Manufacturing on the Cutting Edge

The Exponential Technologies Fueling the Fourth Industrial Revolution

Singularity University

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By Singularity University

Manufacturing, one of society's most fundamental building blocks, is undergoing an unprecedented transformation.

Manufacturing sometimes gets a bad rap—stuck in the past, slow to innovate, and decidedly unsexy compared to headline-grabbing sectors like fintech and media.

The manufacturing sector's influence reaches far beyond the business world. Consider how Henry Ford's development and refinement of the assembly line sparked a major industrial revolution in the early 20th century.

The impact of the automobile and mass production impacted nearly every facet of how we live today. Our modern cities and suburbs, workplaces, commuting, retail landscape, and schools all emerged as a result of modern manufacturing, reshaping our world in the process.

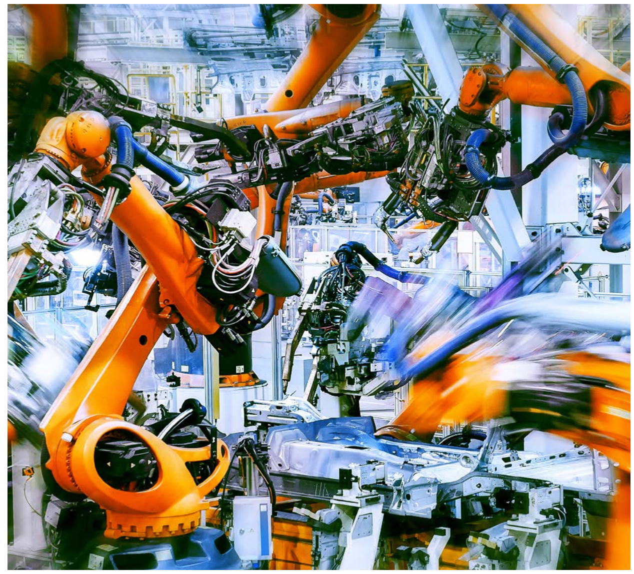
Today, an even more sweeping transformation is in the works. Exponential and emerging technologies are enabling waves of innovation that are changing the face of manufacturing as we know it.

Manufacturing has become a driving force of change, and three technologies—genetics, nanotechnology and robotics—will define our future and usher in a new era, according to SU Co-Founder and Chancellor Ray Kurzweil, who addressed this topic in *The Singularity Is Near*. In this ebook, we'll preview this new era by sharing eight major industry trends that show how quickly manufacturing paradigms are shifting. We'll also examine the technologies fueling these shifts, some of the organizations leading the charge, and how to survive and thrive in this era of exponential change.

Eight Trends Transforming Manufacturing

"It's hard to think of an exponential technology that doesn't feed into the manufacturing sector."

—Ray Kurzweil, Co-Founder and Chancellor of Singularity University



1. The Cutting Edge Quickly Dulls

Manufacturing is getting smarter and faster. Exponential technologies including robotics, artificial intelligence (AI), 3D printing, and the Internet of Things (IoT), are driving amazing advances across many industries. The deep analytical powers of machine learning are transforming raw data into useful insights.

Robots can now safely interact with people and nimbly navigate messy work environments, while 3D printers are giving physical form to digital designs. And, biotech is enabling us to manufacture living systems, such as engineered bacteria, into microscopic, chemical-producing factories.

While these are incredible innovations—and more arrive every day—one could argue that an even greater feat will be keeping up with the latest technology breakthroughs and turning them into actionable business strategies. Organizations that develop a "sensing capability" to recognize innovative technologies before their competitors will come out on top.

2. Data-Driven Decision-Making Gets More Intelligent

Data has the potential to play a huge role in more efficient manufacturing. The entire industry, from sourcing to production runs to sales forecasting, has relied on data for decades.

However, it's estimated that nearly 85% of data goes unused in manufacturing[1]—a huge problem that also presents a huge opportunity. Thanks to IoT's cheap, connected, and increasingly ubiquitous sensors, companies have the potential to monitor more aspects of manufacturing than ever before—including machinery, deliveries, and even employees.

Today, manufacturers typically use data in dashboards and for predictive maintenance. But these applications still have yet to achieve great ROI, according to Andre Wegner, SU's Faculty Chair of Digital Manufacturing.

3. Design and Real-World Market Testing Are Accelerating

Historically, the product development process has remained stubbornly time-consuming. Traditional market research, focus groups, prototyping, testing, and sourcing all take time. What if you could design, build, test, and iterate in real life, before ramping up large-scale production?

You can. In fact, General Electric already does.

FirstBuild, a global co-creation community backed by GE Appliances, is focused on the rapid prototyping of new ideas. If a product proves its worth in a sample market, the design is moved to full production.

These are the changes that technologies like 3D printing and materials science are enabling in product design. When a giant like GE creates a spin-off group that acts like a startup, it becomes obvious that power is being democratized, production times are being slashed, and long-held competitive advantages are evaporating.

4. Production Is Becoming More Automated and Democratized

New technologies are cutting the time and cost of getting products to market. However, there are larger shifts happening in the overall production process as well.

> Robots are becoming more nimble, more versatile, and smarter. Computer-guided fabrication is getting faster, cheaper, and more precise.

Factories are becoming more efficient, while raw material waste is decreasing. These shifts increase competition, making success without these technologies nearly impossible.

What was once possible only in the largest facilities is now performed in factories around the world. While some may doubt the innovative potential of non-professionals, consider the incredible amount of human capital unlocked by this change.

[1] https://medium.com/smarterchains/https-medium-com-smarterchains-bad-data-in-manufacturing-the-cost-and-the-solution-1f0a8b2e5eff

5. The Global Supply Chain Is Being Reimagined

One of the most complex aspects of manufacturing is the supply chain, which spans the sourcing of raw materials around the world to the logistics of delivering finished goods on time. Supply chain managers are responsible for coordinating with hundreds, if not thousands, of partners and service providers to make sure products are delivered on time, on budget, and in good condition.

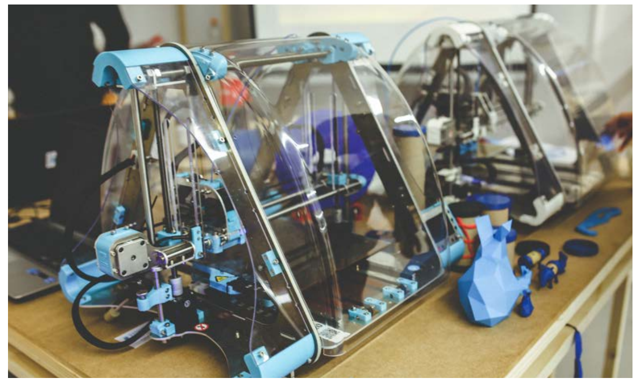
While it may not be the sexiest of puzzles, it's certainly a critical one—and one ripe for improvement. Self-driving trucks, autonomous cargo ships, AI-powered planning software, and localized manufacturing facilities are all converging to reshape the very nature of supply chains.

Supply chains are also an area where blockchain could have a huge potential impact, along with real-time data from sensors built into every process.

6. Mass Customization Is Replacing Mass Production

As manufacturing technology evolves, fixed costs become variable. Companies will no longer need to set up unique production runs to fabricate thousands of identical products or parts. Designs driven by customer data will allow for tailor-made products, and one-off production will become as inexpensive as mass production.

Technological convergence will soon allow both startups and corporations to personalize products at an unparalleled scale. AI-powered production automation will enable the custom configuration of products at scale to meet individual requirements and preferences. Let's take a look at some exciting new enablers of customized manufacturing.



3D printing breakthroughs

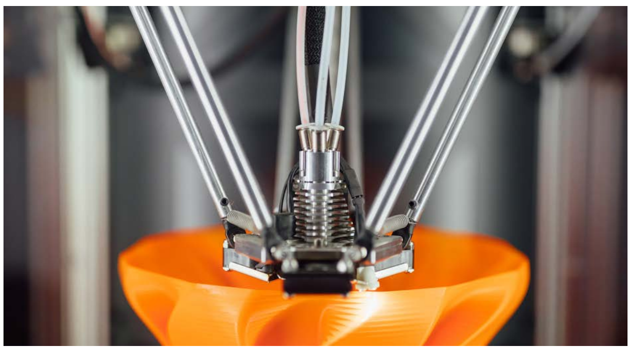
Perhaps the greatest driver of customized manufacturing at scale is 3D printing. Previously a niche and prohibitively priced tool, 3D printing is entering its exponential growth phase.

In 2015, the 3D printing manufacturing industry grew to almost $5.2 billion,[2] and over a quarter-million 3D printers were sold globally, at a price-point less than $5,000. By 2021, IDC analysts expect global spending on 3D printing to reach nearly $20 billion.[3]

Newly accessible design software has enabled an unprecedented array of customized products, from personalized medical and dental products to adapted airplane and auto parts. Microscale fabrication is driving design innovation in sensors, drug delivery technologies, and lab-on-a-chip applications.

[2] https://www.forbes.com/sites/tjmccue/2016/04/25/wohlers-report-2016-3d-printer-industry-surpassed-5-1-billion/#3e2a01c219a0
[3] https://www.idc.com/getdoc.jsp?containerId=prUS43487718

For example, using the interface of light and oxygen, Carbon 3D prints solids from liquids in record time, controlling elasticity, strength-to-weight ratio, and other mechanical and material properties. Carbon 3D and Adidas launched their first running shoe in 2017,[4] which utilizes athlete-specific data and individual cushioning preferences to 3D-print the perfect midsole for each runner.



Another promising 3D technique developed by researchers at the Lawrence Livermore National Laboratory uses holographic light fields to fabricate 3D shapes. By shining laser beams at a vat filled with resin, the technique can fabricate 3D structures in just 10 seconds.[5]

A stunning breakthrough in the manufacturing process is MX3D's multiple-axis printing capability, which enables printing from any direction in mid-air. MX3D, a Dutch company printing steel bridges[6] with remarkable structural integrity, uses six-axis robotic arms to 3D-print the Arc Bicycle, a futuristic bike with a steel lattice frame. While conventional 3D printing requires some form of support for objects as they're printed, multi-axis printing technologies almost entirely eliminate this dependency, opening up incredible new structural possibilities.

Watch a simulation of Lawrence Livermore National Laboratory's holographic fabrication technique.

Get a close look at the 3D printing of the Arc Bicycle.

Printed circuitry

In the past, smart products and electronics had to be manually embedded with circuitry. Not anymore. Using a wide array of conductive inks, new players are printing circuitry directly into their products, all in one go.

Ushering in a new age of customized and on-demand electronics, startups like NanoDimension and Voxel8 use conductive inks to print advanced circuits. Forget lengthy design processes, multi-stage prototyping, costly tooling, and uniform production. Plummeting costs will enable 3D printing to take us directly

[4] https://singularityhub.com/2017/04/07/adidas-to-mass-produce-3d-printed-soles-in-vats-of-warm-liquid-goo/
[5] https://singularityhub.com/2017/12/08/ultrafast-3d-printing-alternative-makes-complete-3d-objects-in-seconds/
[6] https://gizmodo.com/the-first-3d-printed-steel-bridge-looks-like-it-broke-o-1824252512

from design to production, where design becomes adaptable and production is expedited by orders of magnitude.

Embedded provenance data

Establishing provenance, or knowing exactly where parts or components come from, is crucial for medical products and other highly-regulated industries. Because of their increased freedom of design and ability to incorporate a Digital Thread—a framework that connects data to provide a comprehensive view of an asset's lifecycle—3D-printed parts can easily incorporate embedded provenance data.

As a result, product failures won't require mass recalls of thousands of units to investigate what went wrong, which is a current practice many manufacturers use to err on the side of safety. Embedded provenance data will facilitate the ability for manufacturers to pinpoint exactly what, when, and where errors occurred, making it easier to efficiently identify and solve the problem. This development will forever change how we think about risk and data in relation to physical goods.[7]

7. The Process of Invention Is Becoming Democratized

The process that enables technology to become more accessible to more people is often called the democratization of technology—and it's happening more quickly than ever. A great example of this process can be found in Jonathan Zornow's story. Zornow was a young freelance web developer with no background in robotics, manufacturing, or the apparel business. His project, Sewbo, successfully demonstrated the world's first robotically sewn garment.

Other promising high-tech solutions have been employed, unsuccessfully, to automate sewing. In fact, since the 1980s, hundreds of millions of dollars have been spent[8] trying to automate garment sewing, yet a single curious kid inspired by ideas from TV and the internet was able to address the challenge with a different, relatively low-tech approach.

It's worth mentioning that, beyond simply having the idea, Zornow had access to robotic tools to pursue the concept, which just a few years ago would have been cost-prohibitive. On display here is a phenomenon such that big-idea breakthroughs are as accessible to any individual with internet access as they are to well-funded research labs.

It's also an age when experts are being upstaged by radical outsiders, leading biotechnology startups are being founded by aerospace engineers,[9] and novice amateurs are routinely outperforming experts[10] in data science tasks. In the age of the internet, we're seeing the force of ideas accelerate to the extent that a single individual might disrupt a trillion-dollar global industry.

Democratized platforms

Forget exorbitant operational costs, fabrication equipment, prototyping, tooling, and far-flung production plants. Whether in-house or entirely outsourced, design-to-production technologies allow anyone to invent.

[7] https://singularityhub.com/2017/05/22/carbons-bold-mission-to-finally-dematerialize-manufacturing/
[8] https://www.wired.com/2012/06/darpa-sweatshop/
[9] https://www.nytimes.com/2017/01/04/business/dealbook/synthego-raises-41-million-from-investors-including-a-top-biochemist.html?_r=1
[10] http://www.slate.com/articles/health_and_science/new_scientist/2012/12/kaggle_president_jeremy_howard_amateurs_beat_specialists_in_data_prediction.html

Incubator studios and fabrication equipment labs are jumping onto the scene. Advanced 3D printers are quickly becoming affordable enough for home use, and a new ecosystem of hardware studios and eager accelerators is already springing up across urban centers.

Boasting AI-aided robots and swarm 3D printers that work overnight, these urban workshops basically serve as your new testing ground—the physical hands for your digital designs. With newly accessible CAD-like design software and easy-to-use interfaces, everyone can be an inventor.

Technologies only begin to grow exponentially when an accessible user interface emerges. Democratized platforms are the name of the game.[11]

Dematerialized manufacturing

Dematerialization in manufacturing typically means reducing or eliminating materials while delivering the same features and functionality. Companies such as Playground Global and LulzBot want to handle material constraints like engineering, fabrication, supply chain management, and distribution for now-unfettered entrepreneurs.

Providing in-house expertise in exchange for small equity stakes, Flex's Lab IX helps dozens of startups build transformative technologies, like drone systems, super-thin batteries, and sensor-equipped headbands that help you calm or energize your brain.

Attracted by real market value, Silicon Valley's Bestronics is looking to work with startups as both a form of business development and a means to stay on top of new technologies. Bestronics realizes that it's the startups that are developing new products and services which they need to know about.[12]

Think about this: with the growth of these support systems, any manufacturer wanting to build any product can become completely dematerialized.

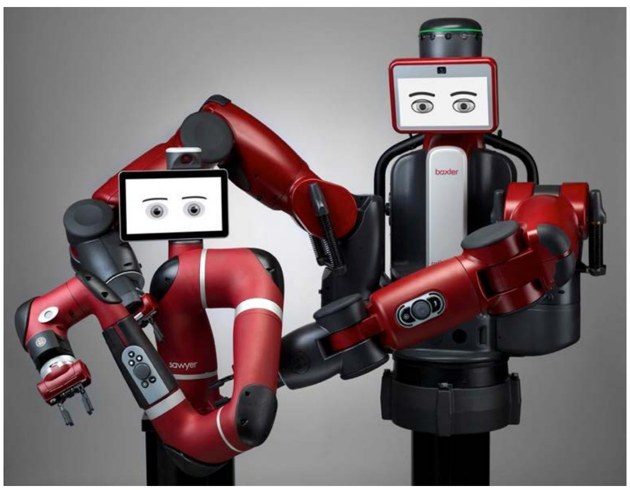
Distributed manufacturing

Distributed manufacturing enables local and global networks of manufacturing facilities to work together using cloud computing technology. Bigger players like 3D Systems and Stratasys are embracing distributed manufacturing. For example, with its Continuous Build 3D Demonstrator, Stratasys supplies a wall of modular 3D printers, all working simultaneously, centrally-controlled through a cloud-based architecture.

[11] https://singularityhub.com/2016/11/22/the-6-ds-of-tech-disruption-a-guide-to-the-digital-economy/
[12] https://hbr.org/2016/02/entrepreneurs-take-on-manufacturing

While venture capital firms like Bolt use similar prototyping equipment labs to support those startups entering Y Combinator and other accelerators, crowdfunding sources like Kickstarter look to give entrepreneurs a leg up through initial finance.

As distributed manufacturing converges with the plunging costs of automated fabrication, we are about to see an explosion of innovative design.



8. Smart and Autonomous Factories Are Coming

Smart factories are ushering in a new era of autonomous production that enables the expansion of product lines, while minimizing recall risk.

A leading player in the Industrial Internet of Things (IIoT), TE Connectivity is one of many companies manufacturing the sensors used to communicate data between equipment and smart devices. Targeting everything from the medical sector to appliances to aerospace and defense, TE's products enable machine-to-machine communication. Long-term, the company hopes to supply factories capable of adapting to workflows in real time.

In more isolated regions, machine-to-machine communication is particularly liberating as it allows for decentralized data transfer between smart bots. Companies like Filament are aiding this movement with low-power industrial sensors and blockchain. Others, like Kepler Communications, use satellite-based solutions for isolated production plants, leveraging a space-based communication network for industrial sensors.

The goal of reducing or eliminating recalls—which are costly and disruptive events for large manufacturers—is drawing new AI-powered solutions to the market. Silicon Valley-based startup Landing.ai now produces machine-vision tools that can find microscopic defects in circuit boards and products. With precise on-site quality analysis, errors are communicated immediately, and IIoT-connected machinery can halt any output before it ever becomes a liability.

These shifts in the factors of production bring the issue of defective machinery front and center. Fortunately, startups like Instrumental, Maana, and Augury Systems are ahead of the game. Using predictive analytics and machine learning techniques, it is now possible to detect abnormalities and risky indicators long before they cause issues. Offering a full suite of sensors, Augury Systems piggybacks on IIoT to analyze machinery's acoustic fingerprints and identify defects before they occur.

Yet, as cloud-connected, collaborative machines[13] begin managing themselves, what's to stop fully automated factories from operating in the dark or without heat? Geared with nine mounted 3D printers, and a huge robotic arm, Voodoo Manufacturing is disrupting 24/7/365 production with Project Skywalker.[14] While Voodoo's 3D printing farms continually print parts, a Universal Robots UR10 arm unloads products as instructed. Voodoo predicts that a single arm will be capable of tending to approximately 100 printers.

We're seeing a staggering convergence of 3D printers, collaborative 3D-printing farms, co-robots, robots that manage 3D printers, and 3D printers that build robots—and this is just the beginning. Here are three compelling technologies now converging on the factory floor:

Augmented reality

Most people are familiar with virtual reality (VR) by now. There are multiple commercial devices on the market, and plenty of speculation about when VR will achieve mainstream adoption.

Right behind VR is augmented reality (AR). Whereas VR is completely immersive, AR adds a digital layer on top of the real world. It's a more complicated engineering problem, but it also has wider applications. In a world of advanced AR, we'll wear a small device to interface with computers, much like Tony Stark does in *Iron Man* movies.

Aside from breakout applications like Pokémon Go, AR device adoption is happening faster in the industrial space than with consumers. And, in the same way consumer connectivity created value for the smartphone, enterprise connectivity is expected to extend the value and use cases for AR devices.

Meet John Werner, VP of Meta, which pioneered the first commercially available augmented reality (AR) system.

In manufacturing, designers will ditch 2D modeling programs to work more quickly, while utilizing a 3D space hovering over their desks. Workers on the factory floor will receive real-time, big data insights about machines and processes laid out in front of their eyes, hands-free, with step-by-step instructions guiding them to repair and build things.[15]

[13] https://singularityhub.com/2018/01/21/machines-teaching-each-other-could-be-the-biggest-exponential-trend-in-ai/
[14] https://mfgtalkradio.com/voodoo-manufacturing-innovation-strong-project-skywalker/
[15] https://singularityhub.com/2017/02/24/why-the-potential-of-augmented-reality-is-greater-than-you-think/

Robots with a brain

Robots have been used for years in manufacturing, but they've tended to need tightly controlled environments to operate in, and PhD holders to program them.

Thanks to inexpensive 3D modeling hardware and enhanced software, robots are also growing smarter, losing weight, and becoming aware enough to work next to humans without accidentally hurting them.

> The next step isn't the end of human workers, but rather a collaboration that combines the best of robots with the best of humans.

While machines are learning to do tasks they've never done before, from locating and retrieving goods from a shelf [16] to driving cars[17] and performing surgery,[18] there are still a lot of tasks which are hard or impossible for robots to perform. In today's manufacturing environment, humans and robots don't mix—they're so different that it's hard for them to work together. This leaves manufacturing engineers designing processes either entirely for robots, or entirely without them.

But, what if the best way to, say, attach a door to a refrigerator is to have a robot lift it, a human guide it into place, the robot put it down, and the human tighten its hinges? For people and robots to work together safely and efficiently, robots need to get smarter.

With the help of 3D sensors, the engineers at Veo Robotics have essentially given robots spatial awareness and a "brain" to make decisions, making human interaction safe. Depth-sensing cameras give the robot visual coverage, and its software learns to differentiate between the objects around it, to the point that it is aware of the size and location of everything in its vicinity. The robot can then be programmed to adjust its behavior to environmental changes—if a human shows up where a human isn't supposed to be, the robot can stop what it's doing to make sure the human doesn't get hurt.

Learn more about how the collaborative robots from Veo Robotics "sense" their environment.

Robots with soft muscles

Jerky mechanical robots are staples of science fiction, but to integrate seamlessly into everyday life, they'll need the precise motor control of humans. One of the main challenges has been creating soft components which match the power and control of the rigid actuators like motors and pistons that drive mechanical robots.

[16] https://singularityhub.com/2017/02/10/how-robots-helped-create-100000-jobs-at-amazon/
[17] https://singularityhub.com/2017/02/05/what-happens-when-self-driving-is-as-common-as-cruise-control/
[18] https://singularityhub.com/2016/10/11/the-future-of-surgery-is-robotic-data-driven-and-artificially-intelligent/

Now, researchers at the University of Colorado have built a series of low-cost artificial muscles—as little as 10 cents per device—using soft plastic pouches filled with electrically insulating liquids. When a voltage is applied to these artificial muscles, they contract with the force and speed of mammalian skeletal muscles.

In January 2018, three different designs of the so-called hydraulically amplified self-healing electrostatic (HASEL) actuators were detailed in two papers in the journals *Science*[19] and *Science Robotics*.[20] At rapid repetition rates, the HASEL actuators could carry out a variety of tasks, from gently picking up delicate objects like eggs or raspberries to lifting objects many times their own weight, such as a gallon of water.

As the name suggests, the HASEL actuators are self-healing. They are still prone to the same kind of electrical damage as dielectric elastomer actuators, but the liquid insulator is able to immediately self-heal by redistributing itself and regaining its insulating properties.

In most of their demonstrations, these soft actuators were being used to power rigid arms and levers, indicating that future robots will likely possess both rigid and soft components, much like animals do. The potential applications for the technology range from more realistic prosthetics to much more dexterous robots that can work easily alongside humans.

It will take some work before these devices appear in commercial robots. However, the combination of high performance with simple and inexpensive fabrication methods mean other researchers are likely to jump in and spur further innovation.

Robots with body awareness

The classical view of a robot as a mechanical body with a central "brain" that controls its behavior could soon be on its way out. The authors of a 2017 article published in *Science Robotics*[21] argue that future robots will have intelligence distributed throughout their bodies. This concept and the emerging discipline behind it is variously referred to as "material robotics" or "robotic materials." As the name implies, the new discipline is a synthesis of ideas from robotics and materials science. Proponents say advances in both fields are making it possible to create composite materials capable of combining sensing, actuation, computation, and communication, eventually granting operation independent of a central processing unit.

Much of the inspiration for the field comes from nature, with practitioners pointing to the adaptive camouflage of the cuttlefish's skin, the ability of bird wings to morph in response to different maneuvers, or the banyan tree's ability to grow roots above the ground to support new branches. These technologies have clear applications in the defense and aerospace sectors, but similar principles could be used to create everything from smart tires that can calculate the traction needed for specific surfaces to grippers that can tailor their force to the specific object which they are grasping.

[19] http://science.sciencemag.org/content/359/6371/61
[20] http://robotics.sciencemag.org/content/3/14/eaar3276
[21] http://robotics.sciencemag.org/content/2/12/eaar4527

By embedding distributed sensors and actuators directly into the material of the robot's body, computational capabilities are engaged, and the rigid information and computational requirements from the central processing system are offloaded.

The idea of making materials more adaptive is not new. There are already a host of "smart materials" that can respond to stimuli like heat, mechanical stress, or magnetic fields by producing a voltage or changing shape. These properties can be carefully tuned to create materials capable of a wide variety of functions, such as movement, self-repair, or sensing.

The biggest challenge remains manufacturing robotic materials in a way that combines all of these capabilities in a small-enough package at an affordable cost. Luckily, the field can draw on convergent advances in both materials science, such as the development of new bulk materials with inherent multifunctionality, and robotics, with its ever tighter integration of components.

By doing away with the prevailing dichotomy of "brain versus body," this work could pave the way for the emergence of robots with brains in their bodies—the foundation of inexpensive and ubiquitous robots that will step into the real world and react to it when needed.

The Impact of Convergence: Why It's Taking Less and Less to Manufacture More of the Things We Want

We've highlighted eight trends currently impacting the global manufacturing landscape. How do we stay ahead of these shifts? The story is still being written, but we know that this is just the beginning.

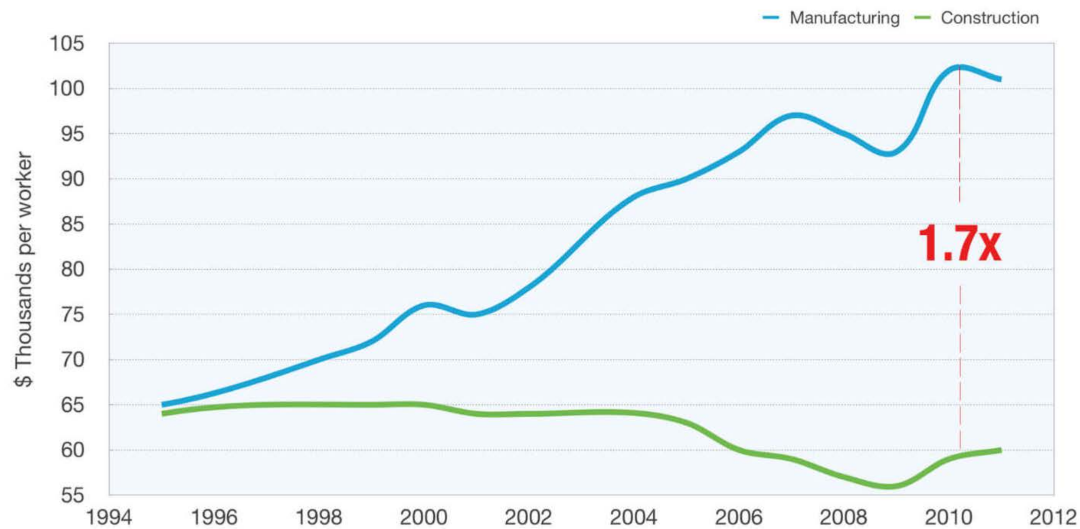
As technologies continue to converge, they will drive ever-accelerating advances, thus compounding the rate of improvement. It's critical, therefore, to understand how the key technologies are converging to survive, and harness exponential change. Only in this way will you be able to avoid disruption and uncover new sources of competitive advantage.

Manufacturing productivity has been on a tear. It's nearly doubled versus construction productivity over the last couple decades. Ever wonder why?

At the heart of the answer is the increasing use of programmable logic controllers. These specialized computers analyze data, act on programmed, complex functions, report on a facility's performance and hiccups, and generally supervise the operation.

Overview of productivity improvement of time

Productivity (value added per worker), real, $2005



Source: Expert Interviews; IHS Global Insights (Belgium, France, Italy, Spain, Germany, United Kingdom, United States); World Input-Output Database.

These tools are getting better at a very rapid pace. Perfectly timed, rapid precision controls enable HP's new 3D printer, equipped with 30,000 nozzles, to deposit 350 million fusing agent droplets per second. They allow computer numerical control (CNC) machines to remove material from an object while moving along seven axes.

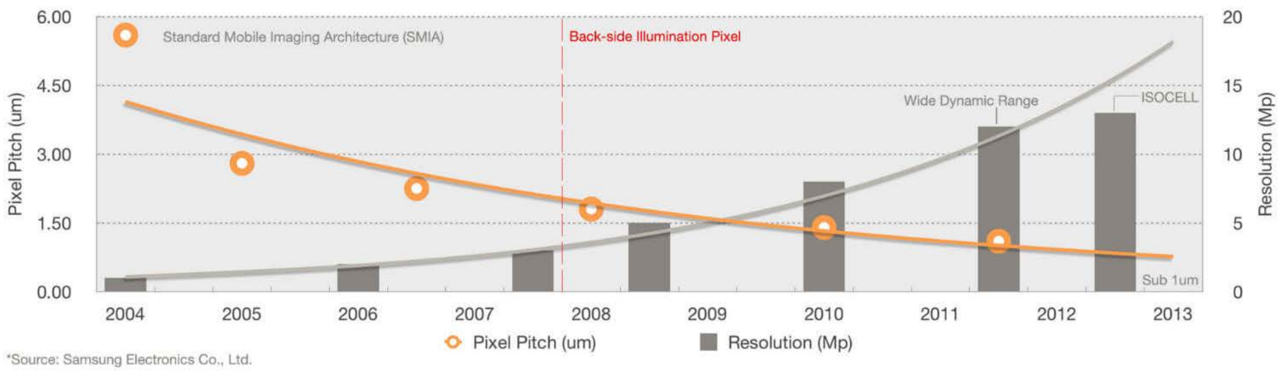
This is just one element delivering performance which only 10 years ago was unthinkable. Imagine what happens when we pair it with others.

A wide range of factors contribute to the improving performance and declining cost of these tools. Microprocessors, digital storage, memory, input-output, software—they've all followed an exponential curve, helping to supercharge manufacturing to deliver what we see today.

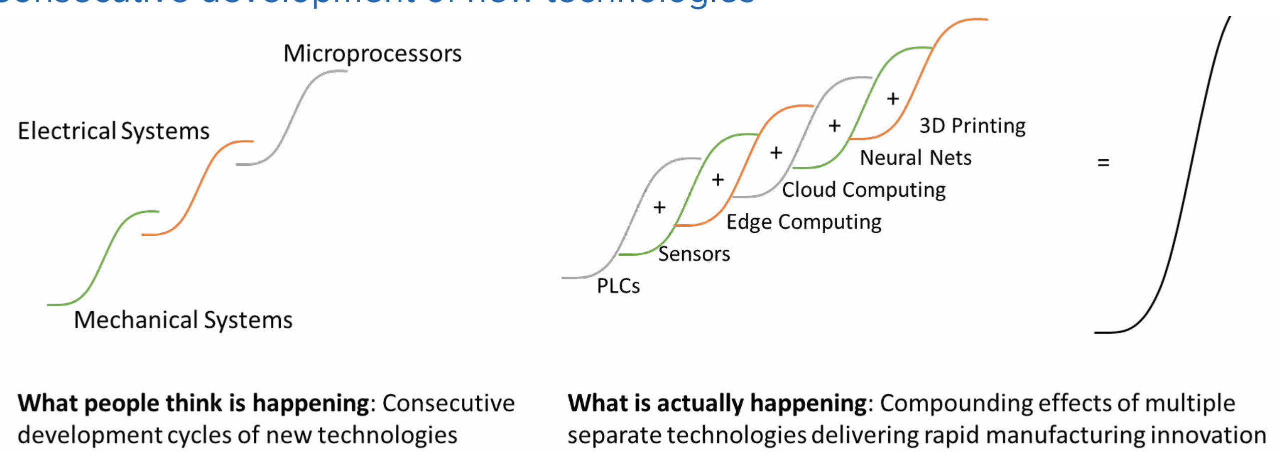
Take sensors, for example. From 2004 to 2013, image sensors have had a 5x decrease in the space between pixels (pixel pitch) and a 10x increase in image resolution. This improvement—which is already compounding the effects of programmable logic controllers by providing pick-and-place robots with the eyes they need to make rapid selections—is further boosted by advances in other areas. Without a greater range of bright and dark areas in images (HDR) and many more frames per second (time resolution), enabled by increased edge computing power, image sensors would not be nearly as effective as they are today.

Improved processing of this data flood, thanks to deep learning algorithms operating in the cloud, for example, makes the evolution look even faster. The results are stunning. We can use sensor input to automatically create new machine toolpaths that adapt to changes in materials or obstacles in real time.

Standard Mobile Imaging Architecture



Consecutive development of new technologies



The same is true for the localization and orchestration of distributed computing in edge devices—computing devices located near machines, instead of a central hub—which are enabling more rapid, autonomous reaction to changing events, instead of following a predefined set of actions. The marriage of sensors and actuators, as outlined above, is another such example.

New technologies reinvigorate the development of an application after previous improvements start to flag. This process looks like a group of linked S-shaped curves that continue over time. In manufacturing, we're instead seeing multiple, simultaneous technology developments stretching over longer time periods, supercharging the opportunities for improvement.

Where will this symbiosis of technological acceleration take us? Distributed, on-demand, agile manufacturing.

How to Survive Exponential Change

Technology is moving so fast that it's difficult to keep track of it all, let alone know how to respond. So, how do you keep pace?

Innovate more on the edge

Companies on the S&P 500 once had 50-to-60-year lifespans. These days that number is more like 20. Small software startups can disrupt industry giants. Innovation is no longer that thing you do on the side, but a critical and increasingly central survival skill.

Along with his team, Geoff Tuff, a principal of Deloitte Consulting LLP, came up with the "golden ratio for innovation" in 2012.[22] Their advice? Focus 70% of your innovation resources on the core, 20% on areas adjacent to the core, and 10% on the transformational space. This wasn't supposed to be a rule set in stone, but rather a way to help organizations balance their time and resources between supporting current core business initiatives and working on innovation programs to support future growth.

Because the pace of change in our world continues to shift from incremental to exponential, Tuff thinks the "right balance" for managing innovation portfolios has shifted. In his 2018 book, Detonate, co-authored with Steven Goldbach, Tuff says the average balance is now more like 50-30-20—suggesting innovative organizations should now be spending about half their time focusing beyond their current core businesses to compete effectively in the future.

Develop the agility to react to competitive changes

As competitive pressures increase, the organizations that understand and apply exponential manufacturing technologies are likely to leap ahead of their less agile competitors. This reality is playing out in the battle to improve the power-to-weight ratio in automotive manufacturing. Take Divergent Microfactories' Blade, which the company calls the first 3D-printed supercar.


betto rodrigues/Shutterstock.com

Divergent 3D's Blade supercar

The Blade's frame, made entirely of carbon fiber and 3D-printed components, is not only stronger than those of traditional cars but also up to 90% lighter. It also reduces tooling costs by a factor of 13. The manufacturing techniques used for the Divergent 3D car are now being licensed to large-scale production runs of well-known brands.

Deploying new technologies such as 3D printing gives companies a large step ahead in highly competitive industries with razor-thin margins, such as the automotive market. Increasingly, those technologies are needed just to be able to compete.

[22] https://hbr.org/2012/05/managing-your-innovation-portfolio

Cultivate the agility to use cheaper inputs and reduce costs

It's not just tooling prices that can be reduced through more agile operations. Smarter manufacturing operations are allowing chemical companies to adapt to changing raw materials prices.[23]

The price of a particular kind of crude oil, for example, becomes an attractive low-cost option—the problem is, it's corrosive. Solution? Corrosion sensors in the pipes.

Or, perhaps chemical companies want to use shale oil and need to monitor heat exchangers. Again, sensors are the answer. With the right monitoring, companies can switch between cheaper inputs.

Harness agility to meet fickle customer demand

The customer is always right. Managing inventory to keep up with changing consumer preferences is a must. For physical product companies, the cost of moving too slowly is high. Some are adopting software-like cycles of testing, measuring, and updating to get an edge.

Zara, the biggest brand in the fashion conglomerate Inditex, is famous for picking higher-cost production locations such as Spain, Portugal, and Morocco to be able to react to customer demands faster. In contrast to rivals, Zara commits to only 50% of the season's production at the outset of the season, giving it the flexibility to add new designs as the season moves along, sometimes in a matter of weeks.

According to a Columbia University case study,[24] this approach gives Zara a strong competitive advantage. The company needs to sell only 15 to 20 percent of its clothing at a discount, compared with 30 to 40 percent at other retailers. Further, it encourages customers to visit the store more often—17 times a season versus three to four times at Gap stores—because they know they're likely to discover new items.

Xiaomi, the billion-dollar Chinese consumer tech startup, built its business on a similar strategy—using flash sales to test demand and producing only after meeting certain thresholds. This approach allows the company to maintain low inventories and have faster product release cycles than its competitors.

Both of those examples, and many others like them, show that hardware release cycles are moving the same way as software. Case in point: Authentise issues 60+ releases a week to fix bugs, address customer needs, and ready its tools for the next stage. As new influences and needs bounce around the internet at the speed of light, all businesses, including product companies, need to react faster.

[23] https://www.linkedin.com/pulse/turning-sensors-agents-shape-industry-40-come-andre-wegner?trk=pulse_spock-articles
[24] http://www.scribd.com/doc/74021699/Colombia-Case-Zara#scribd

Employ agility in the workforce

Who you employ is just as important as what you produce. Manufacturing companies, for example, have long been able to rely on loyal, experienced professionals. Now, many are retiring, with fewer new hires willing to fill manual jobs. The US is expected to have 3.5 million manufacturing vacancies in the next 10 years, according to a Deloitte study,[25] two million of which are likely to go unfilled due to a skills gap.

The rapidly changing manufacturing workplace is partially to blame, as new IT skills are needed. But innovations such as robotics and augmented reality can help make the workforce and hiring process more agile by reducing the need for skilled labor in areas where workers with those skills are retiring.

Companies don't have an alternative route to growth. Previous strategies such as outsourcing have become victims of their own success. China's unit labor production costs were 47% of U.S. levels in 1990. By 2016, they has risen to 75% of U.S. levels, according to the Economist Intelligence Unit.[26] Without intelligent manufacturing processes enabling a more agile workforce, reshoring may prove extremely difficult.

Leverage agility to react to environmental issues

While companies may spend a decade planning for shifts in the workforce, environmental disasters often dictate the need for significantly more agility—and slow responses can cost companies dearly.

When the Tōhoku earthquake and following tsunami wiped out four key Toyota plants and countless suppliers, no contingency plan would hold. Nearly a month later, two-thirds of Toyota's suppliers from northeastern Japan were still not functioning.[27]

A more agile manufacturing operation allowing production to be autonomously re-routed may have been able to keep more of Toyota's operations running during the event. Fixed tooling for factories that produce a single model of an automobile also means fixed points of failure.

Toyota's production declined by over 600,000 cars in 2011,[28] and the firm lost its position as the largest automaker by volume. The price of a less-than-agile manufacturing operation is staggering.

[25] http://www.themanufacturinginstitute.org/~/media/827DBC76533942679A15EF7067A704CD.ashx
[26] https://fas.org/sgp/crs/row/RL33534.pdf
[27] https://www.forbes.com/sites/greatspeculations/2011/04/08/japan-quake-tsunami-take-heavy-toll-on-toyota/#6d75342f7f04
[28] http://www.toyota-global.com/company/profile/figures/vehicle_production_sales_and_exports_by_region.html

Prepare Now for the Changes Driven by Unstoppable Technological Progress

We have walked through numerous examples of how exponential technologies including AI, robotics, and 3D printing are rapidly redefining the future of manufacturing. Trends like democratized technology and platforms are accelerating the replacement of traditional processes for prototyping, design, production, and supply chains with innovations that will shape the future of advanced manufacturing.

In today's dynamic manufacturing sector, competition can come from startups, established companies, and organizations outside your industry—as well as industrious individuals working out of garages and spare bedrooms. This means an upsurge of creative brainpower is coming online to build innovative new products that are personalized, built on-demand, and delivered at record speed.

Simply put, the era of slow, inflexible and inefficient manufacturing is over. Market forces, competitors, and evolving customer preferences are all flashing signals that today's manufacturing leaders must become lifelong learners and adopt more agile strategies in order for their companies to survive. A working knowledge of exponential trends and technologies and the ability to bring the resulting innovative solutions to market are the tools required to become the manufacturing leaders of the future.

At Singularity University, we're laying the groundwork for exponential change. With our learning and innovation platform, proven tools and methods, and world-class faculty, Singularity University helps transform companies of all sizes into adaptable organizations that can get out in front of market disruptions and achieve exceptional business results.

To learn more about how Singularity University can help your company and leadership team be exponential, visit su.org/enterprise and explore our suite of powerful enterprise solutions designed to uplevel your leadership, innovation, and strategy; help you monitor emerging threats and opportunities; and empower you to measure the effectiveness of innovation at your organization.

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