market under- or over-produces a good because private interests differ from society's. Those supportive of enhancing productivity in manufacturing suggest that government policy should target the sector

in order to remedy market failures that may hinder innovation—the development and application of new knowledge. Innovation underpins improvements in the way capital and labor are combined to create new products and increase productivity. This makes it critical for the broader economy and particularly important for manufacturing.

An important element of innovation is research and development (R&D), the testing and application of new ideas. R&D is seen as a key source of innovation and its application to new products and technologies. The private sector, however, faces disincentives to investing in R&D— it may be expensive, it often fails, willing firms may lack sufficient finances, and successful R&D may produce benefits that the investing firm cannot capture — leading to possible underinvestment in R&D and underproduction in innovation without government support. These disincentives may be particularly difficult to overcome for small- and medium-sized enterprises (SME). Though innovation policy can address market failure across all sectors of the economy, advocates of targeted innovation policy argue that it may provide particular benefit to manufacturing. They note that the sector depends on continually creating new ideas for products and ways to make those products. They also observe that manufacturing is a significant source of R&D; according to the National Science Foundation, the sector accounted for 70 percent of private-sector spending on R&D in the United States in 2008.

In practical terms, to support needed innovation, the government may intervene through various policies, some of which may have a focus on the manufacturing sector. These include:

- Public support for "basic" R&D in science and engineering, which, while conducted without specific commercial applications in mind, can spur private-sector innovation. The public sector may be well-suited to conducting basic R&D directly, through government scientific agencies, public universities, and other research institutions, because it is unlikely that most private firms would conduct this type of general research without a potentially profitable application in mind.
- Public support for private-sector "applied" R&D, research that seeks to solve practical problems or develop new products and commercialization. Applied R&D is seen as a key component in helping innovators overcome the so-called "valley of death", the difficult transition between new ideas and commercially viable manufacturing products or processes. Support for applied R&D could take various forms:

- Subsidies for private investment in R&D, through direct funding or tax incentives, and assistance with financing for private R&D projects with commercialization potential, which may overcome the difficulty some firms may face in obtaining funding from private financial markets. However, it may be difficult for the government to figure out which firms merit subsidy because of the lack of information or foresight into an individual firm's growth prospects.
- Public infrastructure investment that facilitates R&D and knowledge transfer, such as research laboratories, transportation investment, and "knowledge" infrastructure such as broadband telecommunications, the development of measurement techniques and databases, and the dissemination of technical expertise. Experts have referred to such widely-accessible infrastructure or knowledge as the "industrial commons" that provides a base for innovation and production, and see investment in these commons as an important source of new ideas for products or processes and solutions to existing problems.
- Public support for innovation clusters — regional concentrations of large and small companies that develop creative products and services, along with specialized suppliers, service providers, universities, and associated institutions. Firms in a cluster may be able to share knowledge and transact business at lower cost than if they were far apart, possibly leading to increased innovation.8

However, the effectiveness of cluster policy has not been established; the formation of successful clusters in the United States, such as California's Silicon Valley, suggests that government support for clusters may not be necessary. Government support for manufacturing can also involve other efforts that support activities that may suffer from market failures:

- Development of knowledge and workforce skills. Like investment in R&D, private firms may lack the incentive to invest in worker training because the firms may not recoup a sufficient investment if workers take their training to another firm or if skills become obsolete. As manufacturing has become more technologically advanced, various experts have highlighted the increased importance of skills training in advanced manufacturing, as well as the adaptability of workers and training resources. Manufacturing in

scientifically-intensive fields will also require a pipeline of workers with advanced degrees in science, technology, engineering, and mathematics. A recent study from the Brookings Institution uses the Bureau of Labor Statistics' data to project that nearly half of all job openings in the U.S. economy over the next decade will be for "middle-skill" jobs, those requiring more than high school but less than a college degree.

- Promotion of open trade and global competition, through trade liberalization, the provision of information, advice, and advocacy for exporters (referred to as export promotion), the protection of intellectual property rights, development and harmonization of international technological standards, and the enforcement of trade rules. While free trade agreements have decreased the significance of tariffs as a trade barrier, some experts have argued that non-tariff barriers have become increasingly problematic. These could include restrictive technical standards, packaging, and local content requirements, among others. Trade policy may be especially critical for manufacturing since the sector may play a key role in restoring a healthy balance of trade. In 2012, Commerce reported that in 2010, manufactured goods represented 86 percent of all U.S. goods exported and 60 percent of total U.S. exports.

In the United States, the federal government has generally taken the lead in supporting basic research, providing the economic framework, and constructing infrastructure. Commerce administers manufacturing programs through sub-agencies such as the National Institute of Standards and Technology (NIST), the Economic Development Administration (EDA), and the International Trade Administration. Other U.S. agencies support manufacturing as part of their program activities, including the Department of Defense, the Department of Energy, National Aeronautics and Space Administration, and the National Science Foundation. Labor administers training programs for job seekers through the Employment and Training Administration. In addition, tax breaks such as the R&D tax credit further benefit manufacturers (although these provisions do not apply exclusively to manufacturers). States and localities have the main responsibility for education and also are most active in promoting regional economic development, including measures that support innovation.

The United States has developed as a global leader, in large part, through the genius and hard work of its scientists, engineers, and innovators. In a world that's becoming increasingly complex, where success is driven not only by what you know, but by what you can do with what you know, it's more important than ever for our youth to be equipped with the knowledge and skills to solve tough problems, gather and evaluate evidence, and make sense of information. These are the types of skills that students learn by studying science, technology, engineering, and math—subjects collectively known as STEM.

Yet today, few American students pursue expertise in STEM fields—and we have an inadequate pipeline of teachers skilled in those subjects. That's why it is a high priority to increase the number of students and teachers who are proficient in these vital fields.

All young people should be prepared to think deeply and to think well so that they have the chance to become the innovators, educators, researchers, and leaders who can solve the most pressing challenges facing our nation and our world, both today and tomorrow. But, right now, not enough of our youth have access to quality STEM learning opportunities and too few students see these disciplines as springboards for their careers.
(Link: https://www.ed.gov/stem)

The STEM Plan in Brief

The Committee on STEM Education (CoSTEM), comprised of 13 agencies—including all of the mission-science agencies and the Department of Education—are facilitating a cohesive national strategy, with new and repurposed funds, to increase the impact of federal investments in five areas: 1.) improving STEM instruction in preschool through 12th grade; 2.) increasing and sustaining public and youth engagement with STEM; 3.) improving the STEM experience for undergraduate students; 4.) better serving groups historically underrepresented in STEM fields; and 5.) designing graduate education for tomorrow's STEM workforce

Coordinated efforts to improve STEM education are outlined in the federal, 5-year Strategic Plan for STEM Education and concentrate on improving the delivery, impact, and visibility of STEM

efforts. Additionally, the Department of Education, the National Science Foundation, and the Smithsonian Institution are leading efforts to improve outcomes for traditionally underrepresented groups.

The health and longevity of our Nation's, citizenry, economy and environmental resources depend in large part on the acceleration of scientific and technological innovations, such as those that improve health care, inspire new industries, protect the environment, and safeguard us from harm. Maintaining America's historical preeminence in the STEM fields will require a concerted and inclusive effort to ensure that the STEM workforce is equipped with the skills and training needed to excel in these fields. During President Obama's first term, the Administration used multiple strategies to make progress on improving STEM education:

- Making STEM a priority in more of the Administration's education efforts. The first round of the Department of Education's $4.3 billion Race to the Top competition offered states a competitive preference priority on developing comprehensive strategies to improve achievement and provide rigorous curricula in STEM subjects; partner with local STEM institutions, businesses, and museums; and broaden participation of women and girls and other groups underrepresented in STEM fields. Other examples include STEM priorities in the Department of Education's Invest in Innovation and Supporting Effective Educator Development programs. Prioritizing STEM in existing programs at the Department of Education has the advantage of leveraging existing resources and embedding STEM within our overall education reform efforts.

- Setting ambitious but achievable goals and challenging the private sector. President Obama announced the goal to prepare 100,000 excellent STEM teachers over the next decade in his 2011 State of the Union Address. Answering this call to action, over 150 organizations led by the Carnegie Corporation of New York formed a coalition called 100Kin10. Members of the coalition have made over 150 commitments to support STEM-teacher preparation and had raised over $30 million for this effort. In mid-March, the Howard Hughes Medical Institute announced a $22.5M investment to support expansion of the successful UTeach program in support of this goal. Additional examples

of this all-hands-on-deck approach to challenging companies, foundations, non-profits, universities, and skilled volunteers include Change the Equation, US2020, and the scaling up and expanding an AP program for children in military families.

- The first-ever White House Science Fair took place in late 2010 and the second in 2012, fulfilling a commitment made at the launch of the Educate to Innovate campaign to directly use the pulpit to inspire more boys and girls to excel in mathematics and science. A call to action was issued to the 200,000 Federal scientists and engineers to volunteer in their local communities and think of creative ways to engage students in STEM subjects. Improving STEM education will continue to be a high priority in President Obama's second term. Guided by the aims articulated in the February 2012 Progress Report and subsequent pre-final drafts of this Strategic Plan—as well by the President's desire to re-organize STEM-education programs for greater coherence, efficiency, ease of evaluation, and focus on his highest priorities—the Executive Office of the President recommended, and the President accepted, a FY2014 Budget Request for STEM education that would increase the total investment in STEM-ed programs by 6 percent over the 2012 appropriated level.

- The Department of Education was designated to play an increased role in improving P-12 STEM instruction by supporting partnerships among school districts and universities, science agencies, businesses, and other community partners to transform teaching and learning. It also invested an additional $80 million in support of the 100,000 new STEM-ed teachers goal and $35 million for the launch of a pilot STEM-ed Master Teacher Corps, as well as in creation of new STEM Innovation Networks to better connect school districts with local, regional, and national STEM resources. The Department also collaborated with all of the CoSTEM agencies to ensure that Federal scientific assets were utilized in the improvement of P-12 STEM education.

- The National Science Foundation increased its focus on improving the delivery of undergraduate STEM teaching and learning through evidence-based reforms, including a new $123 million program aimed at improving retention of undergraduates in STEM

fields. NSF also received $325 million to expand and enhance its graduate fellowship programs, including creation of a new National Graduate Research Fellowship, using a common infrastructure at NSF to reach more students and offer a set of opportunities that address national needs and mission critical workforce needs for the CoSTEM agencies.

- The Smithsonian Institution received $25 million to focus on improving the reach of informal STEM education by ensuring that materials are aligned to what students are learning in the classroom. The Smithsonian worked with NSF, ED, the other CoSTEM agencies including the National Aeronautics and Space Administration (NASA), National Oceanic and Atmospheric Administration (NOAA), U.S. Department of the Interior (DOI), U.S. Department of Agriculture (USDA), National Institutes of Health (NIH), and other science partners to harness their unique expertise and resources to disseminate relevant, evidence-based materials and curricula, on-line resources, and delivery and dissemination mechanisms to reach more teachers and students both inside and outside the classroom.

All of the CoSTEM agencies continued to be key players in the re-organized effort. All of these agencies depend upon the cultivation of a talented and well-trained workforce in order to meet their STEM-related missions, and all of them play a critical role in inspiring and training the next generation of STEM workers. Whether it be through direct support, provision of expertise and content, mobilization of talented STEM role models and mentors, or by exposing students to real-world learning opportunities at Federal STEM facilities, these agencies inspire and inform future scientists, engineers, innovators, and explorers.

The Strategic Plan complements the important steps already taken. The Plan begins by providing an overview of the importance of STEM education to American scientific discovery and innovation, the need to better prepare students for today's jobs and those of the future, and the importance of a STEM-literate society and also describes the current state of Federal STEM education efforts. The document then presents five priority STEM education investment areas