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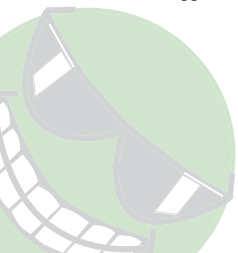


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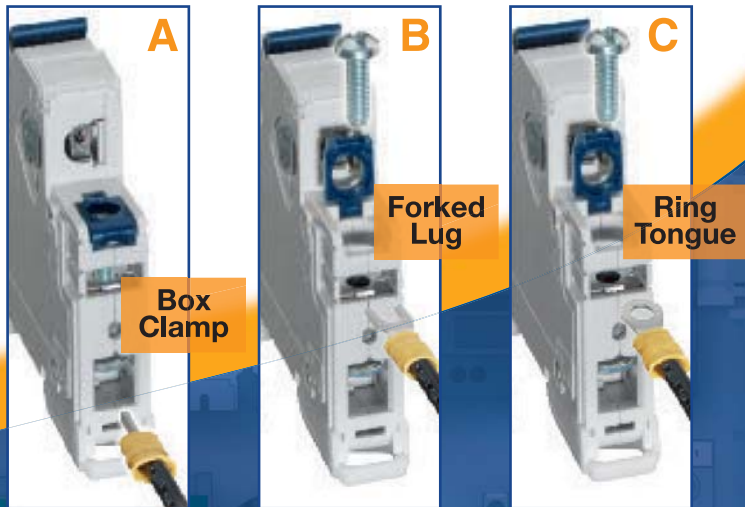
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### Editorial

BOB VAVRA | Senior Content Director  
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## Manufacturing's Springtime is Coming. Are You Ready?

Preparing now for growth requires some faith, but the potential rewards are great.

**AS A LIFELONG CHICAGOAN**, I'm often pleased that so many people comment on how much they like my hometown. In those conversations, however, one thing keeps coming up—winter. Each year, we face the potential for snow measured in feet, temperatures plummeting below zero and a wind whipping through the city like a zephyr. We also face the potential this pattern can repeat throughout the season. And repeat. And repeat.

While there's no denying that winter in Chicago can be challenging, I do remind people that it is winter that makes me appreciate spring just that much more. It is the shared experience of having survived yet another Chicago winter that brings us out of hibernation in March for a green Chicago River on St. Patrick's Day and the enthusiasm around starting the baseball season again.

We have spent the last two years in a long, tough winter. I'm seeing signs that the thaw is breaking. We are moving closer to a return to springtime for American manufacturing and, by extension, a strong return to global manufacturing growth.

Three specific signs of spring for manufacturing are out there:

- Manufacturing remains robust despite its struggles. We have seen processes disrupted by the global pandemic, supply chains fractured and the labor force looking for a more flexible and lucrative workplace. The monthly PMI manufacturing index remains 20% above its growth level despite all of these issues. Solving any one of these problems could drive even greater growth. Fixing all three could push growth to unimagined levels.
- The long-promised infrastructure bill has finally been passed, creating more than \$1 trillion in public sector spending and the likelihood of trillions more in private sector investment to take advantage of the rebuilding effort. And the rebuild itself, long overdue, will lead to further growth.
- The drive to a digital plant is accelerating. Major vendors and small start-ups are leading us to a truly connected process that can create a safer, smarter and more efficient workplace and a better finished product for consumers.

The key decision now to be made is whether to just hunker down and wait for the thaw, or to dig out and clear the way for a new season. While I understand that people want to see signs that things are warming up before increasing the manufacturing investment, it's also a mistake not to be better prepared to embrace the coming future.

This requires some faith, and that too has been a commodity in short supply. Yet history shows us that those who prepare now for growth will best be able to catch it the moment it arrives.

There is one other truth about Chicago's seasons—we often joke that there really are only two seasons—winter and road construction. After this winter, that old saw may become truer than ever. **md**



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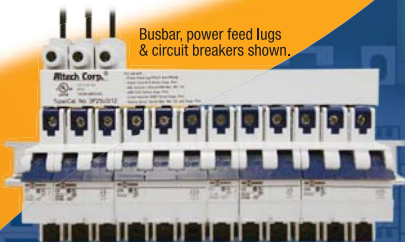
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## 2021 IDEA! CONFERENCE Wraps Up Two Days of Conferences and Exhibitors

THE IDEA CONFERENCE held two days of in-person sessions at the Huntington Convention Center in Cleveland, geared toward engineers and managers who want to leverage the latest trends and innovations to improve manufacturing operations.

If there was topic occupying the minds of conference attendees and exhibitors, it was the dysfunctional supply chain. Talk in the exhibition hall frequently touched on the current breakdown in the supply chain and the shortage of raw materials. Several sessions also focused on it, but presenters had little advice other than to establish and maintain good relations with suppliers and to be prepared for change.

The one prediction most people seemed to agree on, at least when it comes to chips and semiconductors, is that the shortage will likely last through 2022 and into 2023.

On the conference's first day, the IDEA! sessions got off to a great start with Billy Taylor, CEO, LinkedXK, talking about "Driving Excellence Through Diversity and Inclusion." It gave attendees some ideas on how to give a company a diverse

**The Industrial Design, Engineering & Automation Conference took a close look at the emerging trends and innovations in design and engineering targeted at manufacturing.**

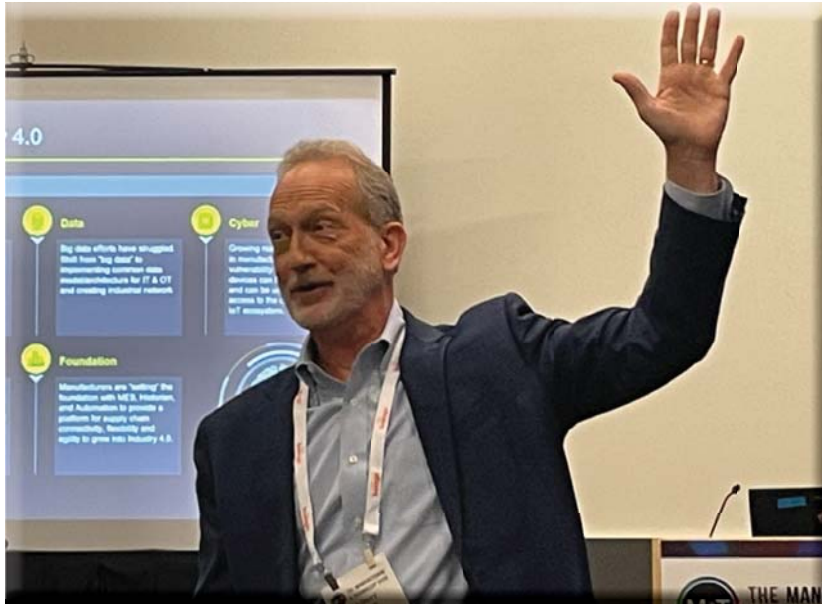
and inclusive culture that encourages communication and cooperation throughout the company. He cited the advantages of diversity and offered advice on how to get companies on the road to enlightened and profitable treatment of employees and in hiring practices.

Next up was Scott Dixon, director of Digital Manufacturing at EY, discussing the "Digital Transformation and the Factory of the Future." He explained how the Factory of the Future concept will help manufacturers prepare for the future changes, whether expected or not (like COVID), and achieving success despite those changes.

He also highlighted two major trends holding companies back from becoming a factory of the future: globalization—with manufacturing companies being worldwide, their employees and IT equipment need information and data on all the far-flung enterprises instantaneously; and demographics—the loss of corporate knowledge as Baby Boomers are retiring and being replaced by employees with different expectations on their careers and what they want from employers.

The third session, titled "Smart Linear Actuators – Another Value Proposition for Factory Automation" was delivered by Richard Vaughn, automation engineering manager for Bosch Rexroth Corp. It focused on mechatronics, the marriage of electrical and electronic technologies with mechanical components and assemblies for linear motion and automation. He pointed out how actuators are getting smarter and why that makes them even better value propositions for factory automation.

The sessions ended on Wednesday with Mo Abuali, a partner at IoTco LLC,



Scott Dixon, director of digital manufacturing, EY

talking about IoT and Industry 4.0 and how they are working “Toward Zero Downtime, Zero-Defect Manufacturing.” He gave attendees ideas and approaches for why to get involved in IoT/Industry 4.0 and how to get started. He also outlined why artificial intelligence (AI) and predictive analytics are competitively necessary for IoT and Industry 4.0. He gave a quick synopsis of several case histories of companies adopting innovative mechatronics and the rewards they reaped. His advice to companies looking to jump on the IoT/Industry 4.0 bandwagon: “Think big, act small and keep an eye on ROI.”

On Thursday, the day started with Aaron Lichtig, VP of marketing at Xometry talking about how to “Digitize Your Manufacturing Process to Stay Ahead of the Competition.” He also explained “manufacturing as a service” (MaaS), and how it can help companies succeed. In MaaS, a firm like Xometry acts as a networked middleman, connecting people and companies who want to have parts made but lack the equipment or expertise with shops that have the capability and capacity to make them.

The conferences wrapped up with Jeff Christensen, vice president of product,

Seegrid, explaining “The Keys to Building a Successful Supply Chain with Mobile Automation.” It gave attendees a look at how to define measurements of success metrics and to use data for generating a strong ROI today while preparing for tomorrow.

He also focused on one aspect of automation: electric vehicles that transported parts from one part of a factory to another. He noted that “Automation is hardly new, but it is very different from what it was 20 years ago. But the question for companies remains the same: Are you applying it in the right place?”

The IDEA Conference was held in conjunction with the Manufacturing and Technology Conference (M&T Conference) and the Safety Leadership Conference. The M&T conference was aimed at helping manufacturing executives improve their firm’s operational efficiencies and product quality despite the constant change. The Safety Leadership Conference was designed for safety leaders in manufacturing, construction,

distribution, transportation, utilities and other industrial sectors.

The 2021 winners of the *Machine Design/Hydraulics & Pneumatics* IDEA! Awards were announced and the new product deemed “most valuable” by readers, was the Branson GMX 20DP. The ultrasonic spot welder has a durable, reliable mechanical design and can monitor its own performance in creating precise welds on thin, fragile nonferrous foils and films. This will make it useful for making lighter, more “energy-dense” battery cells and packs that deliver more power per pound. [mcl](#)

Automation is hardly new, but it is very different from what it was 20 years ago. But the question for companies remains the same: Are you applying it in the right place?”



Jeff Christensen, vice president of product, Seegrid

## HARVESTING RARE-EARTH METALS from Coal Ash

**MATERIAL SCIENTISTS** at Sandia National Laboratory have discovered a way to use citric acid, a harmless food-grade compound found naturally in citrus fruits (especially lemons and limes), along with carbon dioxide and water, to extract rare-earth metals from coal ash. This eliminates some of the coal ash, a residue of coal-fired power, without harming the environment while providing a stream of an important national resource.

The method, if widely adopted, could make coal ash, currently an environmental pariah, into a commercially viable product, says Guangping Xu, lead Sandia researcher on the project.

The most common acids used as chemical separators in mining—nitric, sulfuric and phosphoric acids—can extract rare-earth metals from coal ash but they generate large amounts of acidic waste, leaving the environment in worse shape than before. “These environmentally harmful acids would raise clean-up costs beyond economic feasibility in the U.S.,” says Xu.

The Sandia process uses citric acid as a carrier for rare-earth metals so they separate from coal ash, the host material. Extraction is helped along by using supercritical carbon dioxide as a solvent. The citric acid is an environmentally friendly way to hold the rare earth metals in solution.

The team found that in less than a day, an extraction process running at 158°F (70°C) and pressure at 1,100 psi (about 70 times ordinary atmospheric pressure) could remove and recover 42% of the rare-earth metals in the coal ash.

“Theoretically, an American company could use this technique to mine coal and coal byproducts for rare-earth metals and compete with Chinese mining,” says Xu. Furthermore, for U.S. national security purposes, “it is probably reasonable to have alternate sources of rare-earth metals to avoid being at the mercy of a foreign supply.”

Detoxifying coal ash for reuse alone should be worth the effort, Xu says. There’s no shortage of coal ash as a raw material. According to a 2016 study, approximately 115 million metric tons of coal combustion products are generated annually, and this includes 45 million tons of fly ash, the lightest kind of coal ash.

This technology could open a new avenue for reusing and sequestering carbon-dioxide. The team is looking into using citric acid and supercritical carbon dioxide to mine metals from oil and gas shales that are often rich in metals.

Using existing oil and gas fracking wells, citric acid and supercritical carbon dioxide can cost-effectively mine metals while disposing of the carbon dioxide underground. Subsurface storage of the carbon dioxide should keep it from entering the atmosphere and contributing to climate change. ■



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# Facing the Future

Experience and technology are key factors in *Salary & Career Survey* optimism.

**T**he future of engineering in particular and manufacturing in general has reached a crossroads. Impacted by global economic challenges, supply chain disruptions and worker shortages, manufacturing also has faced an explosion of technology that has replaced or augmented some jobs with robotics and automation.

Yet engineers who participated in the 2021 *Machine Design Salary & Career Survey* were generally optimistic about their profession's short-term benefits and longer-term future. As one respondent put it, "Engineering is not for everyone, but for someone with strong technical interests it can be very rewarding. With all the available jobs, a young candidate can "test the waters" in a couple different fields before settling on a long-term path."

Image courtesy of OSTILL #177849476 | iStock/Getty Images Plus



Another took a more pragmatic approach to the opportunities available in engineering. “[It’s a] great field that is constantly growing. If you want to travel with your job, you can. If you want to stay home with almost no travel, you can,” he wrote. “There are lots of opportunities to either develop new tech or adapt the new tech to current problems or issues. And with the shortage of labor, engineers are always needed to help automate things to make better use of the few employees that choose to still go to work.”

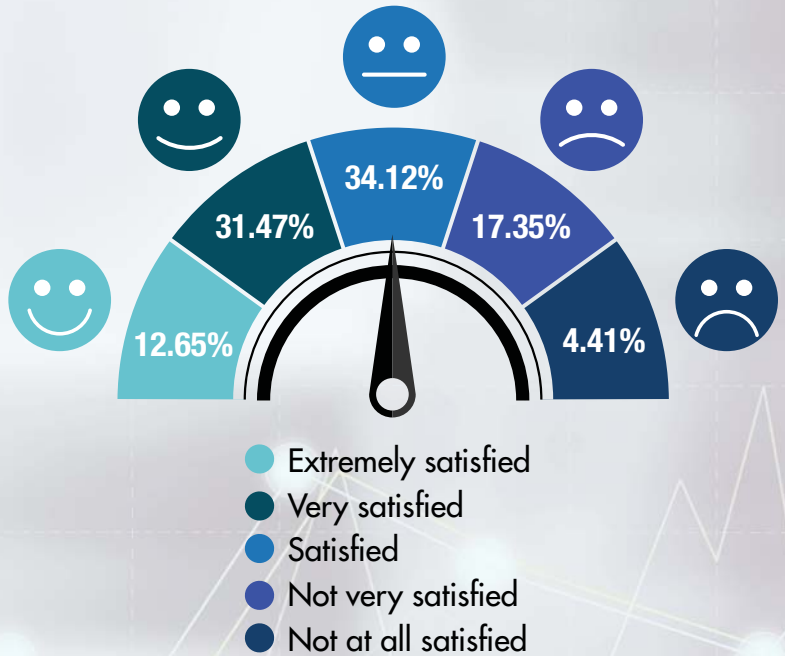
The engineers who responded to this year’s survey come from a variety of disciplines. The majority of this group either are design or project engineers, have project management responsibilities or head up research and development. About 7% of respondents are in executive management.

Regardless of job title, the last two years have been enormously challenging for everyone. Yet engineers remain positive about their profession and its value to themselves, and to society as a whole. Regardless of their field, level of experience or compensation, engineers surveyed are satisfied with their present profession and optimistic about its future.

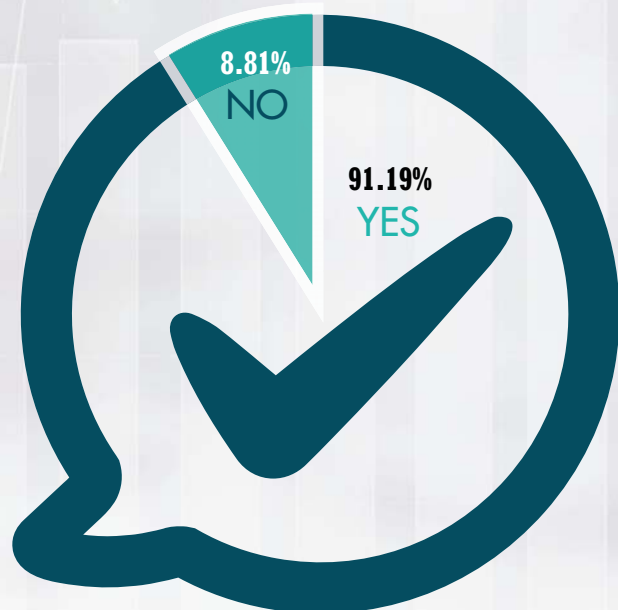
**The Impact of COVID**

12% of the group have changed jobs in the last year, and while 27.5% of those changes were promotions, and 15% were

**How satisfied are you in your current position?**



**Would you recommend engineering as a career path to a young person looking to choose a profession?**



due to COVID layoffs or other job reductions, 32.5% left to pursue other opportunities. About two-thirds of respondents said their company is as focused on employee retention as they were a year ago.

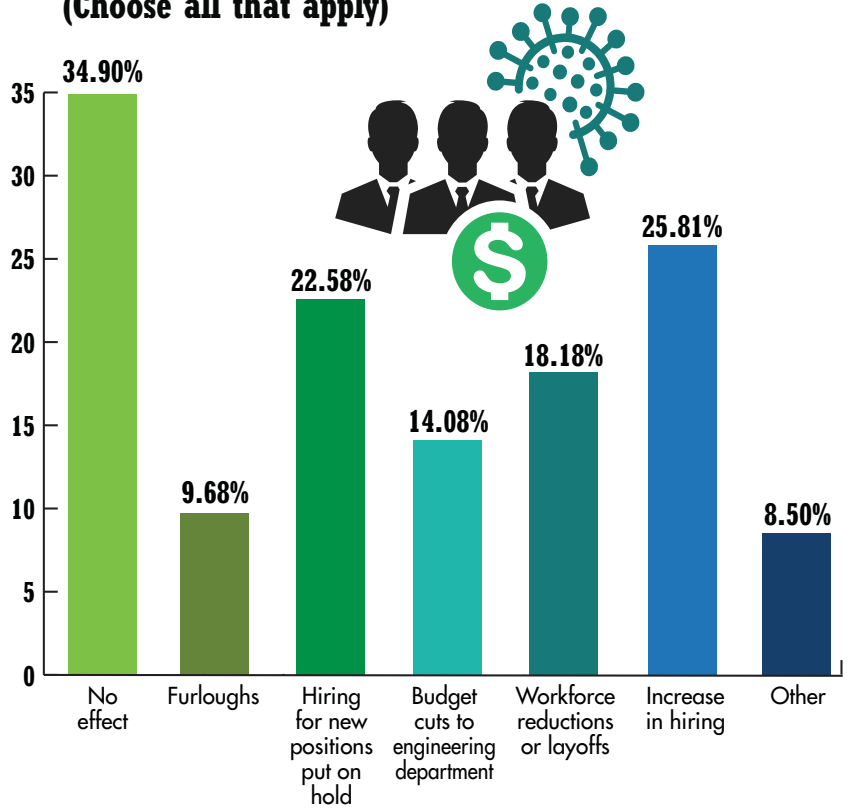
36% don't work from home at all, while 31% work from home due to COVID restrictions and another 8% will remain working from home after COVID, compared with just under 8% that worked from home before COVID.

The COVID impact has been widespread:

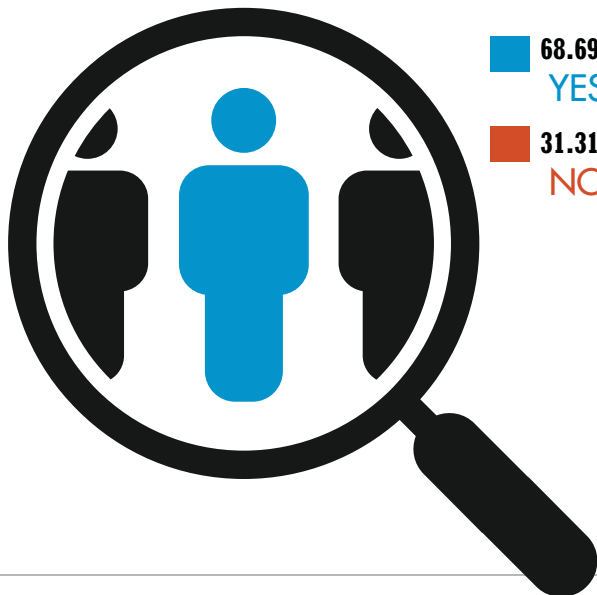
- 40% of respondents faced a corporate ban on travel
- 28.5% had a work-from-home mandate, compared with just 8.7% with a work-from-office mandate
- 67.2% were required to wear masks while at work.

The pandemic also had an impact on hiring and job retention—in both directions. There were job cuts for 18% of respondents, 9.6% experienced furloughs and 14% saw cuts in engineering department budgets. And while 22.5% saw a freeze on new manufacturing hires,

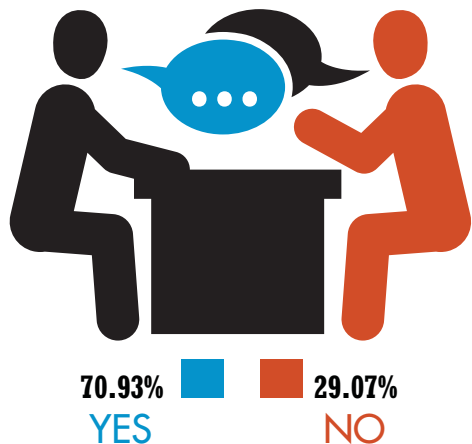
### How has COVID-19 continued to impact hiring and budgeting at your company? (Choose all that apply)



### Do you believe there is an engineer shortage?



### Is your organization having difficulty finding qualified candidates for open engineering positions?





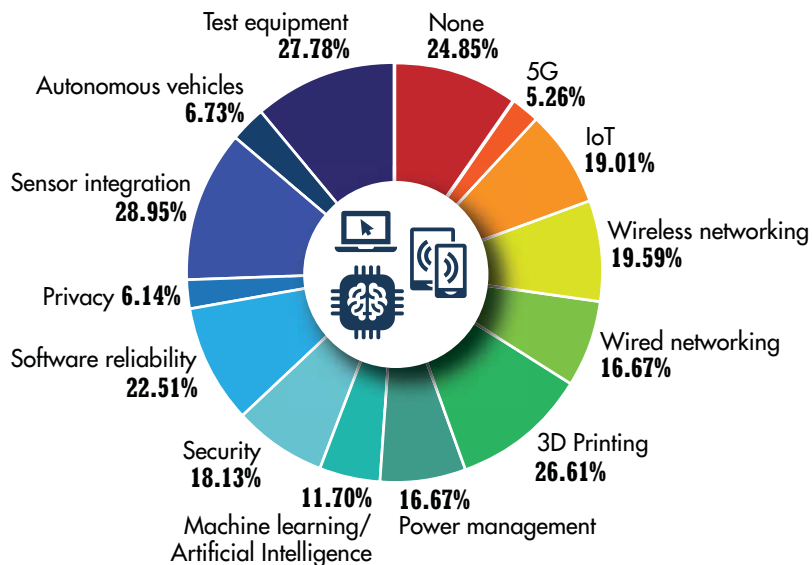
26% saw an increase in hiring. In 2022, 43% of respondents said their company was looking to increase hiring, while 50.5% said staffing would remain at current levels.

The use of online tools also increased—while email, phone and messaging were all primary tools, 82% used video conferencing, 41.3% employed scheduling and planning tools, 38.4% used cloud-based document management and another 15% used an industry-specific collaboration tool. Collaboration in its most basic form has changed as well. While 30% attended conferences through virtual event platforms, 31% were prohibited from attending events in person and 41.5% faced corporate travel bans and 48% were allowed a hybrid home/work option.

### The Role of Technology

Technology played a major role in helping manufacturers stay connected in the throes of the pandemic, and but widespread use of technology on the plant floor remains a future project. While technologies such as the Internet of Things (IoT) are used in 18.9% of facilities, 19.5% employ wireless technology and 18% use

## Which of these technologies have a major impact on your designs? (Choose all that apply)

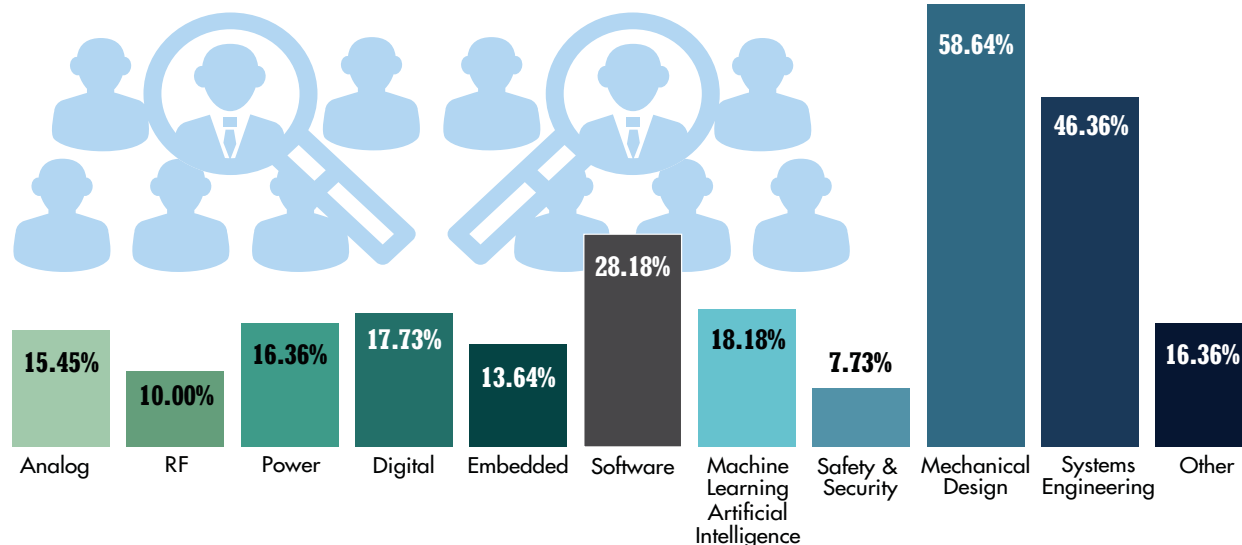


some form of security, a full one-quarter of respondents use none of the technology advances of the last decade. One encouraging sign: 26.5% of respondents mentioned 3D printing, the largest single area cited in the survey.

Technology advancements are being

embraced in some areas of the profession. “If you can find the right company and right attitude of employer, engineering can be an amazing career path simply due to the huge variety of possibilities, and now the speed of innovation is greater than ever,” one respondent wrote.

## For which engineering specialties are you having difficulty finding qualified candidates?



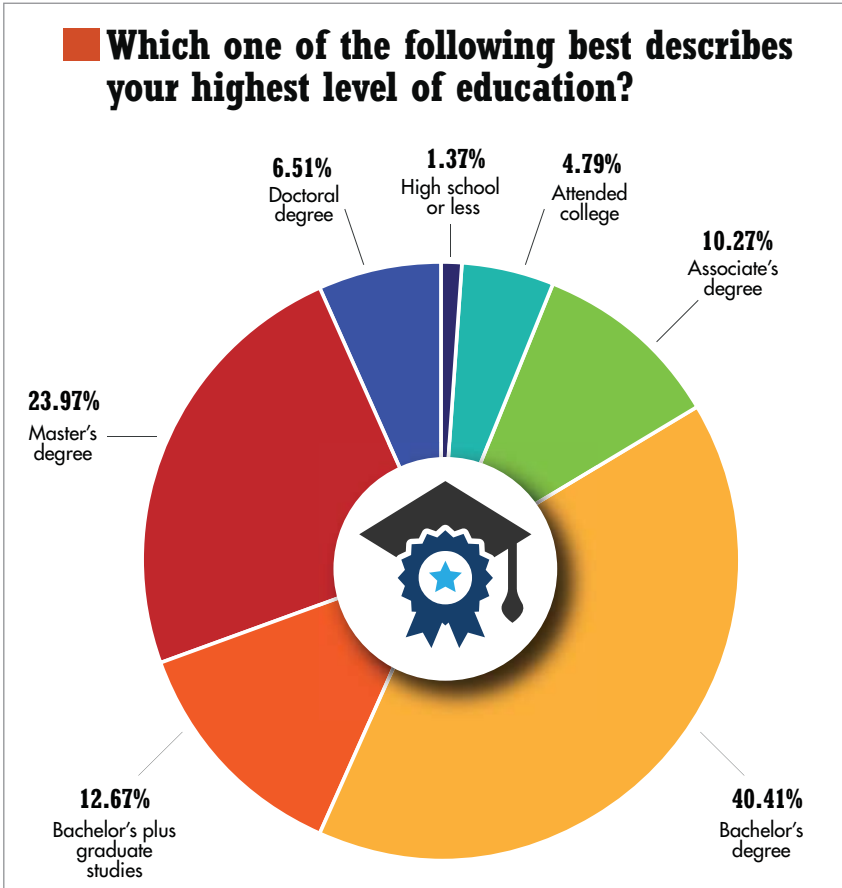
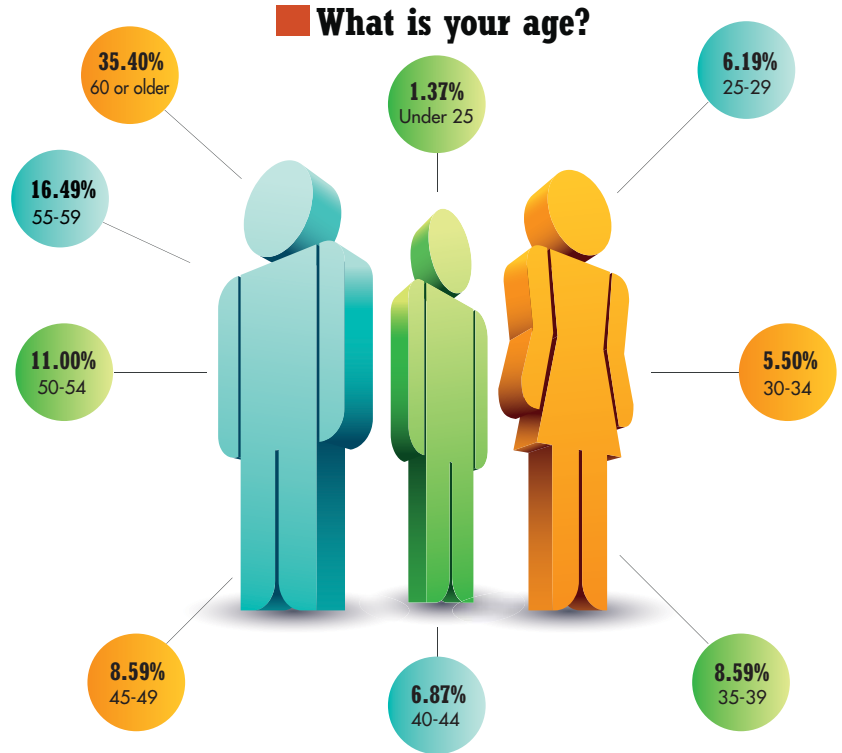
**“If you can find the right company and right attitude of employer, engineering can be an amazing career path simply due to the huge variety of possibilities, and now the speed of innovation is greater than ever.”**

**Present Experience, Future Opportunities**

The *Machine Design* audience is experienced—62% of respondents have been in engineering at least 20 years, and 28% have been in the field more than 35 years. There are 62% of respondents over the age of 50, and 35.7% are above the age of 60. They also are well-educated, with 84% having earned at least a bachelor’s degree, and 23.7% earning a master’s degree. They also remain bullish on the industry—almost three-quarters of respondents say the future for engineering is as promising as it was five years ago, and 90% recommend engineering as a career path for a young person.

That recommendation carries with it the reality of a shortage of engineers, particularly with so many engineers nearing retirement age. The current disconnect between unemployed workers and job openings is especially chronic in manufacturing and engineering, and 68% of respondents said they believe there is a shortage of engineers, while 70.5% said their company is having difficulty finding engineers for open positions. Positions for systems engineers (46.6%) and mechanical design (58.4%) are in particularly short supply.

“The baby boomer generation is due to start retiring en masse,” noted one respondent. “Without a steady sup-



“The baby boomer generation is due to start retiring en masse. Without a steady supply of new, young engineers to replace the retirees, the profession will face an employment crisis.”

ply of new, young engineers to replace the retirees, the profession will face an employment crisis.”

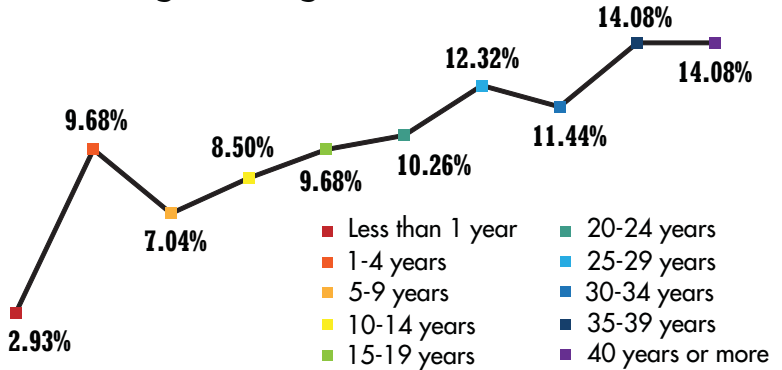
One area that does challenge the current engineering base is their workload. Of those who would consider leaving the profession, 37% said there was no further room for advancement, while 42% cited stress and 37.7% said burnout as contributing factors. Still, 50% said they'd leave just to try something different, 40% would leave to do something more fulfilling and 39.2% would consider a change to make more money.

While COVID was cited by about 15% of respondents as contributing to their stress, other business-related areas garnered far more attention. Issues such as product deadlines, the availability of components, product quality and reliability and price and performance were far greater issues for engineers.

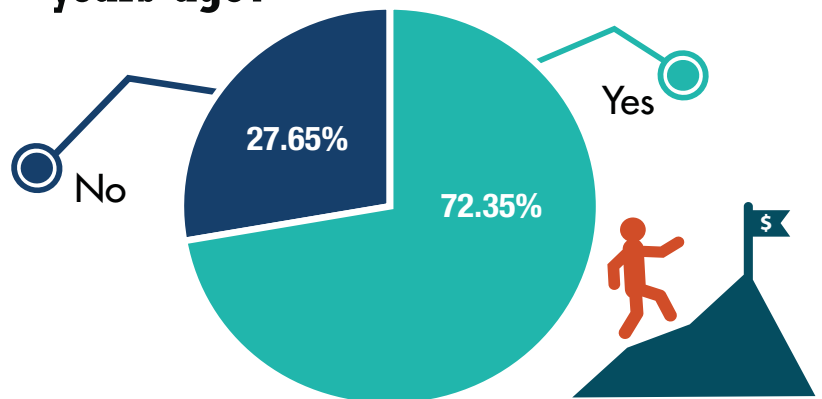
### Salary And Satisfaction

The issue of job satisfaction did have a dollar sign attached to it—more than 80% said their pay was an important, if not critical consideration. The job challenges—areas such as finding the best designs, seeing those designs reach their potential, the collaborative nature of design and the recognition of their work by company management and customers all were significant factors in job satisfaction—all garnered significant support as well, and the opportunity to design products that can benefit society held almost the same level of importance as salary to

### Approximately how long have you worked in engineering?



### Do you believe that a career path in engineering and the potential for salary advancement is as promising today as it was five years ago?



the respondents. As one respondent put it, “Engineering allows a person to grow personally and professionally while being challenged to make a difference to society in general.”

Their views on future employment appear to be evenly divided. While 11.5% are actively seeking new employment, 28.4% said they had no immediate plans to change jobs. The group in the middle also were evenly split—31.2% would respond to an interesting opportunity they heard about, while another 28.7% indicate they

would respond if recruited for such an opportunity.

The compensation levels tend to reflect the level of experience of the *Machine Design* audience respondents. While there are outliers at both ends of the salary spectrum, the general salary compensation range is between \$70,000 and \$200,000 a year. The largest percentage range was between \$100,000 and \$125,000, with 29.7% reporting salaries in that range. There were 31% reporting salaries in the range from \$125,000 to \$200,000 and

22.3% between \$70,000 and \$100,000. Their satisfaction with that compensation is also relatively high—59% rate it as at least competitive with others in the profession, and 61.3% consider themselves adequately compensated.

Other compensation and benefits areas included:

- Stock or stock options—76.7% reported no such benefit
- Bonuses—while 26.5% reported no bonus plan, 34.5% reported a bonus program of at least \$5,000, and 18% reported a bonus plan above \$10,000. The bonuses are primarily based on personal performance and the performance of the company or division.

Respondents are expecting their compensation to increase in 2022—31.8% see an increase of at least 4%, and 63% see some sort of increase for the year. Just 8.5% are projecting a salary decrease.

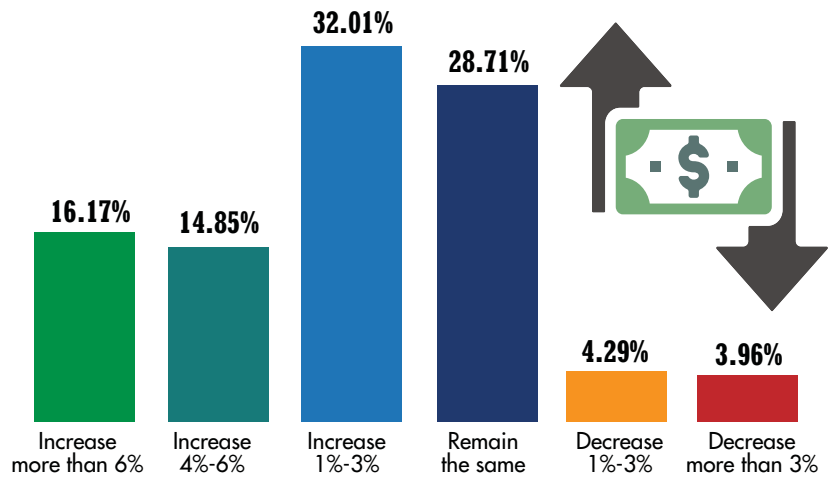
The majority of respondents (53%) said there was no change in compensation, with 14.5% reporting a freeze on raises and 11% noting that bonuses were can-

celled. Overall, 18.9% reported a salary increase and 5.8% said there was a salary decrease.

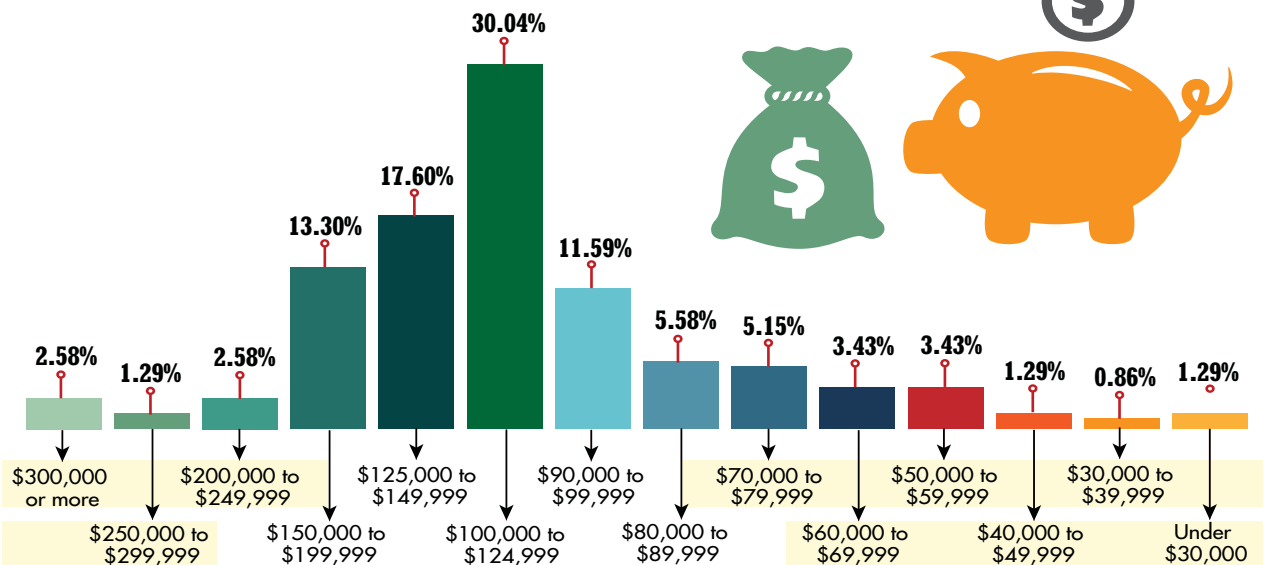
But while compensation is a measuring stick for job satisfaction, it is not what drives many of the *Salary & Career Survey* respondents. “I compare engineering to

art,” one engineer wrote. “I get to create masterpieces that solve a problem or provide a service. I have designed and built machines and process for many years. It is the act of creation, just like art. At the end of the day, one can look back and say, ‘I did that.’” [me](#)

### How will your total 2021 compensation (salary, bonuses, etc.) compare to what you earned in 2020?



### What do you expect your total compensation to be in 2021? (Base Salary)



# Engineering Your Career, Part 1: Challenges Facing the Profession

To determine the future of engineering, let's first take a look at the current role of professional engineers.

Pavel Shiykov 195353446/Dreamstime



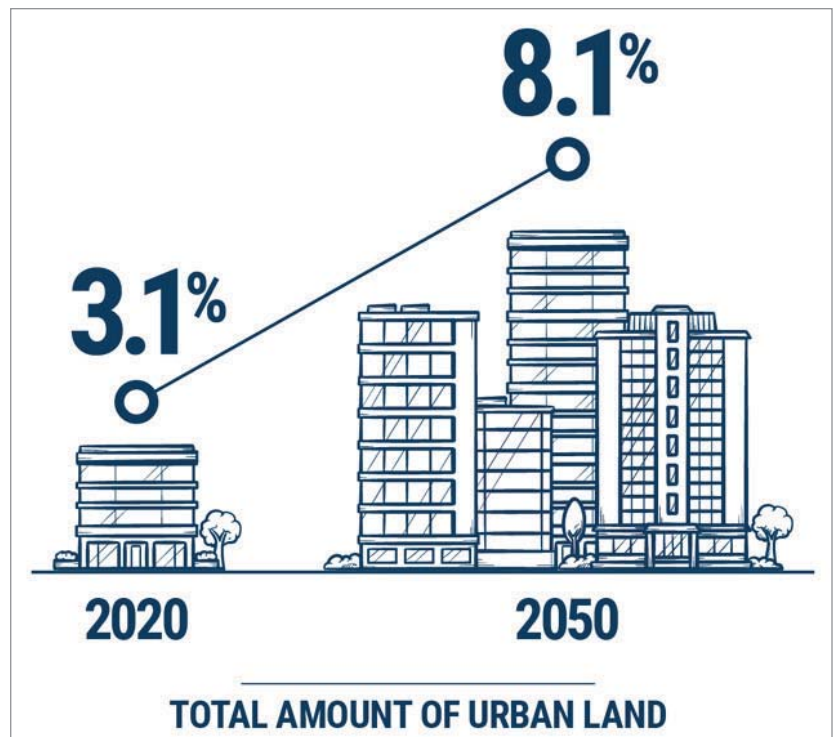
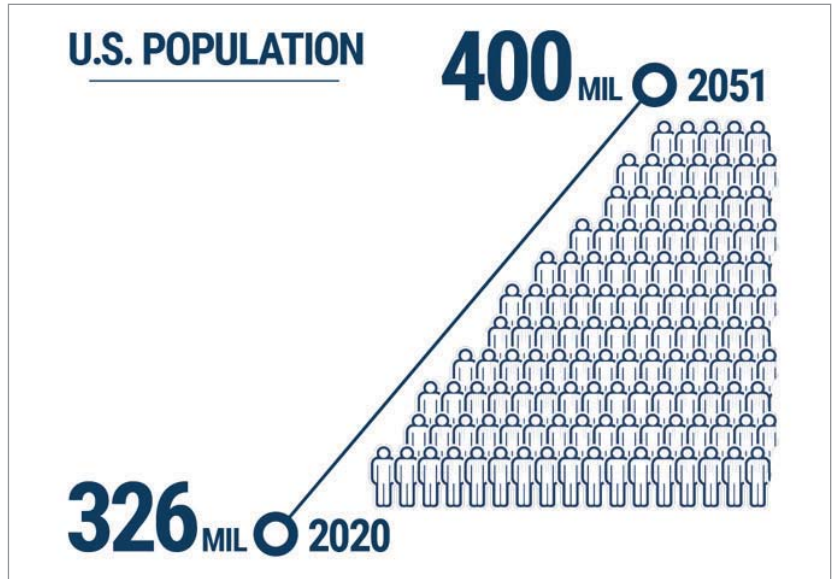
Engineering entails solving societies' real-world problems using machines, systems, materials and processes. There are many different engineering disciplines and diverse specializations, but all involve solving problems for people and therefore they all inherently affect society.

This means licensed professional engineers are ethically obliged to hold paramount the health, safety and welfare of the public. Although our country and the world looked different in 1946 when the National Society of Professional Engineers (NSPE) endorsed its first code of ethics, engineers' obligation to the public has become more important than ever as the infrastructure and technology around us become ever more complex.

As the world rapidly changes, the problem-solving skills that are foundational to engineering are needed now more than ever. Here are just a few trends that may alter our profession.

## Population Growth and Urbanization

According to census data, the U.S. population is projected to grow from 326 million to 400 million between 2020 and 2051. Plus, over the last several decades, there



has been a consistent shift of population from rural to urban areas. Although the COVID-19 pandemic may have forced people to work from home and seek out more rural settings, which slowed migration into the cities, urbanization is likely to continue. In fact, 2020 data shows about 57 million people living in rural U.S. and 273 million people in urban areas.

And cities are growing in size, as well. It's predicted the total amount of urban land will climb from 3.1% of all the land in the U.S. in 2000 to 8.1% in 2050 and encompass an area larger than Montana. By 2050, more than half of some states (e.g., Rhode Island, New Jersey, Massachusetts and Connecticut) are projected to be urban land. Meanwhile, U.S. forested land that equals the size of Pennsylvania will be bulldozed into city land between 2000 and 2050. If these projections bear out, professional engineers will likely be called on to improve the aging and undersized infrastructure in urban cores as well as

expand the infrastructure to accommodate sprawling suburbs.

### Aging Population

In the U.S., the population is growing older, which creates challenges for engineers. For example, the decline in the number of working-age people means a smaller supply of qualified workers, making it difficult for businesses to fill in-demand jobs. An economy that cannot fill these in-demand occupations faces harmful consequences, including declining productivity, higher labor costs, slower business expansion and reduced international competitiveness.

Other concerns include the rise in healthcare costs and the growing need for healthcare that increases with age. Countries with rapidly aging populations must devote more money and resources to healthcare. And with healthcare spending as a share of gross domestic product already high in most advanced econo-

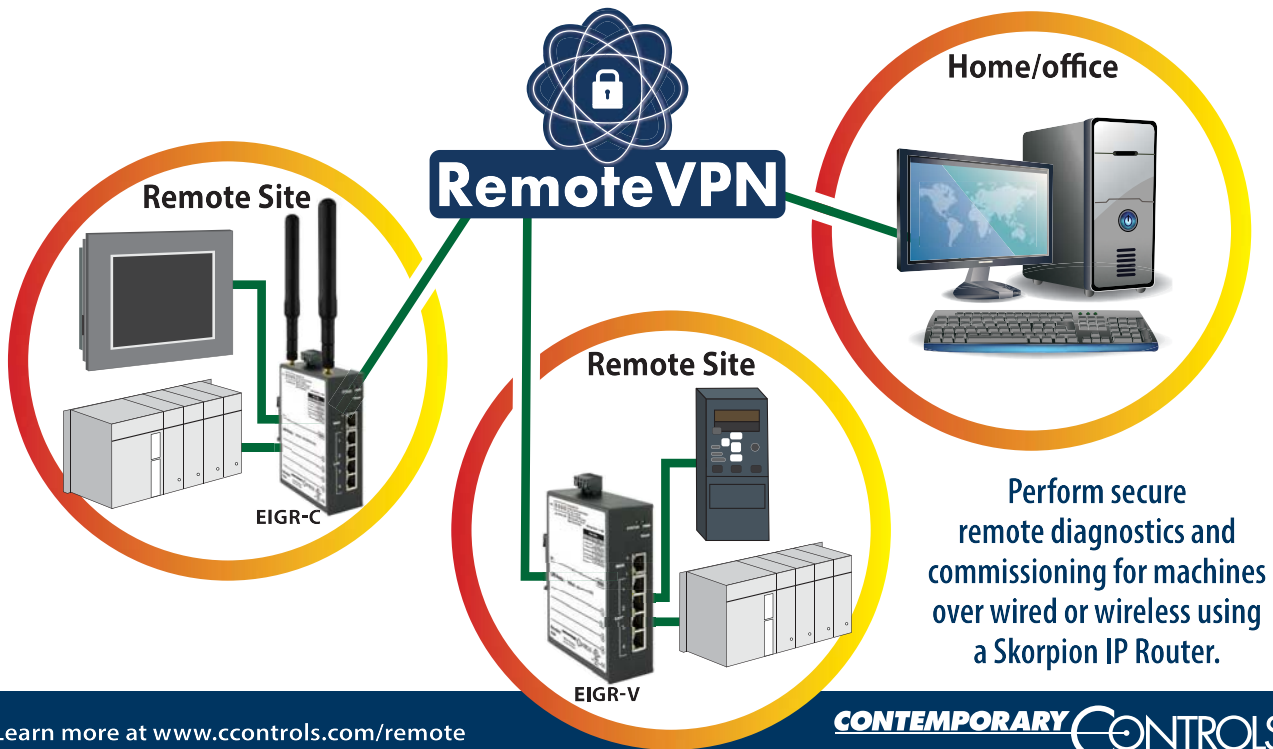
mies, it is difficult to increase spending and ensure care improves.

Countries with large elderly populations must also rely on smaller pools of workers to pay taxes for higher health costs, pension benefits and other publicly funded programs. This is becoming common in advanced economies in which retirees live on fixed incomes that place them in lower tax brackets than active workers. The combination of lower tax revenues and higher spending commitments is a major concern for advanced industrialized nations.

### 2020: Pandemic and Social Upheaval

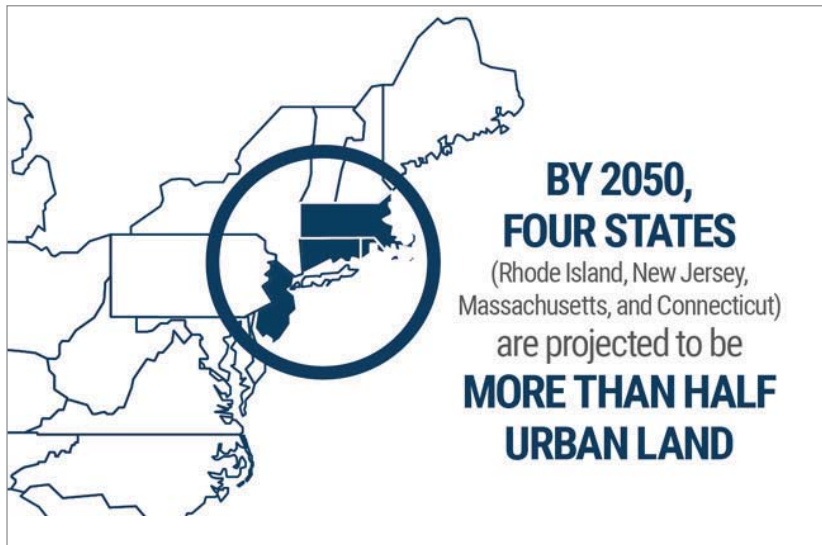
It is apparent that although the pandemic did not necessarily create change, it has certainly accelerated it. For example, although working across international borders has become more common than in previous decades and national economies more interdepen-

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dent, the pandemic-spawned “work from home” or “work from anywhere” movement shrunk the world even more. Businesses that once operated in just a few states have employees living all over the U.S., which has business implications. Additionally, clients no longer seem to put as much value on being “close” to their vendors if work is getting done on time and meets quality expectations. It is unknown if this attitude change will persist, but a reversal to pre-COVID times is highly unlikely.

While not associated with the pandemic, 2020 also brought an increased focus on social and racial injustice in the U.S. It is now a business imperative for all companies and organizations to focus efforts on diversity, equity and inclusion (DEI). Potential employees will decide to join a company base not only on compensation and benefits, but also on the firm’s culture and DEI efforts.

### Workforce Pipeline

The aging population presents engineering challenges and opportunities related to the workforce pipeline. In the U.S., 10,000 Baby Boomers turn 65 every day, and the 65-and-over population will nearly double over the next three decades. Nearly 19,000 engineers, many still working, will turn 69 each year for the next 15 years.

Many companies and organizations have been preparing for this situation. However, have they prepared well enough? Have they thought of all the ramifications and taken action to address the issues? We are at risk of losing critical history and knowledge. No matter the organization, everyone is feeling the effects of the aging engineering population and the knowledge gap.

A focus on workplace diversity seems a logical step in solving the workforce pipeline challenges. Filling the void created by retiring Baby Boomers will require a more diverse pipeline and retaining women and minorities in the profession. For years, the number of female graduates has increased to as much as 50% in fields such as environmental engineering. Challenges persist, however, in retaining these women in engineering as their careers develop. Engineering leaders need to address the issue of inclusion within engineering to keep up with future demands.

### Emerging Fields

There is no doubt industry will develop and implement new and better technologies, often at breakneck speeds. Although new technologies are not inherently bad, they should be developed so that they protect public health, safety, and welfare. Professional engineers must play significant roles in developing new products and

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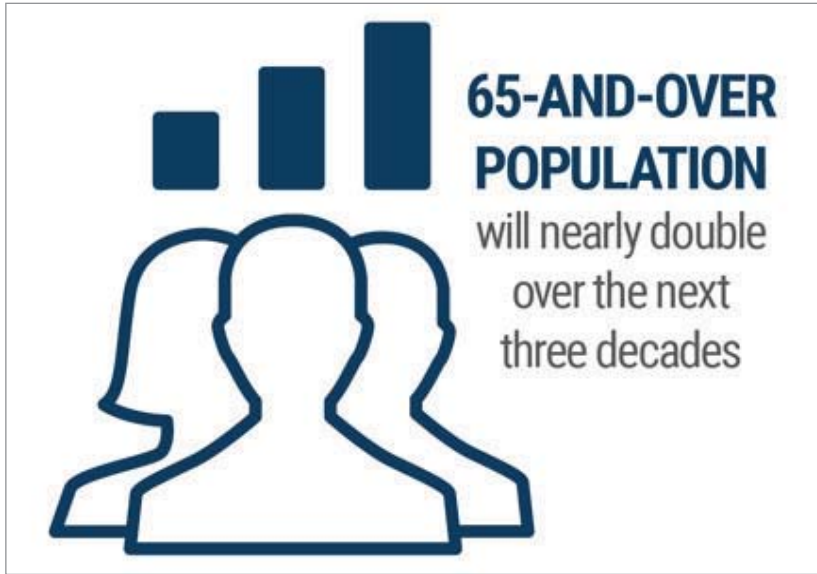
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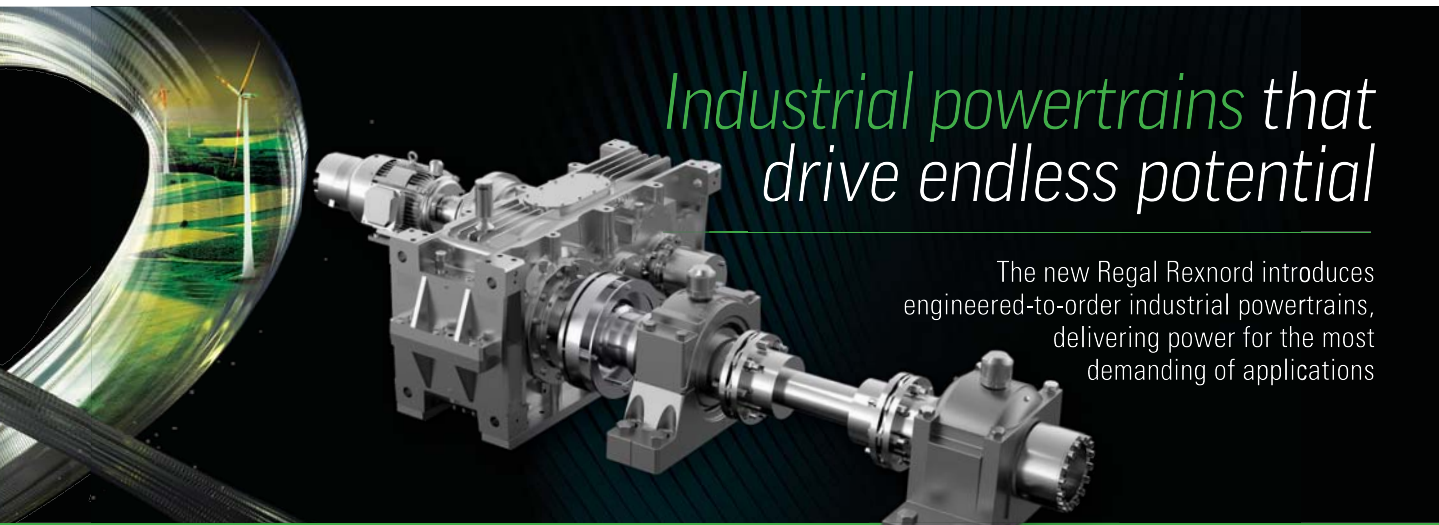
As technology advances, there should be caution regarding complex software that shifts routine engineering tasks

from engineers onto technicians or even end-users. When products are designed and built with minimal human involvement—perhaps without even a professional engineer—the public can be put

at risk. Although it's easy to discount the role of humans as technology does more "thinking and creating," engineers must embrace this change while continuing to protect the public.

**Climate Change**

Engineers will also play key roles in addressing climate change by reducing the contributing effects or mitigating the repercussions of climate changes on the infrastructure and natural resources. The NSPE's *2020 Engineering Outlook & Salary Survey* shows that respondents younger than 25 believe engineers must actively engage on this issue. They are eager to solve climate challenges. And engineers will need to innovate and create new models, products and services to reduce climate effects. They will need to revise standards and develop design processes that protect people and resources. Maybe most importantly, engineers will need a seat at the table with decision-makers



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to offer expert advice on avoiding and reducing risks.

### Engineering Licensure

As discussed, the world is changing, which brings challenges and opportunities. Changes are happening in education, regulation, public opinion and technology, all of which affect PE licensing. As the future unfolds, it is important to remember that engineers are stewards of technology, the natural and built environments, and public health, safety, and welfare. PE licensing, however, was not created to readily support the vital role of engineers in these times.

Professional engineering licensing started during the second industrial revolution, with the first state license issued in Wyoming in 1907. NSPE was formed in 1935 with the goal of spreading licensing across the U.S., a goal achieved during the third industrial revolution.

Now the world is in the fourth Indus-

trial Revolution; has PE licensing kept up to date? For example, consider software engineering. While the number of (and the need for) software engineers grow, the number of candidates seeking PE examination in that field dropped so low the exam was recently eliminated. This prevents software engineers from obtaining a PE license. With technological advances transforming how engineers work and interact, engineering licensure must be transformed.

Although governments have traditionally shaped the societal effects of new technologies, they struggle to keep up with the rapid change, making engineers' professional judgment even more important.

Although most engineers are responsible for activities that affect public health, safety and welfare, there are exemptions to state PE licensing laws that let certain individuals and organizations perform engineering services outside the licensing

system. Exempt individuals and organizations are not subject to the same legal and ethical requirements as those with PE licenses. These exemptions undermine the purpose of engineering licensing and risks leaving the public in danger of receiving services from individuals without the qualifications for making engineering decisions that adequately protect public health, safety and welfare.

For the engineering profession, moving into the 2020s and beyond comes with exciting opportunities and daunting challenges. But history is filled with examples in which engineers rose to meet great challenges and seize new opportunities. I am confident professional engineers are up to the task today. **md**

THIS IS THE FIRST of a four-part series on how engineers must adapt in these changing times. Part II covers PE licensing, Part III covers personal and professional development, and Part IV looks at risk taking.

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## Mechanical & Motion Systems

DAVE CHRISTIAN | Research and Development Engineering Manager, Brenton Engineering

JESSE TINTES | Industry Segment Sales Engineer, End of Line Packaging, Brenton Engineering

# Time to Market a Key In Make or Buy Decisions

A Brenton-Festo collaboration finds a faster specification solution.

If Brenton Engineering had adhered to traditional outsourcing decision-making, the company may have obtained the outsourced component it wanted, but not the one it needed for improving competitiveness. Instead of make-versus-buy calculations based primarily on cost and risk for outsourcing a highly engineered component, Brenton added considerations of higher overall engineering and fabrication productivity, along with faster time to market, for both quotations on new machines and manufacture of sold units. The results proved advantageous across the board.

### Outsourcing Toothed Belt Slides

Brenton is one of North America's leading case packing and palletizing original equipment manufacturers through its Pro-Mach brand, and its M2000 is the company's top selling side-load case packer. Known for its short installation time and intuitive operation, the M2000 also offers high OEE through fast, accurate changeover. This 35 case-per-minute unit packs products in wrap around, knock down and regular slotted cases, as well as trays.

M2000 case packers can support up to three toothed belt linear slide systems—a cantilevered Y and Z axes system for load-

ing cases, a single Y axis for gluing case flaps, and cantilevered Y and Z axes for tamping down flaps after gluing. These slides must be fast, accurate and rigid for long life and high performance under 24/7 operation.

Each slide may have up to 70 different components, 40 of which are manufactured by Brenton. Some of the components are sent out for anodizing, adding time to the manufacturing process. The high number of linear slides required each year, the number of individual parts and time for assembly made linear slides candidates for outsourcing.

**Brenton explored linear axis make-versus-buy decisions for its top selling M2000 case packer, shown here. Nine months of testing showed buying linear axes for all the right reasons pays off.**  
*Brenton Engineering*



A traditional decision-making process would weigh the following:

#### **Manufacture**

- Production cost
- Extra labor cost
- Monitoring cost
- Storage requirement cost
- Waste product disposal cost

#### **Buy**

- Product purchase price
- Sales tax
- Shipping
- Inventory holding cost
- Ordering cost

Another traditional way to decide on outsourcing slides would be to weigh benefits against risks:

#### **Benefits**

- Cost savings
- Quality
- Supplier has advanced skills
- Focus on key competencies

#### **Risks**

- Lack of control
- Quality
- Loss of intellectual property
- Loss of flexibility and responsiveness
- Pricing

These traditional concerns do not mention time, nor is engineering overhead designated as a consideration. The reason that time to market and engineering productivity entered the equation for Brenton is that each M2000 is customized to meet unique package and long-term production requirements. For example, Y/Z axes may be loading packages of identical dimension but with significantly different weights and production speeds, so the slides would be different in each machine.

Creating systems with either one or two axes also requires time and effort in terms of performing computations, providing drawings, formulating quotations and the back-and-forth of communication between OEM and supplier. Finding an outsource supplier offering slides that would stand up for years, and a supplier



**This cantilevered Y and Z axes system, center, pushes product into the wraparound case at the end of the slot. Brenton Engineering**

that could meet product engineering and manufacturing commitments in short timelines, were outsourcing hurdles.

#### **COVID-19 Issues Triggered a Change**

COVID-19 has given manufacturers new considerations. On the one hand, reduced density of workers on the shop floor lowers the risk of exposure to airborne virus contagion. On the other hand, customer demand is high, and more resources are needed to produce products. The answer seems to be to incorporate automation and/or outsource where it makes sense to lower the internal workload.

The other major problems manufacturers are wrestling with include rising supply chain costs and slower overall supply chain delivery. No respite is expected to either problem for the foreseeable future.

Labor and supply chain issues were top of mind when Brenton began exploring the option of outsourcing the linear slides. With 40 individual pieces to manufacture in-house and up to 30 to purchase, outsourcing looked like the strategy that would allow Brenton to reallocate scarce

labor resources and decrease time to market. Through outsourcing, Brenton wanted to accomplish the following:

- Free up the fabrication department for other work
- Lower labor across multiple departments
- Improve turnaround time both for quotations and for manufacturing new M2000s
- Lower hard and soft costs

#### **Engineering a Partnered Solution**

Over nine months, the team within the Brenton Research and Development Engineering Laboratory evaluated linear slides from multiple vendors. Festo, a preferred supplier to ProMach, provided Brenton with its EGC toothed belt linear slide for Y axis consideration. The EGC features speeds up to 10 m/s, acceleration of up to 50 m/s<sup>2</sup>, repetition accuracy of up to +0.08 mm, stroke lengths up to 8,500 mm and flexible motor mountings. Flexible motor mountings were important to Brenton as the company is standardized on Allen-Bradley servo motors.

Festo also supplied the lab with the ELCC cantilevered axis tooth belt slide

for Z axis consideration. The ELCC features high rigidity, small moving mass and vertical load capacity of up to 100 kg. While not a core product with 24-hour guaranteed shipping, this slide would still have assured availability.

Festo also assigned John Bauer, a packaging end-of-line application engineer, to support Brenton personnel during the testing and application stages.

Brenton personnel from many departments visited the research lab during the testing process to observe the comparative tests and then provide feedback based on their needs. The Festo slides proved to be superior in terms of product quality and rigidity.

**Faster Time to Market, Improved Engineering Productivity**

The research and development engineering lab staff then turned their evaluation to the critically important considerations of time and effort to acquire the

slides. Brenton looked at the flexibility and capacity of the supplier to provide many different configurations of slides relatively quickly and the complexity of ordering custom configured slides. Brenton evaluators looked into how fast 2D and 3D drawings could be delivered as well as how long it took to acquire quotations.

Reorder was another issue; if a custom slide had to be replaced, the teams looked at how difficult it would be to order a replacement part. For several suppliers, the time between order and receipt of drawings and a quotation were measured in weeks.

Using Festo's Handling Guide Online to order single and multiple axis slides takes an average of 20 minutes. The tool only required the engineer to plug in parameters and the software did the rest. No calculations are required of the engineer. At the end of each Handling Guide Online session, the engineer has a quote and 2D and 3D drawings ready

for download. This allows designers to work on the project while the slide is manufactured. Applications engineers preparing quotes have what they need in minutes.

Parameters that need to be entered into Handling Guide Online include:

- Axis type, including single or multiple, belt or screw drive, gantry or cantilevered
- Actuator orientation, horizontal or vertical
- Axis information, including tooling load, product weight, force required, stroke and repetition accuracy
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- Center of mass
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- Motors, drives and controls for Festo or customer supplied units



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Before the end of the Handling Guide Online demonstration, one Brenton Engineer opened a project and began

designing a slide. The implications of faster design freeing engineers for other duties excited the entire management and

lab team. The demonstration, plus the fact that the Festo slides were so robust, was a turning point in the evaluation.

Brenton engineers used Handling Guide Online to specify slides that were installed as test cases in a few M2000s. Brenton selected the Festo EGC for the Y axis and the ELCC for the Z-axis for the three areas on the M2000—case loading, applying glue to the case flaps and tamping the flaps down. Festo provides the axial motor mount kits for the Rockwell servo motors.

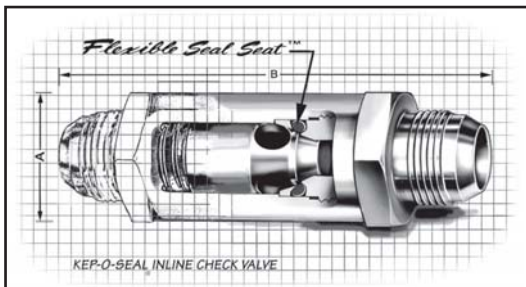
By outsourcing the slides, Brenton now handles eight components instead of 70 when assembling and installing slides, significantly decreasing fabrication and assembly time and cost. Due diligence in outsourcing paid off for this nine-month research and development effort. Brenton believes that outsourcing done with care and with a view to productivity and assured supply produces significant competitive advantages. 



A Festo EGC for the Y axis and the ELCC for the Z-axis move the gluing system over the case flaps. Brenton Engineering

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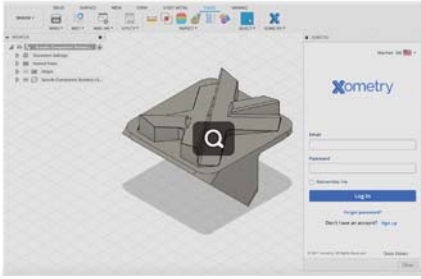
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## New Products

### New Autodesk Fusion App Improves Design Process



Version 2.0 of Xometry's app for Autodesk Fusion 360 can be downloaded directly from the Autodesk Fusion 360 App Store at <https://apps.autodesk.com/>. Updated with new features in addition to the instant price and lead time capabilities launched earlier in 2021, Version 2.0 now offers manufacturability feedback and multiple part upload features, improving processes for engineers and designers working in Autodesk. With manufacturability feedback, engineers and designers receive information on part manufacturability while they are designing in the Fusion 360 interface, allowing them to improve their designs.

**XOMETRY**, [www.xometry.com](http://www.xometry.com)

### RapidRinse Materials Dissolve Quickly in 3D Process

The RapidRinse and ABS-R materials are suited to print a range of industrial applications to specification, from manufacturing tools to production parts. RapidRinse is a fast-dissolving support material designed to eliminate cumbersome and costly post-processing procedures. RapidRinse easily dissolves in warm tap water and does not require caustic chemicals, typical for some soluble support materials. RapidRinse can dissolve significantly quicker than other high-temperature soluble support materials under the same conditions. Without the need for solvents, engineers no longer need to purchase additional post-processing equipment. RapidRinse's water soluble properties are intended to make it an easier and safer support material to work with, leaving behind minimal residue.

**MAKERBOT**, [www.makerbot.com](http://www.makerbot.com)



### CNC Retrofit Protects Older Windows Machines



FANUC America has an upgrade solution for legacy CNC machines running on operating systems older than Windows 10. The Panel i Replacement Program retrofits FANUC CNCs with an industrial PC available

with touch or non-touch LCD display, solid-state drives and Windows 10 IoT Enterprise. CNCs running on obsolete operating systems, such as Windows 7, XP or older, are no longer supported by Microsoft and therefore not receiving their critical updates. If machines connect to an online network, this can leave sensitive manufacturing equipment open to major cybersecurity breaches. Retrofitting industrial PCs on these machines allows businesses to safely and securely connect their CNCs to their network and take advantage of Industrial Internet of Things data.

**FANUC AMERICA**, [www.fanucamerica.com](http://www.fanucamerica.com)

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PRODUCT LENGTH cm		
CENTER OF GRAVITY µm		
ROTATION ANGLE deg		
NUMBER OF HINGES		
RESET CALCULATOR		

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- MH12
- MH14
- MH15
- PHB
- PHC
- PHCA
- PHCS

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## Stretch Hooder Offers Flexible, Small Footprint

The Multi FleX1 Electric stretch hooder features an electrically operated stretch frame; the machine frame movement is electrical, as well. Its overall smaller footprint, due to reduced safety-area fencing, means that the Multi FleX1 Electric can also maximize valuable production floor space and be placed closer to a facility's perimeter. The Multi FleX1 Electric shares the same powerful five-sided protection attributes as the traditional Multi FleX1. It has the ability to be fitted with several film rolls, allowing it to wrap multiple load sizes with greater variations quickly. The machine hosts a variety of film patterns, including fully closed hoods, film sleeves, short hoods and film reinforcement capabilities. The Multi Flex1 Electric is engineered for cubed loads, irregular loads with protrusions and varying product shapes, and is capable of wrapping more than 200 loads per hour.

**SIGNODE**, [www.signode.com](http://www.signode.com)



## Hydraulic Hose is Lighter, More Flexible

The Masais MXG 5K hydraulic hose is lighter, more flexible and more durable than a typical 5,000 psi (350 bar) hose. It has been tested to one million impulse cycles at 250°F (121°C), twice the legacy industry standard for spiral hoses. The new hose platform is 20% lighter, 25% more flexible and 5% more compact than legacy spiral hoses, improving the safety and ergonomics of hose installation while also enhancing the performance of machinery by reducing weight. MXG 5K also offers greater abrasion resistance and more than 800 hours of ozone resistance to minimize downtime related to environmental conditions.

**GATES**, [www.gates.com/mxg](http://www.gates.com/mxg)



## Applied Cobotics Integrates Robotics With Other Functions

Applied Cobotics aims to provide automation solutions by integrating collaborative robots (cobots), material lift systems, 3D printing and other automation technologies into manufacturing systems. Applied

Cobotics strives to implement collaborative cobots to perform tasks side-by-side with the human workforce, provide gripper options that offer greater flexibility in automation; create innovative systems such as the Automated Material Lift (AML) System for more efficient, lights-out manufacturing; and employ 3D printing to create jigs, prototypes, custom grippers and trays for parts set-up and queuing.

**PBC LINEAR**, [www.pbclinear.com](http://www.pbclinear.com)

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# Ultra-Cold Forging Makes Titanium Strong and Ductile

Controlling the grain size in nano-twinned titanium is key to the forging process.

**T**itanium is strong and light, with the highest strength-to-weight ratio of any metal. But giving it a good balance of strength and ductility is difficult and expensive. That's why titanium is used mostly in niche applications in select industries.

To get around this trade-off, researchers at the Lawrence Berkeley National Laboratory have developed a technique called cryo-forging. It manipulates titanium at ultra-low temperatures to create extra-strong nano-twinned titanium that does not lose its ductility.

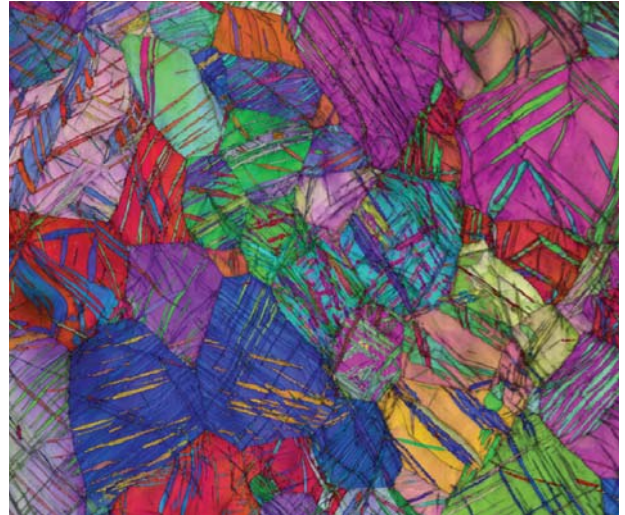
Nanotwins have an atomic arrangement in which the boundaries between grains line up symmetrically. This makes it easier for atoms in the crystalline structure to move around without building up stress while letting the metal retain its increased strength.

Nano-twinned materials are not new. However, making them typically requires specialized techniques that can be costly. These techniques work for some metals, such as copper, and are typically only used to make thin films. Thin-film properties are rarely found in bulk materials.

The mechanical properties of metals depend in part on their grains, small areas of crystals with repeating atomic patterns that form the material's internal structure. Boundaries between grains, where the pattern changes, strengthen the metal by preventing defects (dislocations) from moving across and weakening the material's structure.

One way to strengthen a metal is to forge it and shrink the size of its grains to create more boundaries. This forging compresses the metal at high temperatures or uses rolling and hammering at room temperature to compress it. However, forging to increase strength often comes at the expense of ductility; forging breaks up the internal structure, making it brittle and prone to fracturing.

To create nano-twinned titanium, the researchers used cryo-forging to manipulating the metal's structure at ultra-low temperatures. They started with a cube of 99.95% pure titanium which they submerged in liquid nitrogen at  $-321^{\circ}\text{F}$ . Force applied to all sides of the cube compresses it and nanotwin grain boundaries begin to form in the titanium. The cube is then heated to  $750^{\circ}\text{F}$  to remove any structural defects that may have formed between the grain boundaries.



Researchers used electron backscatter in electron microscopy to reveal the structure of pure titanium with a nano-twinned structure. Each color represents a specific grain orientation. The thin strips of nano-twinned titanium were made using a process called cryo-forging. *Andy Minor/Berkeley Lab*

The researchers put the newly formed version of titanium through several stress tests and used electron microscopes to see how the crystals reacted. They discovered that the nano-twinned titanium had better formability because it can create new nanotwin boundaries and undo previously formed ones, which let it resist deformation.

Tested to temperatures of  $1,112^{\circ}\text{F}$ , the material retained its structure and properties. And at super-cold temperatures, the metal withstood more strain than normal titanium, which is the opposite of what generally happens for most metals—i.e., at low temperatures, most materials become more brittle.

In the case of titanium, the researchers found that nano-twinning doubled the metal's strength and increased its ductility by 30% at room temperature. At super-low temperatures, the improvement was even more pronounced; the nano-twinned titanium could double in length before fracturing. It also retained its high-temperatures properties. So the nano-twinned titanium should perform equally well exposed to the extreme cold of outer space or the intense heat of a jet engine.

Fabricating nano-twinned titanium using cryo-forging is potentially cost-effective, scalable for commercial production and produces an easily recycled metal. The researchers plan to try the new forging process they developed for titanium on other metals. **md**

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