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Every Sector Is a Software Sector: **Manufacturing**

How Software Is Turbocharging Manufacturing Opportunities for All

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Manufacturing has long been the backbone of the American economy. Today we stand on the verge of a major manufacturing renaissance powering more jobs, with economic impacts as transformative as those sparked by the first industrial revolution. Powerful and new software-driven technologies are helping expand a manufacturer's strategic options — enabling companies to create new kinds of jobs, boost efficiency, drive quality, and improve output.

Software has transformed manufacturing and manufacturing jobs. At the heart of this renaissance is a powerful set of revolutionary new software tools that enable manufacturers to radically rethink the way they make almost everything with digital precision and data-driven insights. These game-changing software advances are expanding possibilities throughout the manufacturing life cycle — generating designs never before possible, creating new types of manufacturing workers, fueling entirely new classes of software-enhanced machines, and transforming products from the ordinary into the extraordinary by infusing them directly with software.

At the beginning of the manufacturing life cycle, manufacturers are now able to design smarter prototypes more quickly and test more effectively using 3D design software infused with artificial intelligence. Workers can then feed these digital designs directly into a new class of software-enabled machines like 3D printers, laser cutters, water jet cutters, CNC machines, computer-controlled welders, and multi-axis robots that workers use to make things with digital precision. These changes not only allow manufacturers to make things previously impossible to make, but to expand the materials they make things with and the very ways they fuse, bond, extrude, cut, bend, and combine things.

> Together these software-enabled tools are helping manufacturers imagine the unimaginable, make the unmakeable, and create the unbelievable.

> The test of strength for tomorrow's manufacturing economy isn't whether things are built with gears, pulleys, and levers, but whether our manufacturing future is built with software, the cloud, and data.

Together these software-enabled design and fabrication tools are helping manufacturers imagine the unimaginable, make the unmakeable, and create the unbelievable.[1] These tools reduce the cost of complexity, allowing the consumers of things to also become the creators of things, and enabling the industry to move from mass production to a world of mass customization. Some are finding that it enables entirely new business models by radically improving time to market, lowering startup costs, increasing the speed of innovation, and eliminating the need for costly inventory. And with online marketplaces that enable anyone to upload 3D models for remote 3D printing, these tools democratize manufacturing as anyone with a good idea and an Internet connection can become the machine shop for the entire planet.

Factories are taking advantage of smarter software too. Factories are boosting output by harnessing data from production lines fitted with hundreds of actuators and thousands of sensors to provide a more immediate, dynamic, and comprehensive view for improving control of the manufacturing process. By combining this sensor data with predictive analytics software, managers can better predict costly equipment failures before they occur, enabling time-sensitive adjustments to maintain an uninterrupted factory flow and high-quality output. Software also is improving how the manufacturing process can be integrated and managed. For example, new software advances enable manufacturers to see across separate processes in an interconnected supply chain system so that they can boost orders, reduce errors, and speed delivery.

But the greatest improvement may be in the way that smarter factories now produce smarter products, too — products that are themselves infused with software to magnify and multiply what the product can do. This means that the key differentiators among products are increasingly the software lines in a product's code because software is increasingly incorporated directly into products themselves.

As a result, the test of strength for tomorrow's manufacturing economy isn't how things are built, but whether our manufacturing future is built with software, the cloud, and data.

Manufacturing is already the leading data-driven industry. Manufacturers don't just produce goods, today they produce data, and lots of it. The manufacturing sector generates nearly 2,000 petabytes of data every year — more data than any other sector of the economy, and twice as much as the next largest sector.[2] And yet, because modern software tools have yet to be fully implemented, an estimated 99 percent of manufacturing data gets discarded before decision-makers can take advantage of it.[3] It signals an enormous opportunity, and represents one of the key reasons manufacturers are now turning to software to change data into insights and open vast new opportunities to improve the way they do business.

Amazingly, to take advantage of these opportunities, manufacturers are now hiring more software developers than production line workers.

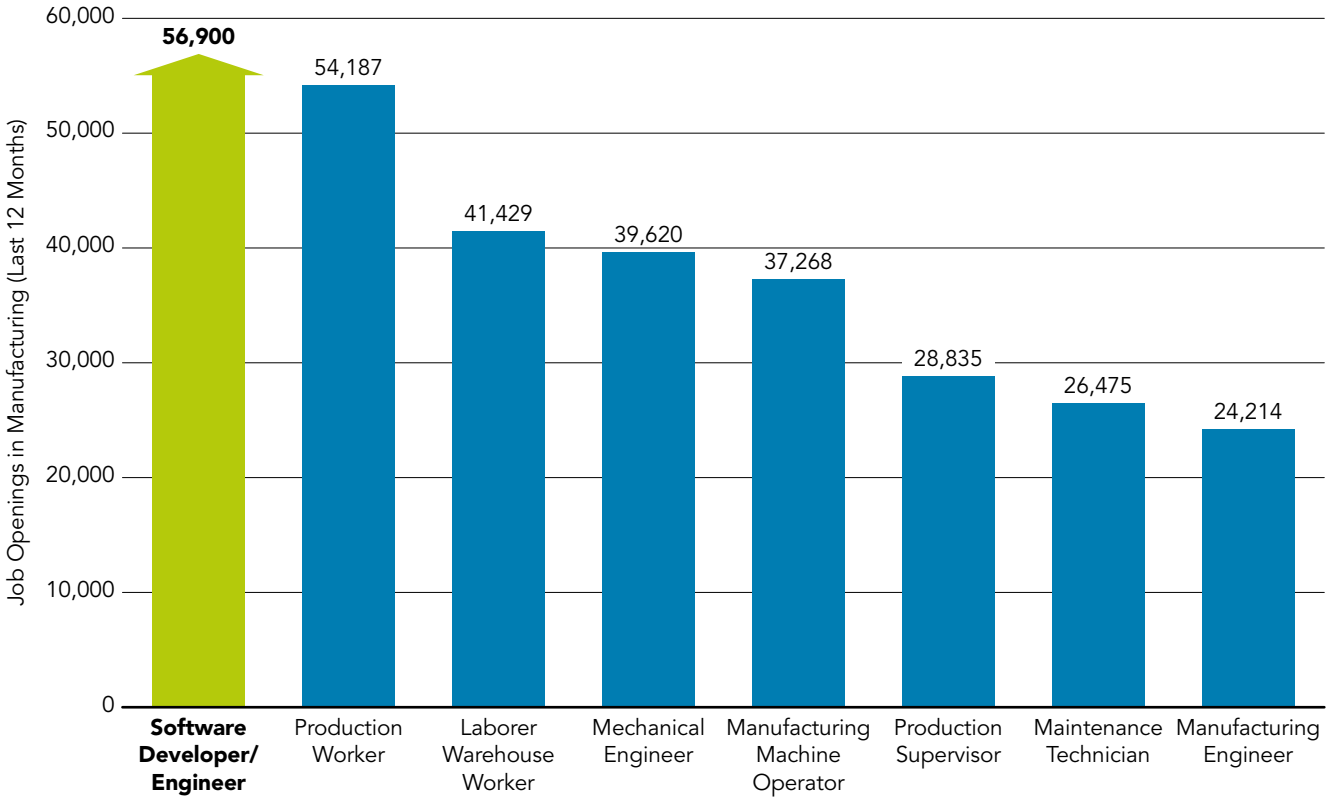
To take advantage of the software opportunity, the average manufacturing site today already uses more than 150 software programs to operate.[4] Now a new generation of cloud-based software capable of integrating systems is taking advantage of the abundance of data as a central focus for improving the way products are designed, built, and distributed.

These software advancements are not just improving the production line, they are also boosting the bottom line. Already, nearly two-thirds of US manufacturers expect digital manufacturing technologies to lower operating costs by at least 11 percent (with nearly a quarter expecting cost-savings exceeding 30 percent).[5]

To achieve these gains, manufacturers have been hiring software programmers in droves. There are already more than 150,000 software programmers who work in the manufacturing industry.[6] In fact, demand for software developers among auto manufacturers alone has grown an astounding 200 percent over just four years.[7] These are signs that what's being made and how it's being made increasingly depend on software.

Together these tools promise to make jobs more plentiful and America more prosperous. It is why some believe this manufacturing renaissance can create entirely new industries, supporting thousands of good paying jobs, and boosting US competitiveness.

Software Is Leading Manufacturing Job Openings



Source: Burning Glass Technologies

The Numbers Show Software Is Turbocharging Manufacturing Opportunity

Manufacturers are quickly adopting a wide range of software-enabled disruptive technologies like 3D design, additive manufacturing, the cloud, and the Internet of Things (IoT) to transform the way they design, build, and deliver new products — and the benefits are enormous.

Cutting Development Time

Up to **50 percent reduction** in development time, and elimination of defects prior to production through software-based design, simulation and testing.[a]

Optimizing the Factory Floor

10 to 25 percent increase in manufacturing productivity using sensors to bring intelligence to production equipment and optimizing their collective use.[b]

Boosting Energy Efficiency

25 percent improvement in energy efficiency by implementing smart manufacturing technologies.[c]

Improving Time to Market

10 times improvement in time to market in target industries by implementing smart manufacturing.[d]

Boosting Output

47 percent more goods are being produced today than 20 years ago through the development of automation, robotics, and advanced manufacturing.[e]

Reducing Safety Incidents

25 percent reduction in safety incidents by implementing smart manufacturing technologies.[f]

Driving Shop Floor Efficiency

67 percent of manufacturers are making investments in disruptive technologies to drive efficiencies in production.[g]

Cutting Downtime

40 percent reduction in maintenance costs, and **50 percent reduction** in downtime by connecting IoT sensors with predictive analytics.[h]

Enabling New Business Models

1 out of every 2 manufacturers are using disruptive technologies to enable new business models/ new revenue streams.[i]

[a] James Manyika, Michael Chui, Brad Brown, Jacques Bughin, Richard Dobbs, Charles Roxburgh, and Angela Hung Byers, "Big Data: The Next Frontier for Innovation, Competition, and Productivity," McKinsey Global Institute Report (June 2011), available at https://www.mckinsey.com/~/media/McKinsey/Business%20Functions/McKinsey%20Digital/Our%20Insights/Big%20data%20The%20next%20frontier%20for%20innovation/MGI_big_data_full_report.ashx.

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[c, d, f] The United States' Smart Manufacturing Leadership Coalition (SMLC), "Economic Benefit," Smart Manufacturing Leadership Coalition, available at https://www.smartmanufacturingcoalition.org/economic-benefit.

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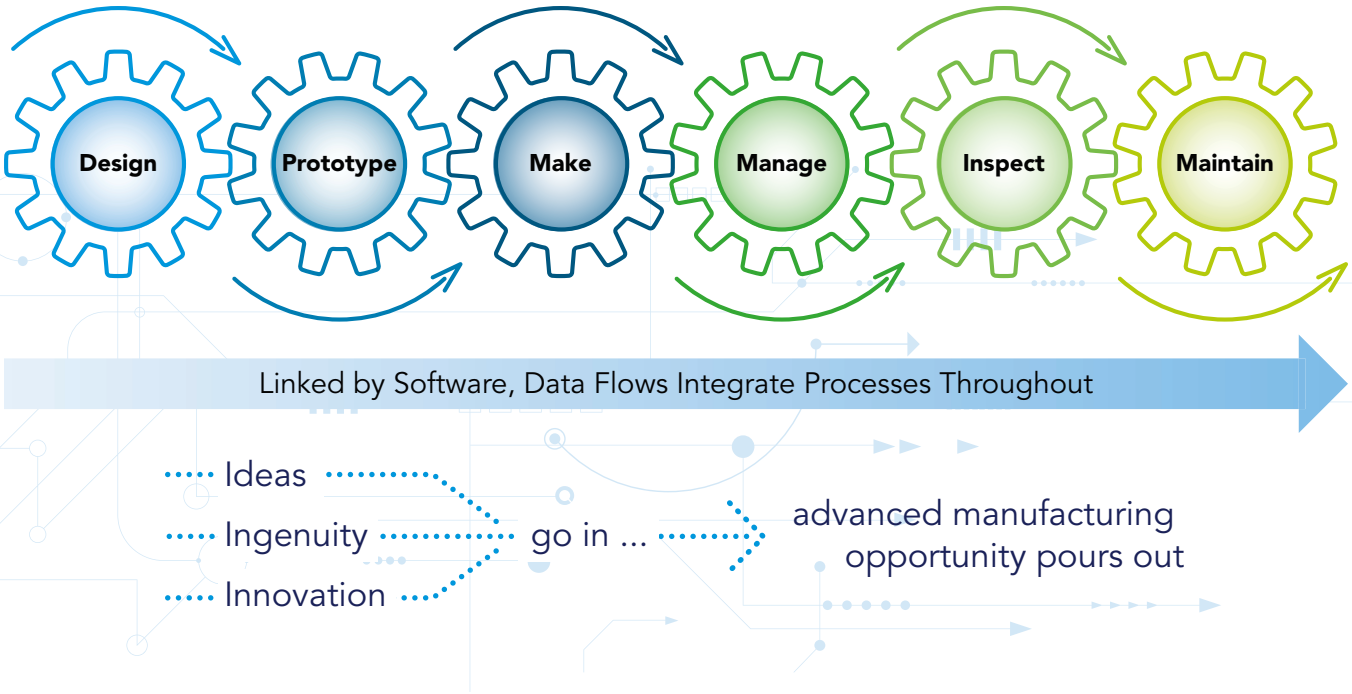
Software and Data: Innovation of the Entire Manufacturing Life Cycle



Making Smarter Designs

3D is the new shape of industrial manufacturing. Long before a product takes form on the factory floor, it takes shape on a computer screen where cutting-edge 3D software is used to generate new types of designs, prototype quicker, and test more effectively. These tools are so powerful that McKinsey found better use of software design and data in manufacturing can cut product development time by 20 to 50 percent by eliminating defects prior to production through simulation and testing.[8]

Generating new types of design. One of the amazing new opportunities now being enabled is the use of artificial intelligence algorithms to assist the design process. Called generative design, designers can now use cloud-based AI infused design tools to rapidly design and test countless computer-generated design options that meet specific design objectives (like cost, size, strength, and materials) to more quickly produce more robust and often unexpected solutions.

- ***Helping engineers create part design improvements.*** Generative design software is being used by GM as part of its ongoing efforts to reduce weight and increase the strength of its car parts. Using innovative new generative design software from Autodesk, GM was able to, for example, consolidate eight different parts into one 3D-printed seat bracket that is 40 percent lighter and 20 percent stronger using a new design whose organic structure no human could have conceived on their own.[9] Making each part lighter is critical because the lighter the part, the lighter the car, the less fuel it uses, the less carbon it emits, and the more money the driver saves.

Making prototypes faster. Today as product cycles shrink, development of the next generation product begins almost as soon as the last one reaches market. To accelerate the new product development cycle, companies are now taking advantage of advanced software that enables them to simulate design performance, test physical attributes in a virtual environment, and reduce the need for costly physical prototypes.

- ***Blowing other designs away.*** In the 1980s, Boeing had to test 77 different prototypes using physical wind tunnels. By 2005 it only needed to run 11 tests for its 787 prototypes using a virtual wind tunnel that took advantage of supercomputer speeds that could run complex computational fluid dynamic (CFD) models. But now, software like Flow Design puts the power of a supercomputer and a virtual wind tunnel on anyone's desktop.[10] For a company like Boeing, the ability to combine virtually tested 3D models with 3D printing has enabled it to produce more than 20,000 3D printed parts used on military platforms today.

- ***Smoothing out design simulations.*** American Axle & Manufacturing (AA&M) produces drivetrain systems for a range of cars and trucks, with the aim of doing it so smoothly that drivers cannot hear or feel vibrations from the driveline's transfer of power from the engine to the wheels. By using Siemens PLM Software for computer-aided engineering, AA&M's designers are able to produce simulated new models and predict product performance before any metal is cut.[11]

Enabling new forms of collaboration. Cloud-based design tools also have the advantage of enabling new kinds of collaboration among often disparate design teams who can work in real-time to improve project decision-making, and to virtually integrate individual parts into a broader assembly to ensure they work together as seamlessly as expected. One team in one location might work on designing a car door handle, and another the overall door assembly. But their designs can be integrated, tested, and modified together regardless of their location. It used to take as long as five years to design a new car. But Toyota, Fiat, and Nissan have all cut new-model development time by 30 to 50 percent through the collaborative use of data and software modelling techniques.[12,13]

Making Things in Entirely New Ways

With a 3D design in hand, a new generation of software-controlled fabrication machines is enabling these digital designs to be directly uploaded and turned into real-world things. By transferring complex 3D designs to a growing variety of digitally controlled fabrication machines, manufacturers can infinitely expand the art of the possible by changing how they fuse, bond, extrude, cut, bend, combine, and make things with digital precision.

3D printing, or additive manufacturing, is especially revolutionary — enabling manufacturers to print components directly from a computer file. It creates new opportunities for designers to create parts that are customized, stronger, lighter, and that frankly can't be manufactured in any other way. Importantly, according to the Department of Energy, using 3D printing to manufacture something can also reduce energy costs by 50 percent and material costs by 90 percent.[14]

As 3D printers have become less expensive, more functional, and able to print an increasing multitude of materials simultaneously, they have become increasingly important in industrial manufacturing. Today they can already print with a range of materials including titanium, glass, rubber, plastic, porcelain, color sandstone, and carbon fiber.

For example, rocket manufacturers are using software to design and 3D print rocket engines that use 100 times fewer parts, to help them fly better rockets.[15] NASA's rocket scientists found that their 3D printed metal rocket engine parts are reducing costs by nearly 35 percent and production time by more than 80 percent.[16]

Moving from mass production to mass customization. One of the most impactful implications of this software revolution is the ability to move manufacturing beyond mere mass production to a world of mass customization — personalizing products at unparalleled scale. Using clever software, digital factories can now mass produce individualized things. For example, today, three-quarters of a million people are smiling with 3D printed custom dental implants, an estimated 10 million people are hearing better with customized 3D printed hearing aids, and an estimated 2 million people are walking around with custom built 3D printed prosthetic devices.[17]

Making Smarter Factories That Run More Efficiently

Software is also creating smarter factories of the future in two distinct ways: (1) using software to improve factory layout and efficiency, and (2) by infusing sensors directly into factory machines to radically improve the way they operate.

Smarter factory layouts. Companies are now discovering huge gains by optimizing the layout of their factories with software that enables them to create a digital version of their factory to find the optimal layout that reduces handling costs, improves throughput, minimizes space requirements, and reduces energy needs. Software can identify ways to streamline everything from assembly lines to conveyor belts to production performance.[18]

Smarter factories using the Internet of Things (IoT). Factories are also making themselves more efficient by infusing sensors and actuators directly into the machines that make things. These IoT technologies enable sensors to produce data that can be used to improve the manufacturing process, monitor quality control, and alert managers to potential failures before they happen.

Because every moment a line is down is lost revenue, poor maintenance strategies can reduce a plant's overall productive capacity by an estimated 5 to 20 percent.[19] In auto manufacturing, downtime is estimated to cost as much as $1.3 million per hour.[20]

To overcome these challenges, companies are combining IoT sensors with predictive analytics software to prevent factory downtime and reduce unplanned maintenance. These software tools analyze real-time performance data from sensors, measuring things like vibration, heat, and energy use to better understand what is going on deep inside machinery and identify potential imminent equipment failures. These insights enable staff to schedule corrective maintenance steps before failures lead to costly downtime. According to McKinsey, companies that are connecting IoT sensors with predictive analytics are seeing a 40 percent reduction in maintenance costs, and 50 percent reduction in downtime.[21]

- To understand the opportunity, one GE manufacturing plant that makes batteries has already incorporated more than 10,000 IoT-enabled sensors spread across 180,000 square feet of manufacturing space to collect temperature, humidity, air pressure, and machine operating data in real time.[22] They use the real-time data to maintain quality control and lead the charge on factory efficiency.

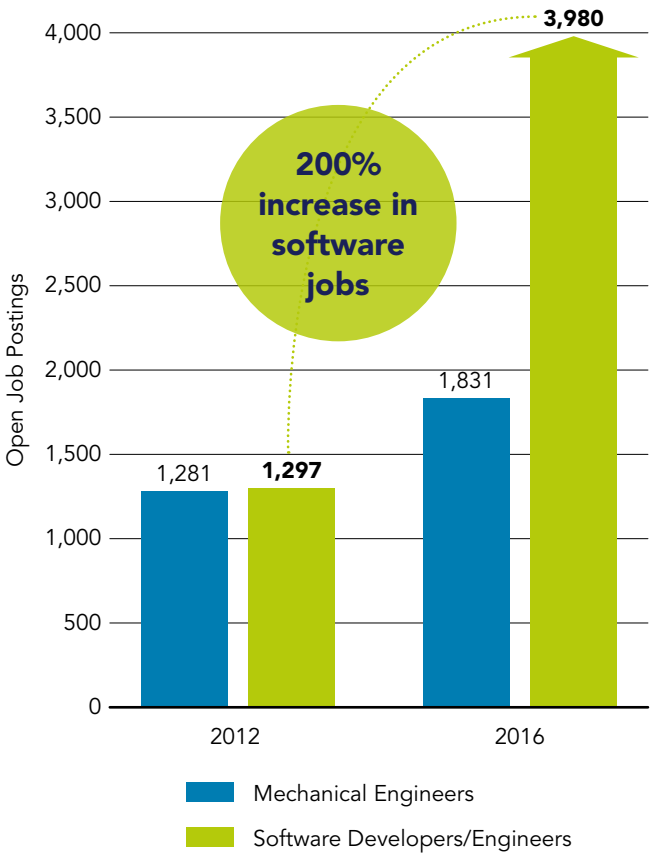
- Similarly in Florida, Jabil, a design and manufacturing solution provider, is using Microsoft's machine learning, predictive analytics, and the cloud to learn ahead of time when a piece of equipment might fail, instead of waiting for it to fail and dealing with the consequences and downtime.[23] By harnessing the cloud to analyze millions of data points from machines running dozens of steps through the manufacturing process, they've had an 80 percent success rate in identifying machine process failures in advance, cut scrap by 17 percent, and reduced energy by 10 percent. As a result, yield has gone up, the amount of re-work has gone down, and they have improved their ability to meet customers' demands for increasingly faster, more customized solutions.

Making the Products Themselves Smarter

Software isn't just spurring innovation of manufactured products, it is also changing what the products themselves can do, too. Software is increasingly being incorporated directly into manufactured goods meaning that manufacturers aren't just users of code, they are also writers of code.

- **Cars are software enabled.** When today's high-end cars are manufactured, they are built with 100 times more lines of code then the Space Shuttle had when it launched.[24] Most of the vital functions in a car are now software controlled, and as a result they have become more reliable, fuel efficient, and safe. Software has become so essential that up to 40 percent of the value of a new vehicle is now determined by its electronics and software content.[25] It's one of the reasons why demand for software developers among car and car part manufacturers has grown an astounding

Demand for Software Developers in Manufacturing Is Growing Like Crazy



Source: Burning Glass Technologies

200 percent over just four years because they continue to build software directly into the products they make to dramatically improve what they are capable of doing.[26]

- **Airlines are software enabled.** Software is not just modifying how airplanes are designed, but what they can do, too. A Boeing 777 is manufactured with 1,280 onboard processors that use more than four million lines of code.[27] In fact, modern jets are so packed with connected sensors on their engines, flaps, and landing gear that they can generate half a terabyte of data per flight to improve flight performance, cut turbulence, improve safety, and identify possible engine defects 2,000 times faster than before.[28, 29]

- **Appliances are software enabled.** Software is also taking ordinary things and making them extraordinary. With each generation, appliances are being manufactured with more and more software and sensor capabilities to enable them to do things never before possible by connecting with the cloud — improving what they can do, and how they can be controlled. It's astounding when you consider that today's newest refrigerators already contain more lines of code than a desktop computer had 20 years ago.[30]

- **Even ball bearings spin smarter with software.** Schaeffler Group, a leader making of ball bearings, envisions a world where even the humble ball bearing has built-in intelligence and sensory capabilities, using cognitive intelligence from IBM Watson.[31] By integrating sensor data with bearings, and integrating the bearings into everything from cars, planes, trains, and wind turbines, it can help reduce failures and make the world smarter, cleaner, and safer.

All of these benefits and opportunities, however, cannot happen without properly skilled workers. These innovations are not replacing workers; on the contrary, they require more and more workers with the right skills. Our country's economic competitiveness depends upon addressing the current talent shortage and skills gap. The renaissance of manufacturing lies in the hands of workers across America.

With innovation-enabled manufacturing opportunities expanding every day, tomorrow's benefits can be more easily maximized when leaders (1) take concrete steps to overcome a looming skills gap by filling the talent pipeline, (2) ensure that everyone is aware of the pathways of the manufacturing sector, and (3) address the talent shortage.

(1) Overcome the Looming Skills Gaps

US manufacturing leadership is rooted in having a well-trained workforce. As home to the world's leading software innovators, the US has a geographic leg up in the global advanced manufacturing race. However, there are twin skill gaps that could impede this opportunity with too few software developers and too few skilled manufacturers available in the pipeline.

Already today almost 40 percent of manufacturers say a skills mismatch is the chief barrier to taking full advantage of advanced manufacturing opportunity.[32] Manufacturers often can't hire enough software developers or the workers with skills necessary to run analytics software, create 3D models, or program 3D printers. Experts now project that the manufacturing sector is facing a shortage of two million workers due to the skills gap over the next decade.[33]

Further exacerbating the problem, demand for coding skills is stronger than ever, too. Today there are more than 500,000 unfilled programming-related positions across the country, and the US Bureau of Labor Statistics predicts that by 2020 there will be 1.4 million more software development jobs than applicants qualified to fill them.[34]

That may be why some studies suggest that a manufacturer's success or failure is increasingly tied to how geographically close they are to a ready supply of software talent.[35]

Because of this shortage and the strategic advantage access to coders provides, the German auto parts giant Bosch for example set up a research facility in the Pittsburgh area and another near Stanford — principally motivated by the desire to tap into the university's software engineering expertise and acquire future talent.[36]

> If we are to meet our manufacturing challenges for the future, we need to seize upon what may be software's greatest untapped potential — its ability to fundamentally expand what manufacturers can achieve.

To ensure every manufacturer has the opportunity to be successful, it's clear that we will need more workers with the skills to design and build the blockbuster products of the future. It's one key reason why leading software companies have stepped forward with ground-breaking commitments to STEM and manufacturing education.[37]

But as software is incorporated into almost everything we make and every connected thing around us suddenly runs on code, we simply aren't preparing enough workers to meet these future needs. It's for this reason that parents and teachers increasingly want computer science taught in K–12 classrooms. To advance a workforce with the skills to meet our 21st century manufacturing opportunities, policymakers need to make investments in computer science education to help prepare the next generation of tech workers.

(2) Highlight the New Career Paths of Manufacturing

Mapping out career pathways and highlighting the new paths available in the manufacturing sector is also key to addressing the skills gap. For those preparing to enter the workforce or those looking to make a career change, a career path is a guidebook on how to proceed. The manufacturing of today does not look like the assembly and production lines of yesterday. The fast pace of innovation in manufacturing has created opportunities in many emerging sectors and technologies. Career pathways are not just in production and assembly; the roadmap can take workers to research and development, engineering and design, programing, user experience research, and many other paths. Showcasing this reality will be crucial to attracting, retaining, and developing the manufacturing workforce of the present and the future.

A PRODUCTION CAREER PATHWAY USED TO LOOK LIKE THIS:

Entry-level

- Industrial Truck and Tractor Operators (Forklift Operators)
- Hand Packers
- Inspectors and Testers

Intermediate-level

- Single Trades
  - Machinists
  - Welder
  - Heavy Tractor-Trailer Drivers
  - Maintenance and Repair Workers
- Machine Operators
  - Printing Press Operators
  - Print Binding and Finishing Workers
  - Food Batchmakers
  - Packaging Machine Operators

Upper-level

- Industrial Machinery Mechanics
- Mechatronics Engineering Technologists
- Supervisors of Production Workers

Source: NIST Manufacturing Workforce Development Playbook

TODAY, IT CAN LOOK JUST LIKE AND INCLUDE THESE OCCUPATIONS ACROSS ALL LEVELS:

Maintenance Pathway

- Mechanical Engineer
- Mechanical Technician
- Front Line Supervisor
- Mechatronics Technician
- Maintenance and Repair Workers

Engineering Pathway

- Engineering Manager
- Project Engineer
- Electrical Engineer
- Electrical Technician Engineer
- Computer Hardware Engineering
- Industrial Machinery Mechanic

Production Pathway

- CAD/CAM Programmer
- Production Supervisor
- CNC Machine Programmer Supervisor
- CNC Machine Programmer
- Machinist
- Machine Set- Up Operator
- CNC Machine Operator
- Machine Operator

Logistics Pathway

- Director, Supply Chain Logistics
- General Operations Manager
- Purchasing Agent
- Logistics Technician
- Shipping and Receiving Clerk
- Forklift Driver

Source: Colorado Manufacturing Careers

(3) Foster Strategic Partnerships and Planning

The manufacturing workforce of the 21st century comes in many shapes and forms, different roles and occupations, skillsets and trades; what stands true and unchanged is that the development of the workforce will require collaboration across companies, government, and educational institutions. These major stakeholders hold the key to solving the talent shortage and fostering America's economic competitiveness and innovation leadership. Forming strategic partnerships to solve our most pressing workforce issues should be accompanied by strategic planning and an outline of what the technological and workforce future looks like and what would it take to bring everyone to a level playing field.

It is and will be possible for everyone to reap the economic benefits of software in industry, but this will require an active role among educators, employers, and policymakers. It will be as important to have a pipeline in place for those new to the workforce to gain the right skills that will secure them a job that will foster innovation in manufacturing, as it is to have a plan for those who need to re-skill and re-train to perform their duties in new ways. On-the-job training, ongoing credentials, certifications, tech skills development programs, and many more opportunities should be available across the board for the workers of today and tomorrow.

Conclusion

Throughout history, key moments have emerged when technology enables great leaps that fundamentally expands the kinds of things we can achieve. Today software is enabling such a manufacturing moment as it catalyzes innovation in what and how we make things — leading to breakthroughs as incredible as the first industrial revolution itself. But critical policy choices lay on the horizon that will determine whether America leads this revolution and benefits from its many economic opportunities. If we are to meet our manufacturing challenges for the future, we need to seize upon what may be software's greatest untapped potential — its ability to fundamentally expand what manufacturers can achieve.

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27 Lyle N. Long, "The Critical Need for Software Engineering Education," *The Journal of Defense Software Engineering* 21, no. 1 (January 2008), available at https://www.researchgate.net/publication/235137886_CrossTalk_The_Journal_of_Defense_Software_Engineering_Volume_21_Number_1.

[28] The 787 uses data sensors to reduce fuel, monitor systems, and even uses accelerometers in the nose of the plane to counteract turbulence. If the sensors register a sudden drop, they immediately tell the wing flaps to adjust (in a matter of nanoseconds) and in so doing, what used to be a nine-foot drop in an older plane can be reduced to just three feet in the 787, making for a much smoother flight. Matthew Humphries, "The Boeing 787 Produces Over 500GB of Data During Every Flight," Geek.com, available at http://www.geek.com/news/the-boeing-787-produces-over-500gb-of-data-during-every-flight-1542105/; Kevin Gosling, E-Enabled Capabilities of the 787 Dreamliner," Boeing.com, available at http://www.boeing.com/commercial/aeromagazine/articles/qtr_01_09/pdfs/AERO_Q109_article05.pdf.

[29] Jet engine maker GE says the engine data allows it to figure out things like possible defects 2,000 times as fast as it could before. Quentin Hardy, "What Cars Did for Today's World, Data May Do for Tomorrow's," *New York Times* (August 10, 2014), available at http://bits.blogs.nytimes.com/2014/08/10/g-e-creates-a-data-lake-for-new-industrial-ecosystem/?_php=true&_type=blogs&_php=true&_type=blogs&module=BlogPost-Title&version=Blogpercent20Main&contentCollection=Bigpercent20Data&action=Click&pgtype=Blogs&region=Body&_r=1&.

[30] Mark Muro, Jonathan Rothwell, Scott Andes, Kenan Fikri, and Siddharth Kulkarni, "America's Advanced Industries: What They Are, Where They Are, And Why They Matter," Brookings Institution (February 2015), available at https://www.brookings.edu/wp-content/uploads/2015/02/AdvancedIndustry_FinalFeb2lores.pdf.

[31] IBM IoT Manufacturing, available at https://www.ibm.com/internet-of-things/industries/iot-manufacturing.

[32] The National Association of Manufacturing asked its members what effect new technologies like the cloud, additive manufacturing, and IoT were having on their businesses. They found out that technology-driven disruption in the manufacturing sector is having a positive effect on their business and products. "Competing to Win: Research, Innovation and Technology in Focus," Policy White Paper, National Association of Manufacturing, available at http://www.nam.org/Data-and-Reports/Competing-to-Win/Policy-White-Paper-Research/.

[33] "Top 20 Facts About Manufacturing," National Association of Manufacturers, available at http://www.nam.org/Newsroom/Top-20-Facts-About-Manufacturing/.

[34] According to code.org, there are currently 526,393 open computing jobs nationwide as of this writing.

[35] Lee G. Branstetter, Matej Drev, and Namho Kwon, "Get With the Program: Software-Driven Innovation in Traditional Manufacturing," Working Paper 21752, National Bureau of Economic Research (November 2015), available at http://www.nber.org/papers/w21752.pdf.

[36] "Get With the Program: Software-Driven Innovation in Traditional Manufacturing."

[37] Autodesk, for example, is providing every secondary school in America with free access to its cutting-edge software to teach the tools of the trade; help train the next generation of designers, engineers, and architects; and help students create a better world with better designs for the future. This Design the Future initiative makes available $250 million of 3D design software, project-based curricula, training, and certification to every middle and high school in the United States as part of the ConnectED initiative. "Autodesk Education's Design the Future program, Today," Autodesk (September 17, 2013), available at http://blogs.autodesk.com/inthefold/autodesk-educations-design-the-future-program-today/. Likewise, to empower more young women to pursue careers in technology, Software.org is supporting the Girls Who Code program. "BSA, Lockheed Martin, and Georgetown University Join Forces to Sponsor Inaugural Washington, DC, Girls Who Code Summer Immersion Program," Press Release, BSA | The Software Alliance (June 24, 2015), available at http://www.bsa.org/news-and-events/news/2015/june/enus06242015girlswhocode.

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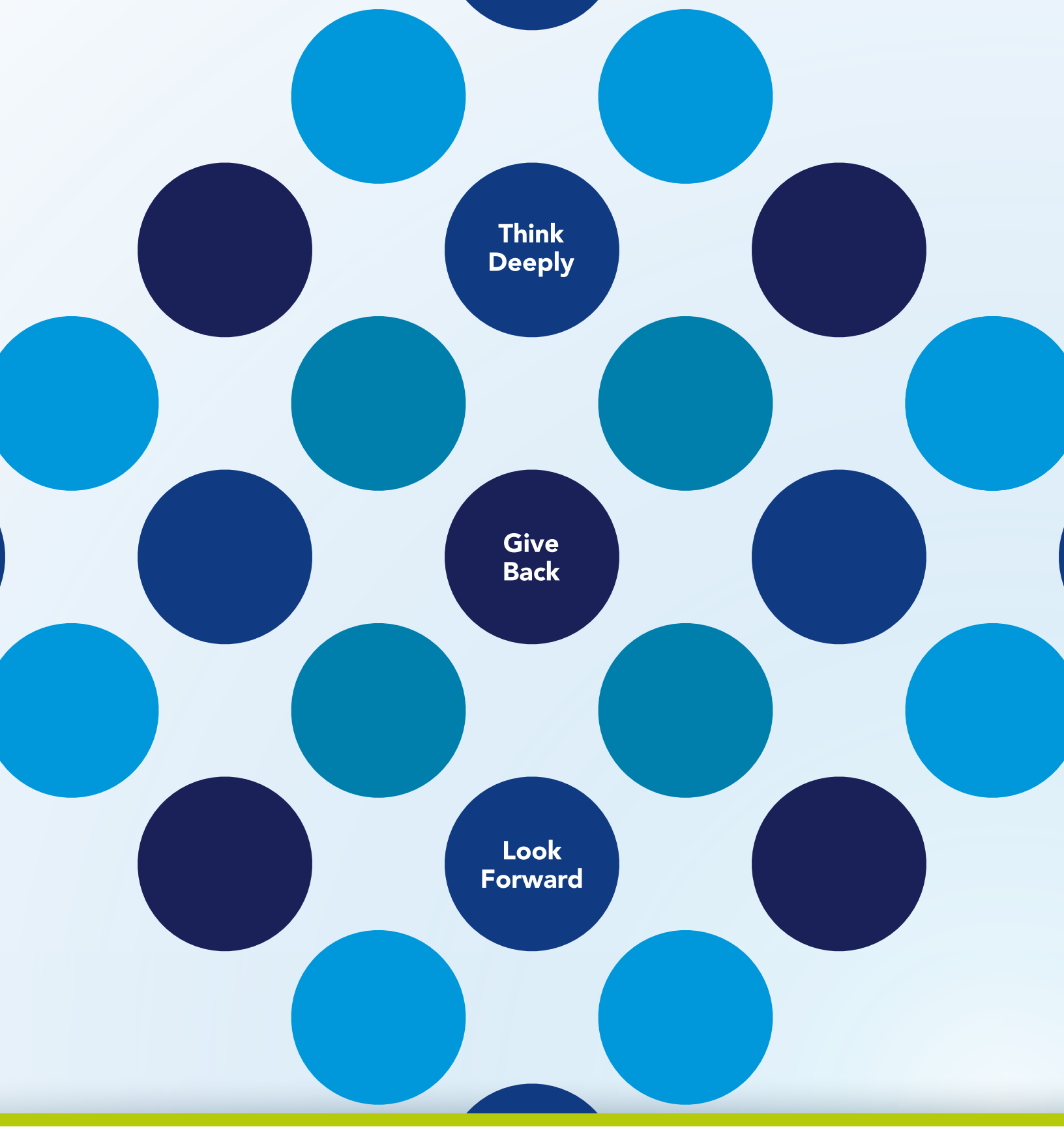

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