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BY DANIEL GROSS

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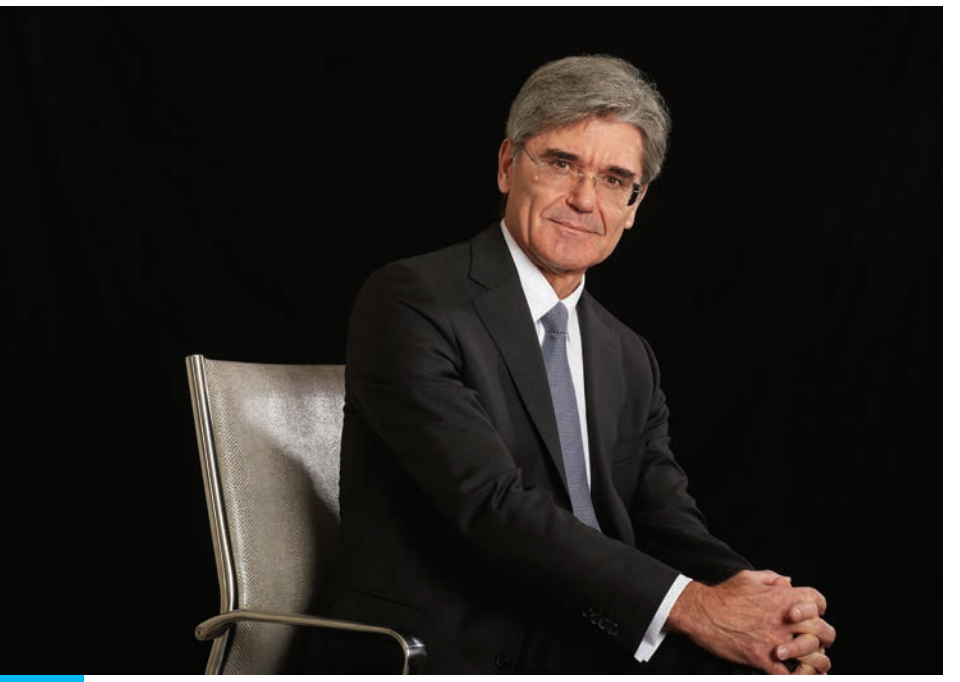

Very few companies have survived as many technological and industrial revolutions as Siemens AG. Founded in Berlin in 1847, Siemens has seen — and prospered through — the advent of steam, trains, electricity, the internal combustion engine, steam turbines, the jet engine, wind power, the personal computer, wireless communications, the Internet, and, now, big data. While other companies managed through these consecutive industrial and information revolutions, Siemens has helped lead them. With fiscal 2015 revenues of €75.6 billion (US$82 billion) and 348,000 employees, it is one of the world's largest industrial enterprises.

Today, Siemens is organized into 10 divisions, most of which offer highly complicated products. The divisions address markets such as wind power and renewables, power generation, energy management, building technologies, mobility, process industries and drives, and healthcare. The sun never sets on this far-flung empire, which stretches from a steel factory in Cilegon, Indonesia, to a software development center in Bangalore, India; from an ultrasound equipment manufacturing facility in Plymouth Meeting, Penn., to a wind turbine plant in Cuxhaven, Germany.

Every business talks about becoming more digital. Buzzwords like *3D printing*, *the Internet of Things*, *mass customization*, and *big data* are bruited at conferences and populate the fundraising decks of startups. But these concepts — and the broader notion of digitizing manufacturing — have a particular meaning for Siemens. It is in the midst of its own digital transformation. The company is putting lots of time, effort, and talent into marrying information technology to the process by which it designs, builds, and delivers its highly sophisticated products. The company's own manufacturing is already largely conducted in fully digital factories.

Steering Siemens through the next industrial revolution is the mission of Joseph Kaeser, who joined the company in 1980 and rose through the ranks of the semiconductor divisions and then into central management as chief financial officer. In August 2013, he was named president and CEO.

Photograph by Matthew Septimus

Kaeser may not have the mien of a millennial technology executive. He doesn't wear hoodies, and his hair is combed carefully in a silver coif. But he is something of a digital native, having spent time in Silicon Valley in the 1990s. (At the time, Kaeser confesses, the locals often confused Siemens with Simmons Bedding Company.) Today, Siemens employs more than 17,500 software engineers. Although much of the conversation about technology revolves around apps and websites, Siemens is providing examples of how IT and data can add a massive amount of leverage in advanced manufacturing.

In conversation, Kaeser is energetic and informal — one favorite word of praise is *cool* — with a wide-ranging, pragmatic perspective on the issues affecting his company and his industry. Over a one-course meal (fish and white wine) at a hotel in San Francisco in November 2015, he sketched out his favored path to relevance for a 170-year-old advanced manufacturing conglomerate in the early 21st century. He described how Siemens's approach to manufacturing brings coherence to a diverse portfolio, and helps drive its culture, and he aired his opinion on the broader implications of the ongoing technology revolution.

S+B: I understand you spent several years in Silicon Valley.
KAESER: More than five years, from 1994 through 1999. I came over as CFO of what was then Siemens Components, which was the semiconductor, passive devices, and electrical components business. Then I ended up becoming the CEO, and I left in 1999, just about at the height of the bubble. I always remember those were tough times.

S+B: Wasn't there a boom going on?
KAESER: Well, in 1994–95, it was still kind of a depressed environment in the Valley. House prices were still down. There were a few companies talking about Internet applications and voice over IP. And then the telecommunication networks began to bloom. Lucent was still around and telecom was very cool, and companies like Cisco and Bay Networks were thriving. You know, when Candlestick Park [the San Francisco Giants' baseball stadium] was renamed 3Com Park in 1995, that was interesting to me. I had never thought about companies like 3Com or Cisco before. We actually were a supplier to Cisco and telecoms and datacoms, and the DRAM [dynamic random-access memory] business was still really strong with the pull from companies like Micron. But when I introduced myself as the big shot from Siemens, people said, "Oh, is that the mattress factory?" I responded that it was kind of close, because whenever you buy products from us, you can sleep well! But this was also a time when Apple was at five bucks a share. I was working in Cupertino, and the Apple complex was just across I-280. And people were joking about Microsoft buying Apple for the price of a Snapple.

Siemens Past and Future

S+B: So you saw the beginnings of one bubble in Silicon Valley. And today we're sitting in San Francisco, which many people regard as the epicenter of an even bigger tech-infused bubble.
KAESER: Well, no one can predict the future. My take would be yes, we are in the middle, if not close to the peak, of another massive bubble. But then again, the ones who survive will change the world. And that's the fascinating thing.

Daniel Gross
gross_daniel@strategy-business.com
is executive editor of *strategy+business.*

S+B: You're the CEO of a massive, diversified global company. With the digitization of information, you can have information and insight into all your different operations on one screen. How does that affect the way you work and manage? Do you have a dashboard of indicators on all the time? Are you texting 500 different people?

KAESER: There are two aspects to managing today. The information comes faster and is more accessible than ever before. There's a lot of data, and the challenge is how to prioritize information. As a company leader — or as any manager, any person — you need to prioritize your tasks. It has become harder to set the priorities correctly because there's so much information. You need to go after that information and understand what's first and second and third [in importance].

The second aspect to managing: How do you manage your company using the data you collect? There's a technocratic approach in which you look at the numbers. But by the time you get the numbers, it's too late already because the numbers only reflect what happened in the past. At the end, managing a company is still very analog, because human beings are analog, and the way you manage your company is you deal with human beings from the top all the way to the bottom. That value chain of human resources needs to be intact.

S+B: So it's not just about the numbers?

KAESER: [At Siemens] we know our numbers, usually daily, in terms of bookings and revenues. We have built a real-time system and we know our cash flow. But in a business like ours, which has cycles from two to seven years, it's much more important to understand the markets. How do we recognize early indicators of a changing world? That object you see — is that going to be there tomorrow? If it's there tomorrow, is it going to be different? What's your competitive environment? How do the customers of your customers change? That's the type of stuff you need to understand because by the time you see the numbers, it's too late.

S+B: What is the Siemens approach to the use of information technology in advanced manufacturing?

KAESER: It's a very powerful approach because we are industry leaders. We have a division called digital factory, where we merge the real world, which is hardware, with the virtual world, which is simulation software. We have all the elements of manufacturing automation in that division. We have hardware such as control systems and CPUs. Then, around that hardware, we have so-called PLM [product life-cycle management] software, which allows us to simulate production and robotics flows ahead of time. So today, we build manufacturing automation lines and design processes before a manufacturing plant has been built.

> "We have a division called digital factory, where we merge the real world with the virtual world."

Merging the real world with the virtual world allows us to create

what we call a digital twin. We copy a real-time manufacturing process into the virtual world to optimize engineering, processing quality, uptime, and load time — and then we copy it back into the real world of manufacturing. That's pretty cool. I believe we are the only company in the world that can do it. And when we simulate processes in manufacturing and in engineering, in R&D, we can go from destructive to nondestructive testing. Together with Boeing, we simulate the whole development and engineering process for new airplanes. And then, we [do simulations that test] whether the airplane can fly or not.

Advancing Data Analytics

S+B: Siemens employs a huge number of software engineers. What are they doing?
KAESER: We have more than 17,500 software engineers in our company, more than many software companies in the world. And those people develop software inside the products, which is called embedded software, as well as build applications and data analytics tools that use the data we get from hardware. The importance of hardware is what people often underestimate when they talk about the Internet of Things. Have you ever thought about where data comes from?

S+B: It comes from the customers, doesn't it?
KAESER: People *say* they are getting the data from their customers. But when I ask who and what is providing the data, they respond, "It's the machines and stuff." Exactly! It's the installed base of machines. If you look at a high-performance energy turbine, like a gas turbine, our flagship, the 8000H, it's a 600-megawatt machine — a really cool machine! There are thousands of sensors in that machine, and every sensor has a story to tell. Every moment, that sensor delivers data to software, which stores it in the cloud.

> "There are thousands of sensors in [a high-performance turbine], and every sensor has a story to tell. Every moment, it delivers data."

There's a two-step process: collecting data and making use of it. Once I have data, how do I make meaningful analytics out of it so my customer has an advantage? My customer would pay me for information that makes life easier, better, less costly, or more valuable. And that's what many people don't understand when they talk about the Internet of Things or open platforms. "I've got data, but why would someone pay me for that data?"

S+B: What does it mean to have every product you make incorporate sensors and be connected in the cloud? Is this your new approach to manufacturing for every one of your diverse businesses?
KAESER: That's exactly what it is. We've got energy generation. We've got energy management. We've got automation for manufacturing, and products for industries like oil and gas, food and beverage, mining, all that good stuff. And there are vertical software applications for certain industries. Those applications are all based on hardware that provides data through sensors. We look at that data, analyze it, and then make applications out of it. Think about turbines for a utility. We help the utility company analyze how much service its power plants need based on fuel consumption, the utilization rates, and the maintenance data.

S+B: Is this a vertically integrated process in the sense that you're manufacturing the machines that produce the data, you're collecting and analyzing the data, and then you're writing software? And are you also making the sensors?
KAESER: We manufacture products that generate power, that automate manufacturing processes, that scan people (like CT and MRI machines),

and that move people and goods from place A to place B. That's a lot of products, and all those products have sensors. But we don't manufacture sensors. However, once we get the data, we have the data analytics platform and the cloud. For example, we have a proprietary cloud system for on-site data. Our customers care about manufacturing and engineering data and intellectual property rights because [this type of data] is the holy grail of innovation.

S+B: How does this approach change your relationship with your customers and the value proposition Siemens offers?

KAESER: It changes the relationship massively because data analytics gives a company a lot of information [it can use] to optimize and shorten the value chain. The value chain consists of the supplier of your supplier, your supplier, your company, your customer, and the customer of your customer. The information you get from data can shorten that value chain. You can make products faster, more cost-efficiently, more flexibly. You can produce in lot sizes of one. You can cut out different links of the value chain. And the links that get cut out provide the least value in the value chain. And that's what you need to understand. "Where am I in the value chain? How can I remain a strong link by providing more value than anyone else in there?" You'd better know what you can do with your data and cut someone else out rather than get cut out yourself. The issue isn't just that your suppliers might try to cut you out. Your *customers* might try to cut you out because they say, "I've got the data, so why do I need you?" That's the paradigm shift.… The telecom space is a good example. Now why would you pay a lot of money for making a phone call if you've got Skype?

> "Production is being changed. In the last five years, we have increased productivity eightfold."

The Industrie 4.0 Difference

S+B: It seems like this approach would require a substantial shift in the culture — as well as how you train people and present yourself to customers.

KAESER: If you look at a company culture and what it takes to stay alive for the next generation or two, or maybe even longer, you need to look at the purpose of the company. Why is it that I'm going to get up in the morning and go to work at that company? Why do I believe it is worth going the extra mile and giving my extra five cents? The way we've been defining the purpose at Siemens is that we are a "business to society" enterprise.

We created that term — *business to society* — because we have B2C (business to consumer) and B2B (business to business) offerings. But we are a business that contributes to society's development in the world, through becoming carbon neutral by 2025 (we're the biggest company in the world that has committed to doing that); or saving lives; or providing people with reliable, safe power; or giving people a more livable life in cities. Our employees

think that's pretty great. That's how we start changing the culture.

Next, everyone in this company, from the receptionists all the way up to the CEO, needs to have an understanding of what we call our ownership culture. I say to them, "Whatever you do, whoever you are, wherever you work in the Siemens world, just act as if this were your own company." That approach is how we do business and how we manage our business.

S+B: That's mostly inward-facing. What about external-facing efforts?

KAESER: You need to change the way you go to market. The world is all about competencies. Never let the hardware guys sell software, never, ever! Just don't even let them get close to it. Our perspective is that we now sell solutions, applications, and comprehensive systems as opposed to just selling the product. We sell value instead of selling functionality. It's a complicated go-to-market method.

S+B: What is Industrie 4.0, and what role is Siemens playing in that?

KAESER: Industrie 4.0 is the German version of the first generation of manufacturing automation (see "A Strategist's Guide to Industry 4.0," by Reinhard Geissbauer, Jesper Vedsø, and Stefan Schrauf, *s+b*, Summer 2016). It basically combines engineering and manufacturing. We call it a digital twin. We've built Industrie 4.0–type manufacturing plants in Germany. And the first one outside Germany is in Chengdu, China. Thousands of people are visiting this plant.

S+B: If I were to show up there, would I notice a difference between it and any other factory?

KAESER: Oh, yeah. You will see a highly automated manufacturing flow, like what the automotive industry uses. But what you see is: Sometimes the flow is like this [he moves one hand off to the side]. Sometimes the flow is like this [he shifts it again], and all of a sudden, the flow is like this [he moves both hands]. And you say, "What the hell is going on here?" Well, what happens is that there's a customer request such as, "I want this product in that size, in that lot size, with that blue color, with that dot on the bottom." So the software steers the manufacturing process into lots as small as one item. And then sometimes all of a sudden, you see that certain products are being sorted out into a queue, because the plant received information about a quality defect in that product. So the simulation fixes the defect and gets approval from quality management to put the fix into the production process. And then off we go.

The production process is being changed. It's machines talking to machines in a self-optimizing manufacturing and engineering process. Using this approach, we have attained a production quality rate of 99.9988%. That is getting pretty close to Six Sigma. In the last five years, we have increased productivity eightfold. It's really something.

S+B: When you go back to the origins of the assembly line in the U.S., Henry Ford said it could work only if you had a standardized product. For 100 years, customization has been the enemy of manufacturing efficiency. But you're saying this approach resolves that contradiction?

KAESER: Exactly. Industrie 4.0 basically takes the cost of scale close to zero. No matter what lot size you need, the unit cost is about the same. At some point, what will happen is this: You are a consumer and you want to buy a car. You go to the

Internet, put your specs together, and send that order to BMW. Someone will check your credit history and your funds. Then, your car will go straight to production and the factory will build it to order. Four weeks from now, you will have a car. No more waiting six months, or compromising at the dealership, where they have 50 cars but not the one you want.

> "By making the cars cheaper, you have maybe another 200 million people who can afford a car."

S+B: There's been a lot of talk about the ability to do mass customization through technologies such as 3D printing. But so far it seems like more of a hobbyist's endeavor.

KAESER: No, no, no! We use a lot of 3D printing already. We print small-volume prototypes, and that's a very important method of speeding up innovation. In the old days, it took ages to design a high-efficiency, high-temperature blade. Today, we simulate it, thanks to our digital factory PLM simulation system. We simulate the airflow, the cooling system, and the coating, which is important because the temperature at the edges of that turbine blade goes up 1,600 degrees Celsius when it's in use, so we've got to really understand what the cooling system is all about and how we minimize the gaps in efficiency. Once we've done the simulation, we print the blade. 3D printing is also a huge help in bridging the gap between scale and scope. Scale used to mean that if you did 5,000 blades, it was cheap, and if you did only five blades, it was very expensive. Today, it doesn't matter because those five blades can be produced by 3D printing. If you take the scalability out of the equation, you can expand your scope — and have a lot size of one. That's the approach. It's interesting. This is real, and it's not a bad thing to have.

Labor and Society

S+B: There's a lot of concern about the impact of technology on jobs and employment. If manufacturing becomes substantially more automated, what effect will that have on employment throughout the supply chain?

KAESER: If you shorten the value chain by cutting out links, as we discussed earlier, it results in lower cost, and that means fewer resources are being used. Fewer material resources will be needed, and fewer human resources will be needed. This is just the way it works. Furthermore, the remaining human resources will need different skills than blue-collar workers used to have. Workers need to deal with machines that are quicker to understand what needs to be done than the workers themselves are. Their experience is dwarfed by the computer's "experience," because the computer stores all the knowledge and calibrates all the data. People will still be in the factory, but they will be doing different work than they used to. Reskilling workers is a lot of hassle. That's not great news, right?

S+B: Certainly not for labor. How do we get around this?

KAESER: Making up the difference is possible only through growth. If you can massively lower the costs of a product, people who were unable to afford that product will become able to afford it. We have 7 billion people on this planet. Of those, maybe 4 billion would be able to drive. But only 2 billion can afford a car. By making the cars cheaper, you have maybe another 200 million who can afford a car. By tearing down the cost barrier, you enable more people to afford it and thus you secure growth.

S+B: Do you see barriers to the rollout of ever more efficient manufacturing technology?

KAESER: We were just having quite a debate and discussion with Andy McAfee [coauthor of *The Second Machine Age,* which argues that revolutions in technology will sharply reduce the need for labor]. And I

said, "There is one thing we really never had a look at. Will the majority of the society be willing and able to deal with the fact that the few smartest, the few brainiest, are going to conquer the world?"

He said: "Why not?" I responded that democracies [are run] by the majority vote and not so much by who is the smartest, the fastest, and the brightest.

And the reality is that we don't know the outcome [of these technological advances]. There is going to be a regulatory catalyst. And there is going to be a societal catalyst. The unions, the churches, those social types of nonprofit organizations say to businesses, "You think you're pretty cool. You're going to cut out all the middlemen, but you're also going to cut out social justice, so you just go to hell. We don't want to deal with you."

That societal impact has always been a massive topic that we, I think, also are trying to understand. How can you as a business contribute to society? Because if you don't provide a value to society, society will just not accept you.

S+B: This would seem to require a different type of leadership from technology and industrial companies.

KAESER: Think about the whole matter of air pollution. We said, we've got to get the CO_2 emissions down. Of course we need to. Then, we talk to China and to India and to Indonesia and say, "You are going to have to stop the coal-fired power plants and you're going to have to stop the pollution of your cities." And they say, "You know, you [in the West] screwed the whole world. You are developed now. You are rich. You've got a lot of money and you are driving nice cars and you are telling us now we cannot do that because you have already produced all the allowable CO_2 emissions?" That's not going to work. So, [if you're a business in the West,] you'd better make sure that your emissions go down.

If you don't bridge the societal divide, you're going to go nowhere with Industrie 4.0 or the Internet of Things or anything else a lot of techies and companies are talking about. That's something that leaders of companies had better think about. They need to ask themselves, "How do I deal with the digital divide, the societal divide? How do I make sure that I bring people along and make a meaningful contribution to society?" +

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