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MANUFACTURING EVERYWHERE

CLOUD-BASED SERVICES AND UBIQUITOUS SENSORS PROMISE A REVOLUTION IN PRODUCTIVITY.

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INFORMATION TECHNOLOGY ON THE FACTORY FLOOR PROMISES A REVOLUTION IN PRODUCTIVITY. BUT CAN MACHINES, PRODUCTS, AND PEOPLE *REALLY LEARN TO TALK WITH EACH OTHER?*

BY ALAN S. BROWN

The industrial hype machine has not worked this hard since the early days of the Internet.

The object of its affections is the full-on mashup of manufacturing with modern information technologies. This goes by many names, from Industrie 4.0 and digital manufacturing to cyberphysical systems and smart—no, make that brilliant—factories.

What they all have in common is the use of intelligent software and machines to interact with one another (and with people) autonomously, both in the factory and through the cloud. According to boosters, this new combination of brains and muscle will revolutionize manufacturing in ways that rival the introduction of steam, electricity, and automation.

Beyond the hype, this could lead to some real and startling changes.

In the data-driven factory of the future, engineers would receive instantaneous feedback on the cost of design changes and on which parts are most likely to fail in the field, so they can improve designs and change production processes.

Factory machines and logistics equipment would communicate with one another autonomously to assign and route jobs through the factory—and reroute them when unexpected problems arise. Cloud-based AI would constantly compare parts and processes to optimize performance.

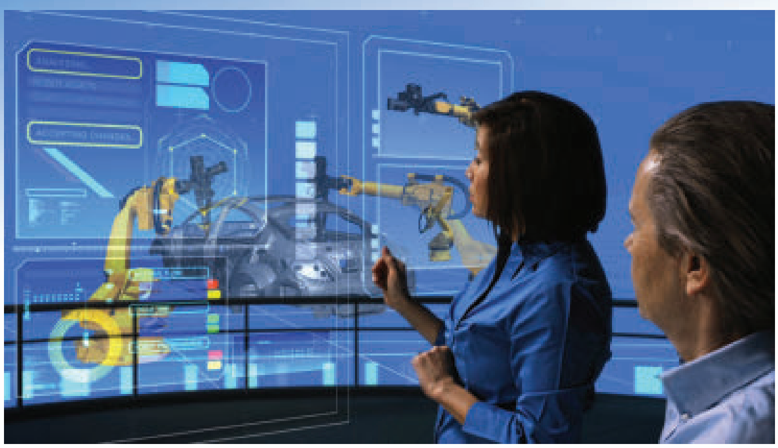
Perhaps one day, entrepreneurs and engineers may even create entire virtual factories, buying time on underutilized assets the way they buy products from different vendors on Amazon.

This vision, like that of the early Internet pioneers, is compelling—and perhaps even closer than we think.

TOWARD DIGITAL TWINS

The Internet blossomed because desktop computers and corporate networks were ready to plug in. Similarly, data-driven manufacturing is emerging now because many critical technologies—from networked machines to the alphabet soup of manufacturing software—PLM, ERP, CAD/CAM, CFD, MES, DMS, PLC and more—are already in place.

Today, these discrete systems collect some of the data, some of the time. Data flows freely within a single software program, and more or less well within software suites from a single vendor. Problems arise when they have to make sense of



Simulation models will play an important role in running factories more autonomously.

machines in geographically diverse factories that may use software from multiple vendors.

Consider engineering design software. While most computer-aided design programs have proprietary file formats, and readily share information with CAD systems from different vendors. They also export data to simulation software and computer-aided manufacturing systems.

Unfortunately, sharing data is far from seamless. When sharing files between CAD systems from different vendors, engineers must still review drawings to fix missing, misplaced, or disconnected features. Some CAD systems share only some of their data. For example, they might keep the material specifications essential for efficient machining locked away. Nor can engineers see how a design change affects a part's performance or its machining time without running separate software programs.

All this makes CAD data sharing too complicated for the plug-and-play world of data-driven manufacturing, said Stephan Biller, GE Global Research's chief manufacturing scientist, who leads the company's digital manufacturing charge under the "Brilliant Factory" banner.

"We want to be able to change a product in CAD and have those changes propagate automatically to product and factory simulations. That way, we get immediate feedback on how design changes modify cost, time, and materials," Biller said.

Biller also wants to link factory software with downstream supply chains and upstream customer service data. This is especially important for GE, which guarantees the performance of turbines and many other products it sells and services.

"When we open a jet engine, we can see exactly how its parts behaved. Maybe some parts are over-engineered or wearing too fast. I want to train technicians to get that information into a digital twin, a model that is an exact virtual twin of that product."

By constantly updating that information, GE wants to use the digital twin to help improve future designs and predict when to take in products for service. "We can see who made the parts, see how operating conditions affected performance, and improve production. The same data can help us manage demand for our service shops better, too," Biller said.

Much of this data already exists in manufacturing execution systems, product lifecycle management software, and enterprise resource planning systems. The problem, Biller explained, is that these systems are typically not well integrated. His goal is to tie that information together. That way, he can capture field service feedback and other types of information that's rarely shared among designers, manufacturers, and technicians.

This is an ambitious agenda. So ambitious that Biller's boss asked him, "How do you know when you're done?"

Biller's answer: "I'm done when I can launch a virtual product in a virtual model of my plant, then run it in my plant and the product behaves exactly like the simulations predicted."

INTERNET OF THINGS

As software gets better at communicating, ubiquitous sensors are adding more data to the mix. A lot more. The industrial Internet of Things is powered by cheap sensors and controllers, some with distributed intelligence, that engineers can slap onto everything from milling centers to RFID readers that track work in progress.

Many companies, such as ABB, Emerson, GE, Honeywell, Mitsubishi, Siemens, and many others, already sell systems that do this. Their platforms are proprietary and costly.

Less expensive IoT sensors and controllers threaten to disrupt this status quo with the same strategies that have slashed prices and boosted the performance of consumer electronics for decades: simple construction, open standards, plug-and-play installation, ease of use, and the substitution of wireless data transfer for expensive cabling.

At Siemens PLM Software, Alastair Orchard, who leads the company's digital enterprise project, is not trying to fight the rising tide.

"We have to embrace the Internet of Things," he said. "We can't try to defend the shop floor and force our customers to take the most expensive and awkward way of doing things. We want to preserve IoT's ability to quickly, simply and cheaply get data."

Fortunately, years of mergers, acquisitions, and globalization have taught companies like Siemens how to weave software and hardware from different vendors into a single system.

But are they prepared for the sudden proliferation of cheap sensors that IoT is making possible? These devices will generate tsunamis of data, enabling machines to talk more fluently with one another while machine-learning algorithms probe the information for better ways to run the plant. But integrating data streams creates its own challenges, said Lihui Wang, an ASME Fellow and well-known expert on digital manufacturing who chairs sustainable engineering at Sweden's Royal Institute of Technology.

"I don't think many people realize the complexity of combining different types of data," Wang said. "Even if we are talking only about digits, we have to deal with the high volume, velocity, and variety of measurements. And some data is unstructured, like speech, photographs, and drawings, which are more difficult to analyze."

To transfer data among various devices, German motor drive and control giant Bosch Rexroth tries to use open standards, said Thomas Buerger, the company's vice president of engineering automation systems. Unfortunately, while some open standards exist, others are still works in progress.

Nevertheless, Buerger argues that installing and integrating extra sensors is worth the fuss. He points to a cardboard carton-folding machine that links a Bosch Rexroth controller with a humidity sensor. It automatically compensates for changes in cardboard stiffness, which varies depending on whether the air is dry or soggy.

As the IoT takes hold, factory machines will work together to keep products flowing, and adapt autonomously to their environment. They will also learn from similar machines in other factories around the world—but only if they can rely on the cloud.

INTO THE CLOUD

Not long after the Soviet Union collapsed, German manufacturers sensed an opportunity. To take advantage of lower labor costs, they began to build factories in Eastern European countries. Those firms had always trusted an intensely loyal workforce to guard their designs and trade secrets closely within their factories. They were unsure what might happen beyond their borders.

To maintain tight control over this information, they began storing it in centralized corporate data centers. They gave local engineers access to only the documents they needed, and barred them from roaming to other parts of the digital library.

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> — Stephan Biller, Chief Manufacturing Scientist, GE Global Research

Today, data-driven manufacturers still want to hold intellectual property close, but they also want to use centralized data centers to help manage shop floor production. In other words, they want to use cloud computing to help run smart factories.

There are good reasons to do it. Centralized, cloud-based software is always up-to-date. It includes the latest security enhancements, and it runs on the latest IT equipment.

What's more, large data centers are highly ef-

ficient, low-cost providers. They could support data-driven production without the company incurring the cost of running a large data center, said Ihab Ragai, who worked 20 years in manufacturing before becoming an assistant professor of engineering at Penn State Behrend in Erie, Pa.

Another plus is that companies can aggregate data on similar equipment in multiple factories. They could then use analytics to benchmark or discover patterns that might affect output. Such analysis could extend to performance in the field.

"If they do this, they will have a database that helps them predict part lifespan and how that lifespan changes if they run their equipment faster or under more extreme conditions," Ragai said.

Yet factories cannot yet rely entirely upon the cloud. Ragai recalls visiting an Egyptian die casting plant when an undersea Internet cable broke. It took three days to restore the Internet connection.

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> — Lihui Wang, ASME Fellow and Sustainable Engineering Chair, Sweden's Royal Institute of Technology.

"Now, imagine if that casting facility got all its drawings from the mother company," Ragai said. They would have experienced a costly shutdown unless they had satellite communications.

Still, as German firms are well aware, the cloud's most important stumbling block is security, said Wang, of Sweden's Royal Institute of Technology. If plant engineers don't feel confident in their cloud-based control software, then they might end up printing out diagrams or downloading backup files just in case. This poses the very security challenges that IT managers turn to data centers to avoid: stacks of valuable proprietary information airing on desks or sticking out of local jump drives.

Solutions are possible, Wang added. "Ten years ago, people were asking if online banking was risky. Now it's accepted. That same technology can be applied to cloud manufacturing to protect data privacy."

Nevertheless, he said, "Companies should also understand that there is no 100 percent security. They have to accept some risk. To reduce that risk, maintain your core software inside the plant."

FACTORIES FOR HIRE

Clearly, data-driven manufacturing is a work in progress. It is easy to see the barriers and perhaps miss the potential. That is why companies like Bosch Rexroth, GE, and Siemens have built plants to demonstrate how data can make a difference.

For example, in the medieval German town of Amberg, a Siemens plant fabricates programmable logic controllers (PLCs), which automate industrial machines and processes.

Amberg plant's performance is impressive. It can turn around a custom PLC for any of its 6,000 customers in just 24 hours. And of the 12 million PLCs that will roll off the plant's gleaming tile floors this year, only 121 (or 0.001 percent) are likely to have any defects.

The reason for this lies in how Siemens uses data and simulation models to run its plant.

Once a customer orders a PLC from Siemens, a computer system in the Amberg Electronics Plant assigns it a unique product code and creates a virtual model that defines the manual and automated processes needed to make the PLC. The system compares the order with other orders to see if it can group products with similar parts together for faster processing. It schedules time on machines that are free, and lines up automated carts to shuttle the components from one work center to another.

Machines assemble PLCs from capacitors, resistors, microchips, and connectors, inspecting components after each operation. As this is going on, the plant's operating system is comparing the time needed for each sequence of tasks with a simulation model of the plant, checking for any deviations that might signal a problem.

The entire conversation takes place between machines, with no human intervention. Only if there is a problem—a flaw needs repair, or a ma-

Siemens' Amberg plant uses data-driven manufacturing to produce 12 million controllers annually. Only 0.001 percent have any defects.

chine begins to deviate from its allowances—does the plant notify a human specialist.

"In Amberg, there are 50 million conversations each day between those agents and smart automation. They are saying: 'Set up correctly to do this. Who can do the next process? Are you ready? Logistics, route me over there. Check and double-check.' It's an almost continuous conversation, and it gives us our flexibility," Orchard said.

In the future, those data-driven conversations will make plants even more adaptive and autonomous. Just as apps and Internet connectivity spurred innovation in smartphones, data-driven factories are likely to evolve in new ways

For example, Dirk Schaefer, as associate professor of design engineering at University of Bath in the United Kingdom, sees a time when highly connected factories will one day be able to sell machine time as a service. Firms that need more output to meet demand or replace a broken piece of equipment could rent it.

Eventually, a global manufacturing network would emerge, and businesses and even individuals could rent machine time online the same way we book cars or hotel rooms online today, Schaefer said. There would be no lasting contracts, supply chains, or physical footprint. "This would allow for entirely new ways of inventing and making breakthrough products," Schaefer said.

When Schaefer trotted out his cloud-based design and manufacturing paradigm at conferences five years ago, engineers were skeptical. Today, they are listening.

After all, we live in a world where a single factory supports 50 million digital conversations every day. Who knows where those dialogues could lead? **ME**

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