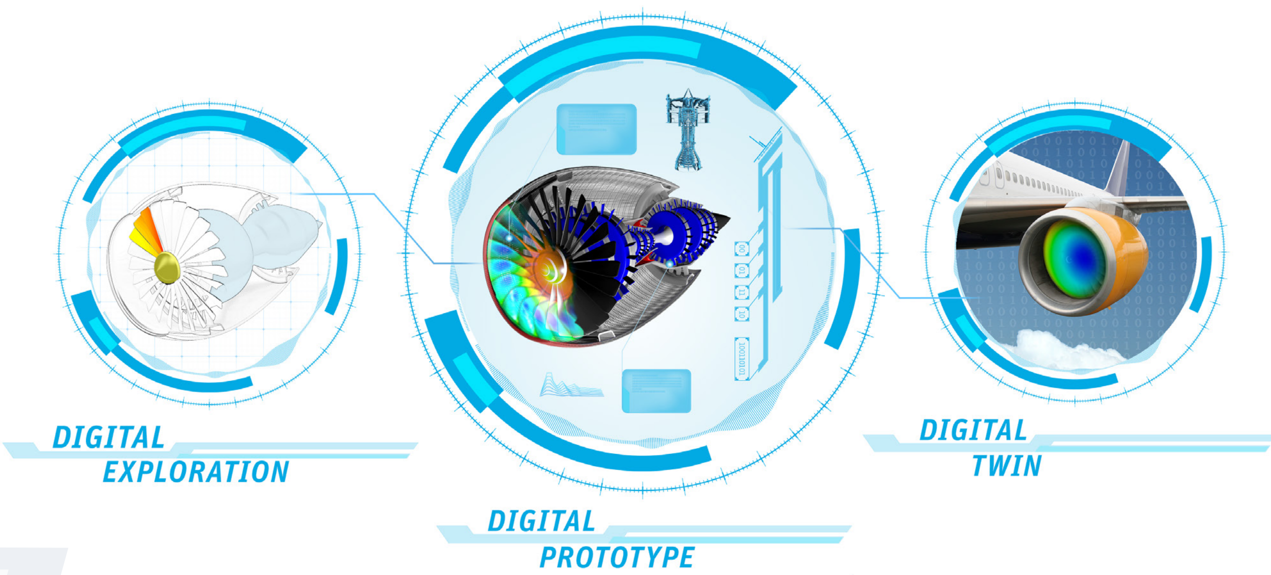
Engineering Simulation: The Future Is Already Here

On a window ledge inside the San Francisco loft office of Nebia, Philip Winter keeps a set of prototypes his engineers built in his company's early days. There's a T-shaped hunk of stainless tubes with welded nozzles dotting the sides; a plastic ring created from a 3-D printer; and another similar-sized hoop that looks like a steering wheel from an arcade game.

The engineering challenge behind each of these objects is an unusual one for Silicon Valley: Nebia, a Kickstarter-launched startup, is re-inventing the shower. We're not talking about another designer fixture. The techno-magic is all on the inside of Nebia's sleek aluminum shower head, inside hundreds of tiny nozzles. The nozzles produce a finely atomized shower spray that accomplishes two feats of engineering—they create an immersive shower experience that cuts water consumption by 70 percent, and they disperse droplets in a specific pattern to maximize heat retention, cutting energy costs and providing a crucial element of the sensory appeal. "Everybody has tried low-flow shower heads, and they suck," says Winter. "This is totally different. It's like stepping into a really warm cloud."

PERVASIVE ENGINEERING SIMULATION



So what helped Nebia get from Winter's unfinished prototypes to breakthrough commercial product? Faced with time and cost pressures, the engineering team went virtual. They turned to high-powered simulation tools from ANSYS—a software partner for dozens of top industrial manufacturers—not just to model new prototypes on screen, but to simulate thousands of virtual showers across thousands of changing variables, all without wasting a drop of H2O. Winter's team could simulate a dozen different variables simultaneously in search of the ideal mix of temperature, droplet size, pressure, velocity, and nozzle angle. New iterations that once took several months now took just a few days—and when they built new prototypes, they performed as perfectly as they did on screen. For Nebia, it was a watershed moment—running simulations conceived the product that Winter's team had dreamed of but never quite achieved on their own. And the real magic in terms of the business, not just the dazzling product? Development time was nine times faster; production costs four times lower.

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While a new shower head won't change the world, the technology that created it holds the potential to reimagine the landscape of industrial design and manufacturing for years to come. As physical products today take on exponentially more complexity in the age of IoT, 3-D printing and mass customization, software is emerging that can unlock vast economic potential by virtualizing every phase of the manufactured-product lifecycle—from initial design concept to prototypes to working products out in the field. Simulation technology is also emerging with predictive models called "digital twins" that can foresee precisely when, say, a nozzle on a jet engine will fail, or how a specific type of wind turbine blade will fare during a rough winter, or if a specific type of lightweight rocket material will launch safely without the need to test it first. And when that happens, the economic benefits can be exponential. Small wonder, then, why the global marketplace for simulation technology is on a steep upward trajectory: According to CIMdata, the global market has tripled in size since 2009, with revenues expected to pass $6 billion annually in 2018.

At GE, simulation modeling from ANSYS is helping the industrial giant unlock some of these capabilities in installed systems across dozens of industrial sectors and trillions of dollars of assets—a greenfield economic opportunity, with even marginal gains in productivity or efficiency achieved through the technology. As John Magee, chief marketing officer of GE Software explains, "one of the big opportunities with the industrial internet is to be able to have enough collected data to do predictive modeling to ask 'what-if' questions. What if we operate our plant differently? What if we push this piece of equipment harder to get the output that we need? What's the impact of that on maintenance? Simulation and modeling become hugely important tools once we've got the data to be able to give the decision-makers the right information."

While the last couple of decades of technology innovation has centered on the explosion of digital products, companies, and services—led by bellwethers like Google, Facebook, Netflix, and Salesforce—simulation modeling and the potential of digital twins are at the center of what GE and others see as a re-imagined manufacturing economy—and not just for Ph.D.s at giants like GE, but for a new audience of next-generation designers and "makers" when they get access to the same kinds of tools. As Ajei Gopal, President and CEO of ANSYS, puts it, "the next big wave of macro-economic wealth is going to be created in this intersection between tphysical and digital products."

In many ways, the evolution of industrial simulation tracks a path similar to the one that computers—and eventually PCs—followed in the 1970s and 1980s. Computers that were for many years the exclusive province of a small number of large universities and corporations were eventually reinvented for the masses, putting powerful new tools into the hands of millions.

Simulation tools have mirrored that progression—albeit on a delayed timeline. During computing's primordial days in the 1960s, mainframe computers ran simulation programs to model complex systems like telephone exchanges, airline reservation systems, and traffic grids. Simulators also became a crucial element in getting the Apollo missions to the moon.

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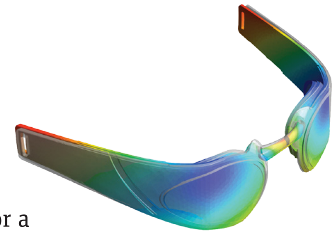
—Ajei Gopal, President and CEO, ANSYS, Inc.

In the realm of industrial design and manufacturing, however, simulation programs that relied on models of physics to design everything from airplane wings to light bulbs have long been the domain of a small population of elite engineers who had the skills to use them. (Even today, it's estimated that just 1 percent of industrial engineers use high-level simulation software.)

In the early years before PCs or sophisticated software applications, engineers would design a part—anything from a pump valve to a new kind of tire tread—then do their best to analyze, build and test it. When it broke or fell short of expectations, they would repeat the process, which might take months or years. In the design phase, engineers might focus on just one aspect of physics—the effect of temperature, say, or force, on the product they wanted. With improving software, engineers could do a bit more—analyze, change, analyze again—but couldn't build until they got a closer approximation of a workable product. "I can come up with a cool design as a designer," ANSYS' Gopal explains, "but does it really work? Can you actually build and put the electronics into that cool little product that looks like this piece of art? The designer didn't really know."

Moreover, this "single-physics" approach to early forms of simulation had big handicaps—especially given that parts as simple as a pump valve operate in dynamic physical environments with performance influenced by myriad factors such as fluid forces, electromagnetic radiation, thermal effects, structural integrity and so on.

THE PROMISE OF DIGITAL EXPLORATION



Eventually, the software took on broader capabilities that didn't just delight the engineers but lured in new industrial designers who suddenly didn't need a Ph.D. in thermodynamics to find out if their sleek-looking design for, say, a rear spoiler for a Corvette or a new type of office chair was physically buildable—much less comfortable, durable, or ergonomic. (Herman Miller, one of the great brands in industrial design, has tapped into ANSYS simulation tools to deliver the complex ergonomic benefits of its popular Mirra office chair.)

Simulation experts call this concept "digital exploration"— a key advance in helping get sim-tech out of the back rooms of industrial manufacturing and into the hands of folks who can make its capabilities shine. In short, digital exploration describes the ability to explore a range of creative product designs that match up with complex materials requirements and other parameters laid down by the laws of physics.

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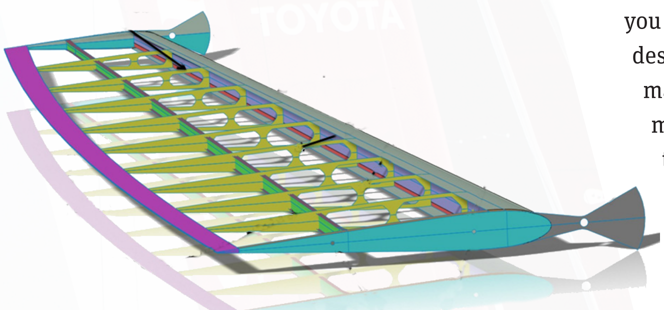
"We've been using this term 'digital exploration' for a designer who's really less into the deep physics and more into the usability and the aesthetics and the gestalt of a device or product," says Gopal. "Imagine if you gave them the capability to explore the entire universe of potential designs but at the same time validate that what you're coming up with make sense. It might not be the final design, because the designer may not have the skills to do that, but it gives them the opportunity to explore all the directions and come much closer to a viable product much faster than ever was possible before."



DIGITAL PROTOTYPING

After digital exploration came a natural next advance—software that manages additional layers of data complexity to allow designers, engineers and analysts to build an entire product in 3-D. Once a designer has "explored" all the options, today's simulation tools step in to complete the process and build a viable—but virtual—working product. This advance solved another set of exciting "what-ifs"—and allowed manufacturers to create digital designs earlier in the process that weren't just physically buildable, but whose performance could be predicted without the need for physical prototypes and lengthy, costly bench tests. "What happens if we can combine all these things into a complete virtual prototype in the computer and it was accurate?" says Jim Cashman, ANSYS' chairman

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and a longtime simulation technology veteran. "And it was not just indicative of what could happen but it was predictive of what could happen? That's pretty exciting." Digital prototyping is what has helped Emirates Team New Zealand optimize the performance of its America's Cup boats; the same technology helped create the infamous one-piece Speedo LZR swimsuits that helped Olympic swimmers shatter many records.

Prototyping also promises significant bottom-line perks. "By bringing simulation into the development cycle early on," says Shawn Wasserman, simulation editor at ENGINEERING.com, "errors in a design can be caught and corrected before expensive decisions have been made."

DEMOCRATIZING THE TECHNOLOGY

Two other macro trends helped make what Cashman describes feasible for small-scale tinkerers like Philip Winter at Nebia as well as industrial giants like GE. First was the cloud computing revolution and low-cost access to on-demand computing power—allowing simulation software to run in the background of inexpensive PCs. Then came the explosion of the Internet of Things, and the challenge of tethering products and parts with connected sensors and onboard software, all operating in concert, allowing engineers to explore and model the behavior of complex systems—not just individual parts or machines.

Think about Airbus, for instance, which installs over 10,000 sensors on every wing of its A380 jumbo jet, tracking minute changes everywhere throughout the wing in temperature, humidity, air pressure and structural forces. Or consider U.S. soldiers who, as Gopal says, "push IoT to the extreme." A typical soldier might carry three or four antennas. The vehicle they connect with carries even more. "Then you have radar going in over the battlefield," Gopal says, "and all these devices have to operate in an enormously complex environment where everything is talking to everything at the same time. So just figuring how to get reliable signals presents huge complexity. But that complexity is our friend—it's what simulation today was designed to handle."

THINK GLOBAL, BUILD LOCAL

Recent macro trends in global manufacturing are also pushing simulation technologies to center stage today—and towards the explosive breakout growth of the PC revolution. Low-cost commoditized manufacturing in China and other countries has been getting costlier each year, while near-shore manufacturing—aided by advances such has on-demand additive manufacturing and 3-D printing—is gaining new appeal. Simulation, many believe, will play a central role in exploiting the opportunities not only for near-shoring, but for improving leading-edge product design in a world driven by the demand for mass customization.

> **"Using big data analytics and simulations, engineers will be able to predict more effectively when their products and equipment will need maintenance."**
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ANSYS CEO Gopal lays out a common problem that handicaps entrepreneurs—they can't get to market fast enough. "Say you've come up with a cool skateboard design," says Gopal. "But the board has to have certain physical properties, and you want to make sure it doesn't break. So you come up with the design, build a few and try it out, then send it off to China for manufacturing. By the time they come back, you're talking about a two-year period."

Enter simulation-powered design and manufacturing that can all be done locally. "Now imagine you could just say, 'hey, I don't want to go through that process,'" says Gopal. "I want to just sit at my computer screen. I'm going to draw it out and I'm going to evaluate exactly how it's going to look and behave, and the modeling tells me what materials make it perfectly buildable. Then you 3-D-print your prototype and find a local additive manufacturing partner. You simply hand give him a file and he turns around 1,000 skateboards in a couple days and they're yours to sell. Your turnaround time is now instantaneous, your costs are minimal, and you've kept your IP out of the hands of a foreign factory. Just think about the rate and pace of change as a result of that. Additive manufacturing will be hugely transformative."

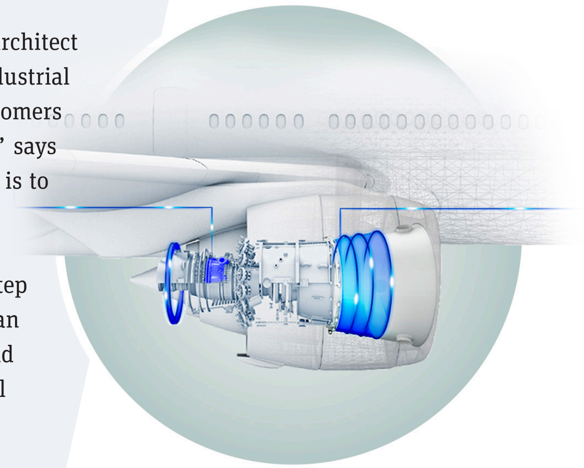
THE ULTIMATE SIMULATION TECHNOLOGY— THE DIGITAL TWIN

The biggest macro-trend that is the natural consequence of all of the others is obvious—big data. The ability of manufacturers to collect and organize the massive amounts of new data spun off by connected systems and devices is giving manufacturers building blocks for their own virtual reality-like platforms for industrial design. They're called digital twins—complete, functional, virtual doppelgangers of a physical asset performing in a live environment.

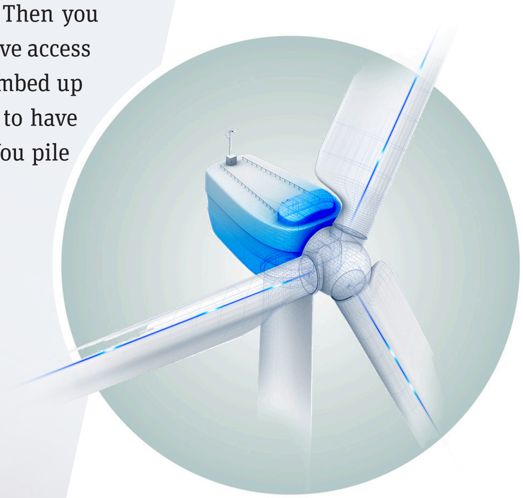
With digital twins, engineers can analyze and optimize the performance of products in real-world operating conditions. They can see not just what is happening at any given time, but why. They can speed up simulations in operation and productivity, pinpoint when breakdown will occur (and why), and reduce the cost and risk of unplanned downtime. With digital twins, engineers can accurately predict the future performance of a product as it operates within a larger system—a wing on a plane as it travels from San Francisco to London; a rocket engine as it undergoes the violent progression from launch to stage separation; an office building, as it manages power, energy and HVAC systems through the course of a day; extending much further, a driverless car, navigating city streets at rush hour with hundreds of other virtual cars on the road, each one represented by complex sets of very real physical and operating data. Says ENGINEERING.com's Wasserman: "The potential of the digital twin isn't just that vast amounts of data will be collected on a product. It also isn't that the data will be collected into a unified location or dashboard. The power of the twin is what you do with that information. For instance, using big data analytics and simulations, engineers will be able to predict more effectively when their products and equipment will need maintenance."

REDUCED DOWNTIME AT MASS SCALE

At GE Predix—an ANSYS partner and GE's industrial Internet platform—chief architect Marc-Thomas Schmitt sees digital twins as critical new building blocks for industrial customers looking to expand or innovate their assets. "When I encounter customers and they ask, where do I start, how do I write my first application in Predix," says Schmitt, "I tell them, don't write an application. The first thing you want to do is to start designing a digital twin."



Looking to invest in a new wind farm? All the critical groundwork is virtual. Step one is to start pooling the right data to create a twin, says Schmitt, so you can model exactly how your wind farm will truly perform. "Let's start with the wind turbines," he says. "You need with the basics—describe your turbine, what model it is you probably want to tap into, and the materials it's built from. If you're lucky, you might find a model that actually describes the 3-D geometry around it. And if you're really lucky, you might actually have a simulation model that describes what the expected behavior of the wind turbine will be. Then you might also want to tap into some operation assistance--you might have access to a system that that logs the service records of people who have climbed up that wind turbine and performed maintenance. You basically want to have any kind of information that is applicable to this particular asset. You pile it all up and that that establishes your digital twin."



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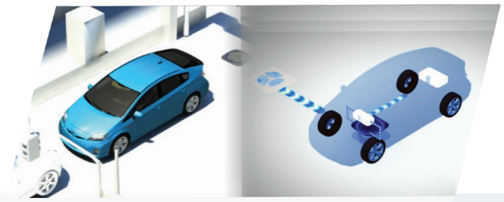
Where else will digital twins and simulation models plotting out our futures? Consider the building you may be sitting in right now. Humans have long engineered buildings a little like our bodies—with plumbing that circulates through walls, wires connecting the rooms like nerves, concrete and I-beams providing the skeleton. But until recently these indispensable bedrocks of the modern world have lacked the most critical body part—a brain. For years, it's been left to humans to manage the lights, power and temperature, to service the elevators and other equipment, and monitor security cameras, and keep rooms stocked with supplies.

In similar fashion as GE, IBM is beginning to build digital twins of physical structures — dynamic, simulated models of the real thing, powered by the massive amounts of data that a single structure generates around the clock—everything from design specs, energy data, equipment parameters and live occupancy data pulled from elevators. The promise of all this—powered by IBM Watson—is to use digital twins for everything from predictive maintenance and optimized facility management to streamlining workspace design based on the data flows showing how real people truly use the physical space.



“The future is already here—
it’s just not evenly distributed.”

— William Gibson

Back at the Nebia lab in San Francisco, Philip Winter is preparing to get his product to ship—yet already thinking about what he will develop next with the simulation tools his entire team knows how to use. “I think we would have gotten there eventually,” he says of the team’s earlier efforts, “but the technology allowed us to do it so much more quickly. It allowed us to be a lot faster and lot more sure of our work. And the engineers now swear by it—because they want it to be perfect.”

As William Gibson famously wrote, “the future is already here—it’s just not evenly distributed.” The same might be said of simulation technology today, which still just serves 1 percent of the population of engineers who could be taking advantage of it. But what happens when these tools get into the hands of more designers, engineers, and developers who can apply these exotic forms of simulation at scale? They will be able to draw up perfectly engineered products—like a shower head—that humans may never have figured out themselves. They can be put to work to accelerate the development cycles of future space missions, driverless cars and even bio-printed human organs—obviating the need for endless “build and break” human testing cycles and simulating not just the single physical thing but its real-time operating environment over any length of time. Think “Sim City,” but it’s not a game and it’s not about people— it’s about a whole new universe of man-made things.