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When the CHIPS Were Down

Manufacturing Navigates the Semiconductor Crisis

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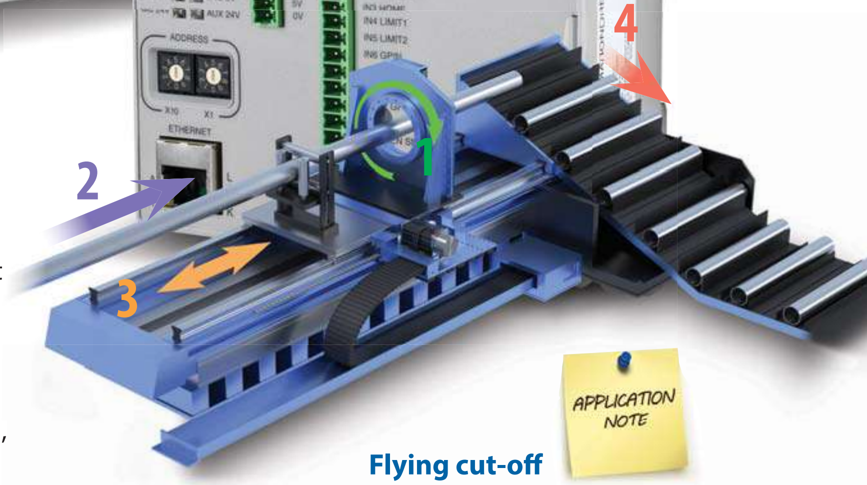

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INSIDE

MachineDesign.
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Volume 94, Issue 3

"The shift from designing based on first choice to designing based on first available for a prolonged period is a ripple effect from the overall shortages that could significantly impact the electronics industry."

COVER STORY

FEATURES

COLUMNS

DIGITAL EXTRAS

NEWS & NOTES

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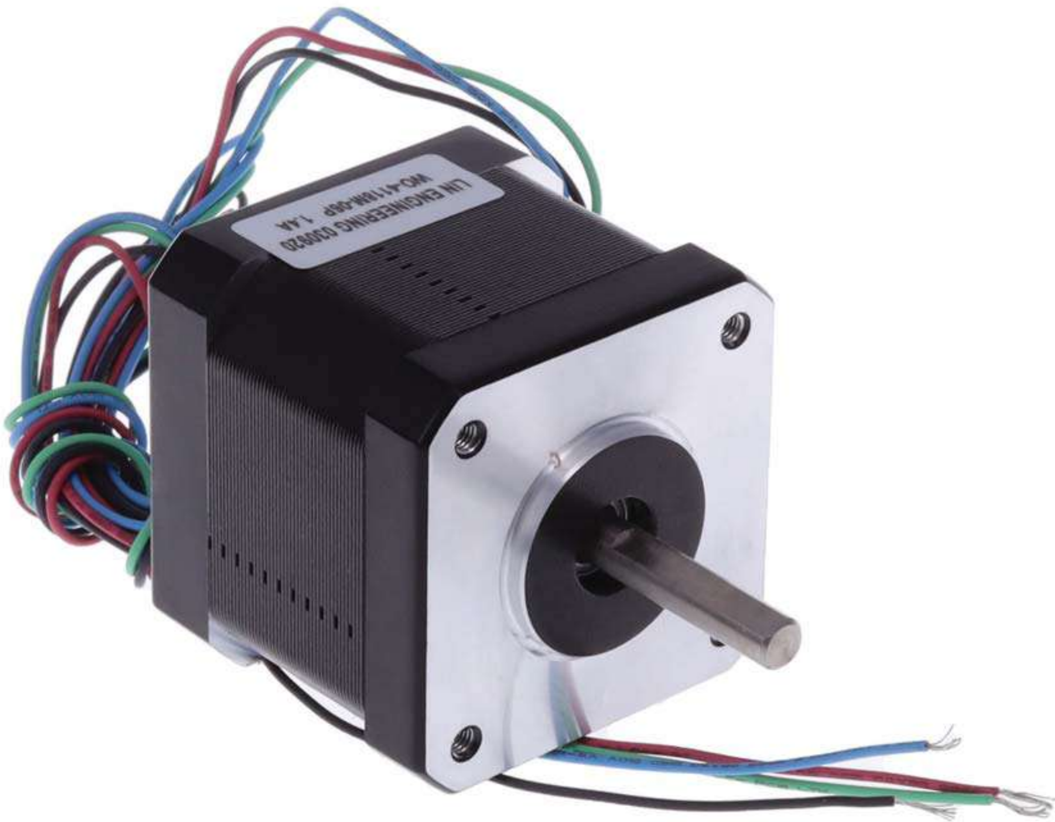
HYBRID STEPPER MOTORS



From the Editor

By **Bob Vavra**, Senior Content Director

Reinforcing the Weak Links

One very notable consequence of our supply chain woes: No one is taking semiconductors for granted anymore.

THE SEMICONDUCTOR WAS once a mostly overlooked commodity—cheap and plentiful for manufacturers and little understood by the consumer. No longer. That little chip that makes the Digital Age possible now is at the center of the discussion about how and where everything will be made.

For the longest time, semiconductors were manufacturing at select global sites, and everything ran fairly smoothly. It was a cost-effective and efficient system. After geopolitical disruption, supply chain fracturing and a fire at one of the leading manufacturing facilities in the world, the system was thrust into chaos and the chip drought affected both the price of everything from automobiles to phones. People who had never heard the term "supply chain" were suddenly talking about it.

It also forced manufacturers and distributors to re-examine the supply chain itself. As *Machine Design* reports this month, the announcement of Intel's initial $20 billion plant investment in Ohio earned the sort of fanfare usually reserved for new football stadiums. And like football stadium announcements, once the fanfare ended, there still was an empty space where the press conference had been held.

It will be three years until the first chip comes out of the Ohio manufacturing facility, so the solution to the semiconductor shortage will remain with us. It has forced manufacturers to look within their own organizations and their own geographies to better manage the chip supply chain. At the intersection of political influence and business profits, both sides are under pressure to deliver a better solution.

The chip shortage is one of the most visible of the supply chain issues all manufacturing economies face today. The tangling of that supply chain has been a driver of inflation and a strain on productivity. The solution is not going to be found strictly by bringing all manufacturing back inside our continental borders, but by better rationalizing what can be made where.

This isn't the first time in this century we've faced this issue. The 2008-09 Great Recession brought the issues of transportation and logistics costs to the fore. We must deal with similar questions again, keenly aware we allowed ourselves to relax in the mid-2010s when things got much better.

Dreamstime

The good news is that supply chain experts suggest that by the end of this year, we should see a normalizing of product flow. When that occurs, it should serve to harden our effort and reinforce the weak links in the chain. ■

The TRUTH About COMPRESSED AIR!

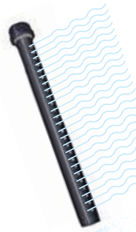
If you think compressed air is too expensive and noisy - read this. The facts will surprise you!

Compare These Blowoffs

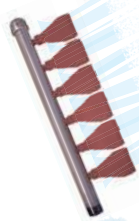
There are a variety of ways to dry, clean or cool products and surfaces, but which method is best? To decide, we ran a comparison test on the same application using four different blowoff methods: drilled pipe, flat air nozzles, Super Air Knife (each using compressed air as a power source), and a blower supplied air knife (using an electric motor as a power source). Each system consisted of two twelve inch long air knives.

The following comparison proves that the EXAIR Super Air Knife is the best choice for your blowoff, cooling or drying application.

The goal for each of the blowoff choices was to use the least amount of air possible to get the job done (lowest energy and noise level). The compressed air pressure required was 60 PSIG. The blower used had a ten horsepower motor and was a centrifugal type blower at 18,000 RPM. The table below summarizes the overall performance.



Drilled Pipe This common blowoff is very inexpensive and easy to make. For this test, we used (2) drilled pipes, each with (25) 1/16" diameter holes on 1/2" centers. The drilled pipe performed poorly. The initial cost of the drilled pipe is overshadowed by its high energy use. The holes are easily blocked and the noise level is excessive. Velocity across the entire length was very inconsistent with spikes of air and numerous dead spots.



Flat Air Nozzles This inexpensive air nozzle was the worst performer. It is available in plastic, aluminum and stainless steel from several manufacturers. The flat air nozzle provides some entrainment, but suffers from many of the same problems as the drilled pipe. Operating cost and noise level are high. For some flat air nozzles the holes can be blocked - an OSHA violation. Velocity was inconsistent with spikes of air.

Blower Air Knife The blower proved to be an expensive, noisy option. As noted below, the purchase price is high. Operating cost was considerably lower than the drilled pipe and flat air nozzle, but was comparable to EXAIR's Super Air Knife. The large blower with its two 3" (8cm) diameter hoses requires significant mounting space. Noise level was high at 90 dBA. There was no option for cycling it on and off to conserve energy. Costly bearing and filter maintenance along with downtime were also negative factors.

EXAIR Super Air Knife The Super Air Knife did an exceptional job of removing moisture on one pass due to the uniformity of the laminar airflow. The sound level was very low. For this application, energy use was slightly higher than the blower but can be less than the blower if cycling on and off is possible. Safe operation is not an issue since the Super Air Knife can not be dead-ended. Maintenance costs are low with no moving parts to wear out.

The Super Air Knife is the low cost way to blowoff, dry, clean and cool.

Blowoff Comparison

Type of blowoff	PSIG	BAR	Comp. Air SCFM	Comp. Air SLPM	Horsepower Required	Sound Level dBA	Purchase Price	Annual Electrical Cost*	Approx. Annual Maintenance Cost	First Year Cost
Drilled Pipes	60	4.1	174	4,924	35	91	$50	$4,508	$920	$5,478
Flat Air Nozzles	60	4.1	257	7,273	51	102	$300	$6,569	$1,450	$8,227
Blower Air Knife	3	0.2	N/A	N/A	10	90	$7,000	$1,288	$1,500	$8,288
Super Air Knife	60	4.1	55	1,557	11	69	$720	$1,417	$300	$2,437

*Based on national average electricity cost of 8.3 cents per kWh. Annual cost reflects 40 hours per week, 52 weeks per year.

Facts about Blowers

Energy conscious plants might think a blower to be a better choice due to its slightly lower electrical consumption compared to a compressor. In reality, a blower is an expensive capital expenditure that requires frequent downtime and costly maintenance of filters, belts and bearings.

Here are some important facts:

- Filters must be replaced every one to three months.
- Belts must be replaced every three to six months.
- Typical bearing replacement is at least once a year at a cost near $1000.

- Blower bearings wear out quickly due to the high speeds (17-20,000 RPM) required to generate effective airflows.
- Poorly designed seals that allow dirt and moisture infiltration and environments above 125°F decrease the one year bearing life.
- Many bearings can not be replaced in the field, resulting in downtime to send the assembly back to the manufacturer.

Blowers take up a lot of space and often produce sound levels that exceed OSHA noise level exposure requirements. Air volume and velocity are often difficult to control since mechanical adjustments are required.

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What Industry 4.0 Means for Product Management

Industry 4.0 is all about taking advantage of current technologies such as cloud computing, Internet of Things (IoT) devices and AI to improve products and their manufacturing processes.

Product management leaders and their teams oversee the processes of designing and building products customers want. Industry 4.0 will lead them to new ways to improve and update products using real-time data from internet-connected sensors.

Here's how Industry 4.0 will change manufacturing processes:

Real-time Maintenance and Insights

Maintenance and part replacement guidelines may soon become obsolete and tool lifecycles may get longer, thanks to increased use of internet-enabled intelligence and real-time monitoring. New sensors in production equipment can document performance and output. When this data is analyzed (data analytics), product managers should learn more about how equipment is functioning and make maintenance more precise. This should let managers coax more work and production from each part for longer timespans before they need to be replaced.

If there is something wrong with a machine, managers can manipulate and test adjustments on a digital twin to understand the issue before making fixes and replacements on the actual machine. This should save on maintenance costs and times and increase production, a big win for product managers.

The same data and analysis can be used on products being used in the field by customers to show product managers how the machines they design and build are actually used in the field, which features are used the most and which could be improved. They can base future product designs on this feedback to make their machines and parts more efficient and user-friendly.

Building with Agility: Evolving from Stage Gating Processes

In product development, there is always a laundry list of steps that must be taken to improve a product. Product managers are charged with overseeing this list and ensuring each step is addressed in the right order. However, selecting the right steps to prioritize is a constant challenge. Industry 4.0 will push product managers to implement agile processes in manufacturing and simplify the task of prioritizing the many steps in product development.

With any IoT device, users have eyes and ears and more on the ground 24/7 to determine how products are performing in real-time. This approach has been used effectively in software and is sold as part of consumer products.

The next step, in the fourth Industrial Revolution, will see the same sensors and real-time insights used in making hardware and physical products. This will set the stage for manufacturers tracking the development of every feature and even make updates in real time during development. Industry 4.0 products will also let companies gather data from machines in remote locations.

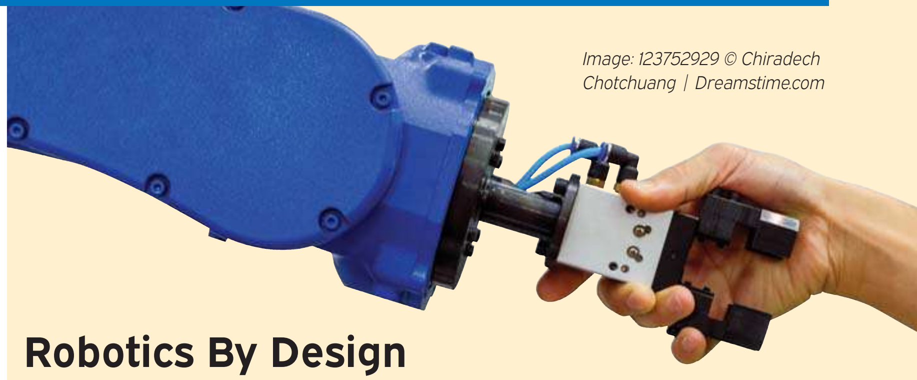
For example, consider the auto industry. Vehicles are quite different from those of even just decades ago. Many now have video screens instead of analog speedometers, odometers and entertainment controls. Vehicles that lack these digital interfaces are considered technologically obsolete by many. Cars developed with an agile Industry 4.0 approach will have adaptable hardware and internet-connected software that can be continually remotely updated throughout the vehicle's life. Agile manufacturing processes will lead to hardware being built into the vehicle before its software is ready for market.

For product managers, this type of workflow means abandoning the traditional stage gates workflow, where parts of the development process are delayed until the hardware or software elements are ready. A car or truck's platform can be built while software features are simultaneously developed for future testing and remote implementation, accelerating launch schedules and ensuring products have the best and latest advances.

Industry 4.0 will change the way product management teams design and maintain products. For companies, embracing Industry 4.0 could make a difference in competitive industries.

Building a business that can grow and scale profitably requires tools and strategies that are collaborative, agile and leverage data in real-time. Industry 4.0 fits this model. It's time for a revolution, and it will be exciting to see what new innovative technologies grow out of Industry 4.0. ■

MAZIAR ADL is co-founder and CTO of Gocious, a product portfolio management and planning SaaS firm.



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Robotics By Design Kicks Off Engineering Academy

ROBOTICS HAVE PROVEN to be crucial to meet the need of manufacturing even before the pandemic. The strategic use of robotics has improved plant safety and productivity, and innovative deployments of robotics have helped address worker shortages and supply chain challenges. Yet there still are manufacturers who have hesitation about how to effectively deploy robots in their plants.

As part of its new Engineering Academy, *Machine Design* will present a **Day of Learning: Robotics By Design** virtual event on Thursday, April 28. During these sessions, industry experts will discuss the value of robotics deployment, how best to integrate those robots safely and efficiently with their human co-workers, and how robotics can deliver a return on the investment and provide a competitive advantage as manufacturing continues to grow and evolve.

The keynote will be a discussion with Jeff Burnstein, president of A3 and Bob Vavra, senior content director of *Machine Design*. They will talk about the increased use of robotics during the pandemic and what manufacturers—and robotics companies—can do next to build on the momentum of the past decade. Burnstein also will highlight the upcoming Automate Conference in Detroit in June.

The technical sessions include:

- **Industrial Robots, Machine Tools and 3D Printers:** Prabh Gowrisankaran, Performance Motion Devices' (PMD) vice president of engineering and strategy, will look at machines with non-Cartesian movement systems. These include SCARA robots, PUMA-style arms, Delta Robots, and a variety of other mechanisms. These non-Cartesian mechanisms present special challenges, but there are some basic techniques that will take you a long way toward getting these useful and common mechanisms under control.
- **Motion Control Techniques for Non-Cartesian Motion Systems:** Mike Buchli of Dassault Systemes 3DEXPERIENCE Works discusses how manufacturing companies are adopting and incorporating robotics technologies to reduce overhead while staying productive in a global marketplace. He will be joined by Andrew Valentine of Valentine Automation and Tony Karew of DELMIA as they provide a live demonstration of the software and strategies involved with robotics deployment in a 3D setting.
- **The How and Whys of Cobot Deployment:** The effective use of cobots in a variety of manufacturing settings will be discussed by Joe Campbell, a of the robotics and automation industry and head of strategic marketing for Universal Robots.

Panel Discussion: Integrating Robots Into Your Plant's Future

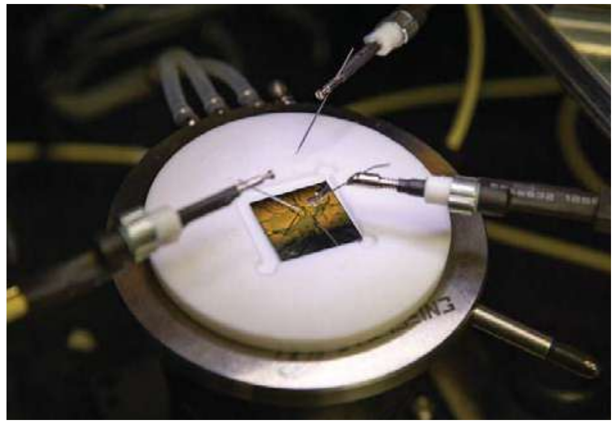
Panelists Include:

- Neil Stroud, VP, Marketing & Business Development, CoreAVI
- Thomas D. Pyper Jr., Automated Systems Group, Business Development Manager, Applied Manufacturing Technologies (AMT)
- Juan Aparicio, VP Product, Ready Robotics ■

Organic Semiconductors Make it to the 5G Circuit

Scientists overcome the limitation of organic semiconductors and redesign the way Schottky diodes are used in large-area electronics of the future.

THE DEMAND FOR low-cost, flexible wireless communications and applications has stoked interest in wireless energy harvesting innovation. For example, scientists were able to use organic material for a novel design of a semiconductor for radio-frequency circuits. Notably, the organic semiconductor has applicability in 5G applications, according to the group of international scientists led by King Abdullah University of Science and Technology (KAUST).



Organic semiconductors are made using solvent-based processing techniques, making them cheaper and more flexible than their inorganic counterparts. *Image: KAUST*

Basic Principles

Although organic semiconductors share some of the same physical properties as their inorganic counterparts, such as silicon-based semiconductors, there are significant differences. One difference is that inorganic semiconductor molecules are held together by weak van der Waals interactions, whereas organic semiconductors are held together by covalent bonds.

This distinction underscores property variations of devices using organic versus inorganic semiconductors. On the upside, organic semiconductors are made using solvent-based processing techniques, making them cheaper and more flexible for use in printing or blade and die coating, explained Ph.D. student Kalaivanan Loganathan.

On the downside, electrical charges move much slower in organic materials. This drawback is a barrier to applying organic semiconductors for use in fast applications such as radio-frequency electronics, noted the scientists.

"To make this technology useful for the 5G frequency band, there is a need to fabricate organic Schottky diodes," Loganathan said.

The Schottky diode allows current to pass through in one direction but blocks flow in the other. The most important difference between the more ubiquitous p–n diode and the Schottky diode, noted the scientists, is that the latter can switch from the conducting to the nonconducting state much faster. This makes them essential in radio-frequency applications.

They explained that the speed of Schottky diodes is generally limited by the device capacitance and the resistance. But organic semiconductors are often associated with high capacitance and resistance due to their low charge carrier mobility, the authors said. They are mostly employed in conventional sandwich-type architecture in which the semiconductors, metals and electrical contacts are laid one on top of the other.

Reimagined for the 5G frequency range, Loganathan, working with Professor Thomas Anthopoulos and his team, redesigned the device architecture and placed the two electrical connections side-by-side. The organic semiconductor, referred to as C16IDT-BT, was placed in a tiny gap of just 25 nanometers in between the diodes. The diodes in this structure have an ultralow capacitance and resistance.

Kalaivanan Loganathan (left) and Professor Thomas Anthopoulos hope to integrate their diodes into radio-frequency circuits, ID tags and wireless energy harvesting devices. *Image: KAUST*

The scientists showed that the Schottky diode operated up to a frequency of 6 GHz (6 billion cycles per second). They extended the frequency to 14 GHz by chemically doping the semiconductor with the addition of another molecule.

"Our results show that organic semiconductors are capable of operating in the 5G frequency range, like their inorganic counterpart," said Loganathan, adding that these organic semiconductors can be mass-manufactured at low cost using solution processing.

The team noted that they hope to integrate their diodes into radio-frequency circuits, ID tags and wireless energy harvesting devices.

The findings were published in *Advanced Materials*. ■

COMMENTARY:
Engineering Licensing-Exemptions Put the Public at Unnecessary Risk

THE OCTOBER 2018 and March 2019 crashes of Boeing 737 MAX 8 airliners killed 346 passengers and crewmembers and caused sorrow and grief for many times that number of family members and friends. Those disasters share a common characteristic with many tragedies such as the Ford Pinto fires, the space shuttle *Challenger* explosion, the GM ignition switch disaster, the *Deepwater Horizon* oilrig tragedy, amusement ride accidents, the Merrimack Valley gas distribution system fires and Volkswagen's emissions fraud.

The common characteristic? All the engineering organizations behind these failures were exempt from placing licensed engineers in charge. Engineering did not need to be conducted under the direction of competent and accountable engineers whose paramount ethical and legal responsibility was public protection. Instead, the "engineering" was primarily driven by bottom-line-oriented managers and executives.

Licensing

Understanding how this illogical practice prevails begins with a review of engineering licensing in the U.S. *Dent v. West Virginia*, a landmark 1889 U.S. Supreme Court case, gave states essentially unlimited power to regulate professions for public-protection purposes.

In 1907, Wyoming became the first U.S. jurisdiction to adopt an engineering licensing law. Other jurisdictions, often stimulated by engineering disasters, followed suit so that by 1950 all 48 states, the then-territories of Alaska and Hawaii, and the District of Columbia had adopted such laws.

To become a Professional Engineer (PE), candidates must earn an accredited engineering degree, complete four years of increasingly responsible experience, and pass two examinations. PEs then become participants in what Richard and Daniel Susskind, authors of *The Futures of the Professions,* call the grand bargain between a profession's members and the public.

PEs apply their expertise, experience and judgment in delivering affordable, current and reliable services and put the interests of those they serve ahead of their own. Individuals and organizations contracting for services trust PEs to do those things and grant them exclusivity over a range of services by paying them a fair fee and conferring autonomy on them.

"You can't escape the responsibility of tomorrow by evading it today."

—Abraham Lincoln

Ethics Codes

Introducing ethics codes prompts us to ask, what is engineering's purpose? If the medical profession provides care without doing harm and the legal profession seeks justice within the law, what is engineering's goal? In my view, engineering's purpose is to meet society's physical needs while keeping public protection paramount.

To further define what licensing meant, engineering began to construct, and then build on, a foundation of ethics. The American Institute of Chemical Engineers (AIChE), what became the Institute of Electrical and Electronics Engineers (IEEE), as well as the American Society of Mechanical Engineers (ASME) and American Society of Civil Engineers (ASCE) all created and adopted codes between 1912 and 1914.

Other engineering groups followed, so that today they all admirably state the following, or something very similar: The engineer will "hold paramount the safety, health and welfare of the public."

Remarkably, more than half a century ago, U.S. engineering had achieved universal licensing laws plus unanimous commitment, via ethics codes, to hold public protection paramount. Engineering was on its way to becoming a profession, on par with any, because it promised to meet society's physical needs while protecting the public. But did that promise lead to consistent actions on risky engineering projects to protect the public?

Licensure-Exemption Laws

Unfortunately, the answer is no because, beginning in about 1940, three decades after adoption of the first state engineering licensing law and during World War II, many U.S. companies began a campaign to get exemptions for their engineers from mandatory licensing. How would this work?

These employers would be responsible for their engineers' work and be liable for errors and decisions that caused injuries, deaths and destruction. Liability assumption by manufacturers, industries, utilities and others would "protect" the public. For example, the 346 families who lost parents, spouses, children and siblings in the two recent 737 disasters will receive an average of about $1.45 million from Boeing. Is that enough? Would any amount be enough?

Americans harmed by engineering disasters realize that this "closing the barn door after the horses are gone" approach, while it may provide some justice and financial remuneration for victims, does not bring back the dead, heal the maimed or restore what was destroyed. Furthermore, the inevitable negotiation and litigation forces survivors to relive the tragedy.

Putting profit over public protection, in other than low-risk engineering situations, and accepting unnecessary deaths, injuries and destruction is terrible public policy. However, it persists today in that DC and all states, except Arkansas and Oklahoma, have engineering licensing-exemption laws.

The Licensure-Exemption Law Culture

According to engineer-author Stephen Armstrong, company/organizational "culture wields great power over what people consider permissible and appropriate… culture sends its energy into every corner of the organization, influencing virtually everything." My consistent, but shorter, definition of culture is: the way things really work around here, especially when the chips are down.

Research reveals that manufacturers, industries, utilities and other organizations that hire engineers to work under licensing-exemption laws tend to develop bottom-line-first cultures, which override public protection. Consider some examples of the culture created by licensing-exemption laws:

- According to Boeing, its engineers reported that PEs were not needed in aircraft design, including the 737 MAX.
- During the design of the Ford Pinto, engineers learned that the explosion risk due to a poorly placed fuel tank could be eliminated for $11 per vehicle, but engineers and management decided that settling accident claims would cost less.
- Morton-Thiokol management was warned by a lead engineer to delay the launch of space shuttle Challenger because of the harmful effect of low temperatures on gaskets. Managers rejected the advice and told the engineer: "Take off your engineering hat and put on your management hat." This, in effect, killed seven astronauts.
- For a decade, GM engineers brushed off reports that occupants of six car models were being injured or killed because of a faulty ignition switch, which was eventually re-designed.
- Reporter and author Abraham Lustgarten, who studied two decades of British Petroleum operations leading up to the Deepwater Horizon oil rig tragedy, concluded that "oil companies…could not be trusted to police themselves and balance the public good against their own profits."
- After studying the fires at the Merrimack Valley gas distribution system and recognizing the potential for similar disasters in 30 states because of their license-exemption cultures, the National Transportation Safety Board recommended that all those states "remove the exemption" that caused the Massachusetts tragedy. Several states have done so or are considering that option.

This dangerous bottom line-first culture, like all company cultures, is driven from the top and enters "every corner of the organization, influencing virtually everything." A bottom line-first culture is especially dangerous in engineering organizations because one engineering failure can injure and kill many. In contrast, if a surgeon errs during an operation, the consequences—however dire—are limited to one or a few individuals.

"It is easy to dodge our responsibilities, but we cannot dodge the consequences of dodging our responsibilities."

—Sir Josiah Stamp, English economist, industrialist, banker and civil servant

Show Me the Data

Interested engineers, as well as other thinking individuals, naturally want to see the data that show how licensing-exemption laws lead to unnecessary injuries, deaths and destruction. I believe this could be done, but it has yet to happen. However, absence of statistical proof does not begin to reduce my and others' concern for public safety.

Therefore, some colleagues and I apply a powerful "tool" used every day in our engineering work—judgement. My judgement draws on examining engineering disasters, understanding human behavior (especially groupthink), contrasting engineering's approach with that of most professions, and empathizing with actual and potential victims.

The common U.S. practice of not placing PEs in responsible charge of risky engineering projects would be like:

- Hospitals not placing licensed physicians "in responsible charge" of surgery.
- Law firms not placing licensed attorneys "in responsible charge" of legal services.
- Veterinary clinics not placing licensed vets "in responsible charge" of neutering and spaying.

Of course, those three professions don't do that. They don't let physicians, lawyers and vets practice without licenses. However, that is exactly what engineering does, frequently and sometimes disastrously, across America.

Those who defend licensing-exemptions often note that tragedies sometimes occur even when PEs are in charge, which is true. However, in my judgement, engineering projects guided by PEs are much more likely to protect the public than those guided by non-PEs or non-engineer managers. PEs are more likely to:

- Be competent, partly because continuing education is a condition of maintaining a PE license in 75% of U.S. licensing jurisdictions.
- Behave ethically, mainly because they are subject to the ethics code of the jurisdiction(s) that licensed them, and code violations have legal consequences.
- View themselves as members of a profession whose paramount responsibility is public protection, rather than as being technical employees answerable mainly to corporate directives.

Engineering's approach to public protection is a predicament. The engineering community's widespread public-protection-is-paramount claims, via ethics codes, stand in sharp and hypocritical conflict with the equally widespread licensure-exemption laws. If this dilemma stands, the public faces unnecessary risks. We need reform so that competent and accountable PEs who place public protection first are responsible for risky engineering projects.

Reform requires first identifying and understanding any group or organization that supports licensure-exemption laws. That is, who is culpable? Second, reform must begin with describing how change-minded individuals and organizations could dismantle, or at least weaken, the support for those exemptions. ■

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HEIDENHAIN

CHIP C

Changes How Engineers Design

On the heels of the semiconductor shortage, design engineers explore new ways to design.

by Rehana Begg, Senior Editor

Uncertainty has been a characteristic of supply chain management ever since business became international. But in recent years, the complexity of global trade, compounded by the COVID-19 crisis, has directed major companies to become more strongly focused on supply chain risk.

"Semiconductors and electronics are historically a cyclical business, so we usually see a market cycle ebb and flow about every four years," said Peggy Carrieres, vice president of Sales Enablement and Supplier Development, Avnet, a global technology distributor based in Phoenix, Ariz. that employs more than 2,000 engineers in 48 countries.

Before the pandemic, Avnet forecasted an 8% uptick in revenue in 2020, said Carrieres. But a number of macroeconomic factors would shift the balance. "In September 2020, due to trade issues between the U.S. and China, we saw some changes for manufacturers," she explained. "We had global output issues because of the pandemic, we had logistics challenges, there were natural disasters, fab fires, earthquakes…All of this happened over the past two years."

Geopolitical market challenges have become the norm. "Where a customer chooses to build will impact the supply chain," said Carrieres, adding that Avnet's advantage of being a broadline distributor means that it has a reach that spans across the globe. "We can pivot and stay agile to meet the changing needs of the market and in the macroeconomic state."

On March 1, Avnet made public the results of an inaugural survey, *Avnet Insights*, which focused on trends impacting design engineers in the electronics industry. Among the key takeaways, it showed that due to chip shortages, access to electronic components has been a very significant challenge.

Carrieres pointed out that shortages are changing the way engineers design. According to the survey, availability is impacting more than just where engineers are seeking the parts for their designs. It is impacting *how* they create designs, she

According to Avnet Insights, a survey on the trends and market forces in the electronics industry, design engineers are exploring new ways to get their products to market. *Credit: Avnet*

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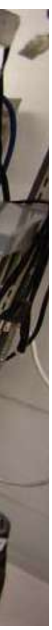
said. Two-thirds (64%) of survey respondents said their company is designing more based on availability of components over preference.

"The shift from designing based on first choice to designing based on first available for a prolonged period is a ripple effect from the overall shortages that could significantly impact the electronics industry," said Carrieres. "However, it also represents an opportunity for engineers to lean on their partners with added visibility into the supply chain to ensure they are creating flexibility in their designs based on market conditions to avoid compromising quality."

Respondents who experienced a significant impact due to the shortages (93%) cited lead times as having a direct effect. This impact was followed by delayed production schedules (74%) and higher prices (72%). A strong majority of respondents (96%) expressed concerns about lead times getting longer and about price increases over the coming year.

In addition, the survey found that design engineers are seeking additional routes to source parts, including through spot market brokers. "Current conditions call for having dual sources, where you can make sure that you have supplier A and B that are qualified, so that if one is a stock out, you can pivot to the other," advised Carrieres.

These considerations are important in designing flexibility into the next generation of components, she explained, as designers might consider the cost of swapping out a piece from a module and change 20%, as opposed to redesigning the whole unit.



Avnet's time-to-market capabilities cover sourcing and design, including the complex hardware and software integration required for embedded and IoT solutions. *Credit: Avnet*

According to the survey results, when design-in components are not available, most respondents rely on redesigned boards (55%), pin-to-pin replacements with better specs (53%) or drop-in replacements (49%). These preferences vary regionally, noted Avnet. For instance, designers in the Americas are most likely to use drop-in replacements, with nearly three-in-four (73%) reporting they have done so.

"Some ICs, such as a microcontroller or FPGA, are really hard to retrofit for another supplier," said Carrieres. "But having a dual design up front—option A and option B—means you can take that into production and have some flexibility."

The survey also found that respondents had significant concerns about counterfeit control, which could compound design and quality issues over the long-term, noted Avnet.

About the Survey

The Avnet Insights customer survey was conducted among n=530 global engineers. Regionally, 31% of respondents were based in the Americas; 56% in EMEA; 10% in Asia and 2% in Japan. The survey was fielded online from Nov. 4 to Dec. 3, 2021 using Avnet's global customer database. ■

The Semiconductor Race is On!

Designing chips isn't the issue—manufacturing is. Finding new capacity is an imperative with geopolitical implications.

by Rehana Begg, Senior Editor

Nikolajs Strigins | Dreamstime

When supply chain vulnerabilities resulted in breakdowns in shipping and logistics systems and shortages in personal protective equipment, a boom in demand erupted for cloud services and home electronics. And then came the pandemic, further straining both manufacturing and distribution.

A confluence of events along the half-trillion-dollar global chip supply chain unfolded throughout the pandemic. Manufacturers dealt with issues ranging from trade issues between China in the U.S. to global output and logistical challenges. Then there were the human and man-made disasters, including earthquakes and a fire in a major semiconductor plant in Japan.

In early 2020, vehicle sales plummeted, forcing automakers to cut chip orders. By the time there were signs of recovery in the latter half of the year, the semiconductor industry had already shifted production lines to meet demand for such product categories as 5G smartphones, laptop computers and webcams.

The ripple effect extended beyond semiconductors, said Peggy Carrieres, vice president of Sales Enablement and Supplier Development, Avnet, a global semiconductor distributor with headquarters in Phoenix, Ariz.

"Semiconductors are historically a cyclical business, so we usually expect to see a market cycle ebb and flow about every four years," said Carrieres. At the cusp of the pandemic in 2019, an industry forecast from the World Semiconductor Trade Statistics (WSTS) organization projected annual global sales would slump 12.8%. Markets were expected to rebound with moderate growth and forecast worldwide semiconductor market growth to rise to 25.6 % in 2021 from 6.8% in 2020. The boost, noted WSTS analysts, is the biggest since a 31.8% increase in 2010.

Chip Design Thrives

A more complete view of the chip shortage traces its roots to long-term forces. The semiconductor industry has evolved into a highly specialized industry racked by intense competitive pressure. From its origins in Silicon Valley in the 1970s, semiconductors have roughly doubled in circuit density every two years, when Gordon Moore, co-founder of Fairchild Semiconductor and former CEO of Intel, made the historical trend known as Moore's Law. Simplistically described, the moniker means one can cram more functionality into a smaller chip and that more chips per wafer plummets the cost per unit.

The biggest threat to the semiconductor industry in the United States is that semiconductor manufacturing has suffered a steady decline for decades. Fabrication capacity has fallen to about 12% in 2020 from about 37% in 1990, according to a report by the Semiconductor Industry Association (SIA) and the Boston Consulting Group. These statistics tell us that few semiconductors are actually made in America. Many major semi firms—Nvidia, Qualcomm and AMD—design and test chips in-house, but outsource production to foreign foundries.

The concern for U.S. policymakers is that the semiconductor manufacturing is concentrated in the Asia Pacific region, which leaves America exposed to geopolitical risk, trade restrictions and further supply chain disruptions. "We would have better control if [semiconductors] can be locally sourced," said Brian Matas, vice president, market research, IC Insights.

Local production had proven to be cost-prohibitive for most private companies and makes clear why there's no short-term solution for bringing semiconductor manufacturing back to the U.S. The 10-year total cost of ownership of a new fab in the U.S. can run 30% to 50% higher than competing countries, according to SIA data.

"What many in the United States think about is that one can throw $50 billion toward the infrastructure in the semiconductor industry," said Matas. "That's a nice plan, but there's no immediate fix. Rather, to become a manufacturing power, we need a long-term plan and to spend significantly on the semiconductor industry in the country."

AT A GLANCE:

- A confluence of events along the half-trillion-dollar global chip supply chain is behind the semiconductor shortage.
- The biggest threat to the semiconductor industry in the United States is that semiconductor manufacturing has suffered a steady decline for decades.
- In the U.S., designing chips is really not a problem—manufacturing is the critical issue, according to Brian Matas, VP, market research, IC Insights.
- The concern for U.S. policymakers is that the semiconductor manufacturing is concentrated in the Asia Pacific region, which leaves America exposed to geopolitical risk.

China Wants to Take Charge

Advanced manufacturing capabilities, complex equipment and the capital outlay needed to compete globally have in recent years rested semiconductor manufacturing in the hands of a few companies and countries, said Matas. This is largely owing to government incentives and subsidies afforded to chipmaking companies in that region.

Backed by government financing, China has been able to bolster industry collaboration and expansion for the country's fabrication capacity. Still, its role in the semiconductor manufacturing remains limited. Integrated circuit (IC) products produced by Chinese firms are generally less technologically advanced than those produced by non-Chinese fabs. Eurasia-Group, a political risk advisory, reported that while Beijing will continue to pour funding into the sector, manufacturers there will be challenged to penetrate the upper tier of global manufacturers that produce chips at nodes below 7-10 nm for the foreseeable future. That's because growing costs hamper their ability to install the semiconductor manufacturing equipment and capabilities needed to produce volumes at process nodes below 10 nm.

In general terms, "nodes" refer to the generation of chips for a particular technology. The complexities of shrinking (remember Moore's Law), expertise and high capital cost have propelled only three companies to the forefront. Intel in the U.S., Samsung in South Korea and TSMC in Taiwan can fabricate integrated circuits at the process nodes of 7 nm and are charging ahead to transition to 5 nm and 3 nm capacity by the mid-2020s. China's largest semiconductor foundry, Semiconductor Manufacturing International Corporation (SMIC), reportedly lags by about three years.

Policy and Protectionism

The Asia-Pacific monopoly has bolstered concerns about the long-term security of supply chains to the extent that it has become a matter of national importance to the United States. The Biden Administration's $2 trillion infrastructure package includes a proposal of $50 billion in funding earmarked for such initiatives as a public-private consortium to build and operate a National Semiconductor Technology Center for conducting research and prototyping.

To compete with foreign competition, an aggressive policy framework is being enacted via the CHIPS for America Act and is buoyed by federal legislation (FABS Act), which promises incentives that could infuse $52 billion into semiconductor manufacturing, research and development, design and manufacturing. BCG analysts estimate that the incentive program can strengthen competitiveness by bringing in 19 new fabs (fabrication labs) online. The gains would accrue to a share of global installed capacity of about 13% by 2030 and increase local capacity by 57%, which reverses the downward trend of the past three decades.

As the global shortage continues, semiconductor fab investments are materializing around the world. According to industry association SEMI, 29 new fabs started construction in 2021 and 2022, but many won't start installing equipment until 2023. It takes up to two years after ground is broken to reach that phase, though some could begin equipping as soon as the first half of next year, noted a SEMI press note.

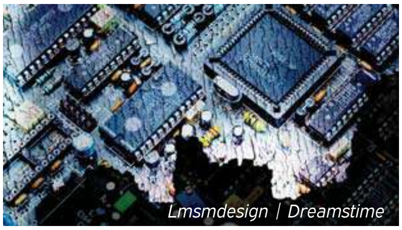
In the U.S., designing chips is really not a problem—manufacturing is the critical issue, Matas noted. With support from government, he said the numbers are expected to climb. In his view, Samsung's manufacturing fab in Taylor, Tex. is proof of that. The $17 billion investment, including buildings and machinery and equipment, is Samsung's largest-ever investment in the U.S.

"There's a lot around the corner to keep the semiconductor industry active and vibrant," said Matas. "And that's just one reason it's important to decrease reliance on foreign production and bring some of the manufacturing back." ■

Chipping Away at the Backlog

As the hype subsides, the hard work of semiconductor manufacturing and testing remains.

by Bob Vavra, Senior Content Editor


Lmsmdesign | Dreamstime

The fevered excitement following Intel's January announcement that it would start construction on a $20 billion semiconductor manufacturing campus near Columbus, Ohio generated sound bites and adjectives reminiscent of 1960s space launches.

Intel CEO Pat Gelsinger called the new Ohio plant "a new epicenter for advanced chipmaking in the U.S." As *Electronic Design* reported in January, Intel expects to start construction this year on the manufacturing plants, and there are ambitious plans to expand manufacturing capacity beyond the initial 100 acres announced at the event. The investment could grow to 200 acres and $100 billion over time, Gelsinger said. It also adds to Intel's manufacturing network in Oregon and Arizona.

President Joe Biden said the announcement moves the manufacturing of chips closer to their origins—and to their customers. "America invented these chips and federal research and development led to the creation of these chips," Biden said at the press conference announcing the factory project launch.

When the press conference was over, the excitement lingered but the hard realities set in like winter in Ohio. Production wasn't expected to begin at the new Intel plant until at least 2025. The global semiconductor shortage remains a drag on global manufacturing growth. The supply chain still is recovering from the pandemic, the existing geopolitical challenges and now the uncertainty over the war in Ukraine.

There was hype, and there is hope, but there is no immediate help.

Developing the Workforce

In an interview with *Industry Week* in March, Mark Granahan, CEO and founder of iDeal Semiconductor in Bethlehem, Pa. said that simply manufacturing more chips in the U.S. is only one factor in the challenges for the future.

"Maybe the next question is, where are they going to be packaging and testing these products? Because if they have to send that overseas, it really doesn't help the supply chain as much as it should," Granahan said. "As technology becomes more advanced, it's less about actual labor cost, and more about the technical expertise to actually manufacture and build the products.

"These factories, once they're up and running, will be producing chips for 20-plus years, at least," Granahan added. "And so, as we move into the latter part of this decade, next, having that assembly and test capability in the U.S. will be a really strong calling card for U.S. supply chain base."

A new wave of workers will be needed to deliver on the longer-term promise of the success at Intel's Ohio plant and the others that may follow. "It will be operators, basically hourly individuals that will definitely need training, but a lot of that training can be on the job. Then there will be technicians, the next level up in terms of education. Most will likely need a two-year degree or some type of associate's degree, in equipment, maintenance, electronic electronics, chemistry," Granahan noted.

"The good news is this will be an across-the-board opportunity for people who don't necessarily have a college degree all the way up to very advanced Ph.D. types of individuals in the areas of chemistry material science, metallurgy, ceramics, polymers, physics, electrical engineering—a pretty wide range of engineering functions will be necessary," he added.

Restoring and Reshoring

In his press conference, Intel's Gelsinger said the Ohio facility marked "another significant way Intel is leading the effort to restore U.S. semiconductor manufacturing leadership. Intel's actions will help build a more resilient supply chain and ensure reliable access to advanced semiconductors for years to come."

Part of that challenge is to bring not just the design and manufacturing but also the testing closer to the end-users in North America. To do that, Granahan suggested, it would take further investment from Intel, and from others.

"Most assembly and testing for the industry is in Asia. And trading and expanding that type of capability in the Americas would be a really good thing," he said. "I believe it's going to take some initiative by the federal government to start talking about, and putting money towards expansion of that capability here in the Americas.

"Clearly, this supply of semiconductors here in the U.S. as it expands, it creates more and more of the conditions for having the total supply chain in the in the Americas, as opposed to sending stuff overseas all the time," Granahan added. "It's not taking away from Asia; it's actually adding more capability and capacity here in the Americas."

That remains an elusive goal. New products, new markets and new communication protocols will require more chips now. As the world shifts to a more robust regional and local supply chain strategy, the next challenge is to reduce the current backlog of production, and Intel's announcement—while significant—won't resolve the current issues.

The federal government has proposed $52 billion in additional funding for semiconductor manufacturing, and Granahan knows where he'd like to see it spent. "I'm hoping that a lot of that $52 billion goes towards more advanced research so that we can stay ahead. The U.S. is actually behind; (Taiwan Semiconductor Manufacturing Corporation) has surpassed Intel in terms of their technology performance," he said. "I'd like to see funding go toward advanced research in very high-performance areas like silicon and advanced materials." ■

RE-ENGINEERING the Digital Transformation

Processes and people alike must be upgraded to take full advantage of tools and technology.

by Tom Gill, Practice Manager, PLM Enterprise Value & Integration, CIMdata

Author Tom Gill at work on a process re-engineering project. *Image: CIMdata Inc.*

The tools and techniques of digital transformation greatly simplify and speed up new product development. They are counterproductive and even senseless, however, if put to work supporting the "same-old, same-old" processes of product development, design engineering, manufacturing and service. The same is true for the processes used in every other business unit in the enterprise.

For project managers and enterprise leadership in digital transformation, the need for process modernization should be obvious. Digital transformation's tools and techniques can greatly improve collaboration and innovation in new product development, as just one example, but not until many existing processes are updated—or, as is often necessary, re-engineered. This is never simple.

Just as products are re-engineered to accommodate new capabilities, processes also must be re-engineered. Re-engineering is a proven way to address processes ill-suited to the trends and enablers of digital transformation; these can be large stumbling blocks for collaboration, productivity and even enterprise sustainability.

These views were spelled out in a recent virtual conference I participated in on process innovation and digital transformation ("PI-DX") run by Marketkey Ltd., a London-based business-information company focused on refining data into intelligence, business insights and innovation.

The panel focused on what Marketkey labels "legacy technical debt." The remedies discussed included process "modernization" and process "innovation," but problems in some processes run deep. These can only be addressed by re-engineering the process, ideally while replacing obsolete legacy systems and upgrading the technical skills of the workforce.

Process re-engineering is tied to digital transformation at several levels wherein information is freed from pre-operative formats such as spreadsheets, CAD-generated drawings and e-mail attachments; many critical processes are rendered obsolete.

Digital transformation requires up-to-date systems, tools, techniques and

solutions; they can be difficult to work with. Amid new realities of data and information, these challenges require skills updates, too.

Processes that until recently were expected to change little have been demolished by technology and tech-savvy new workers, choosier customers, ceaseless innovation and shorter product lifecycles. Consequently, many long-established practices in the handling of information in processes are headed for the dustbin of digital history.

Changing the Thinking

As goes information, so go the processes we use to search, use and manage it. Enterprises, business units and solution providers clearly see that their assumptions about many everyday processes have become questionable.

"The way we have been getting things done" no longer keeps up with the speed of innovation in today's marketplaces. And it is product and process innovation that helps fend off competitors, hang on to demanding customers and shore up profit margins.

Viewed in this light, it is little wonder that processes are being impacted in every product and asset lifecycle. These impacts are most disruptive in determining new product requirements and throughout design, engineering, production, service, and all data handling and information gathering tasks.

Users and managers also struggle with fallout from legacy systems and tools and the processes that support them. A pair of all-too-common examples:

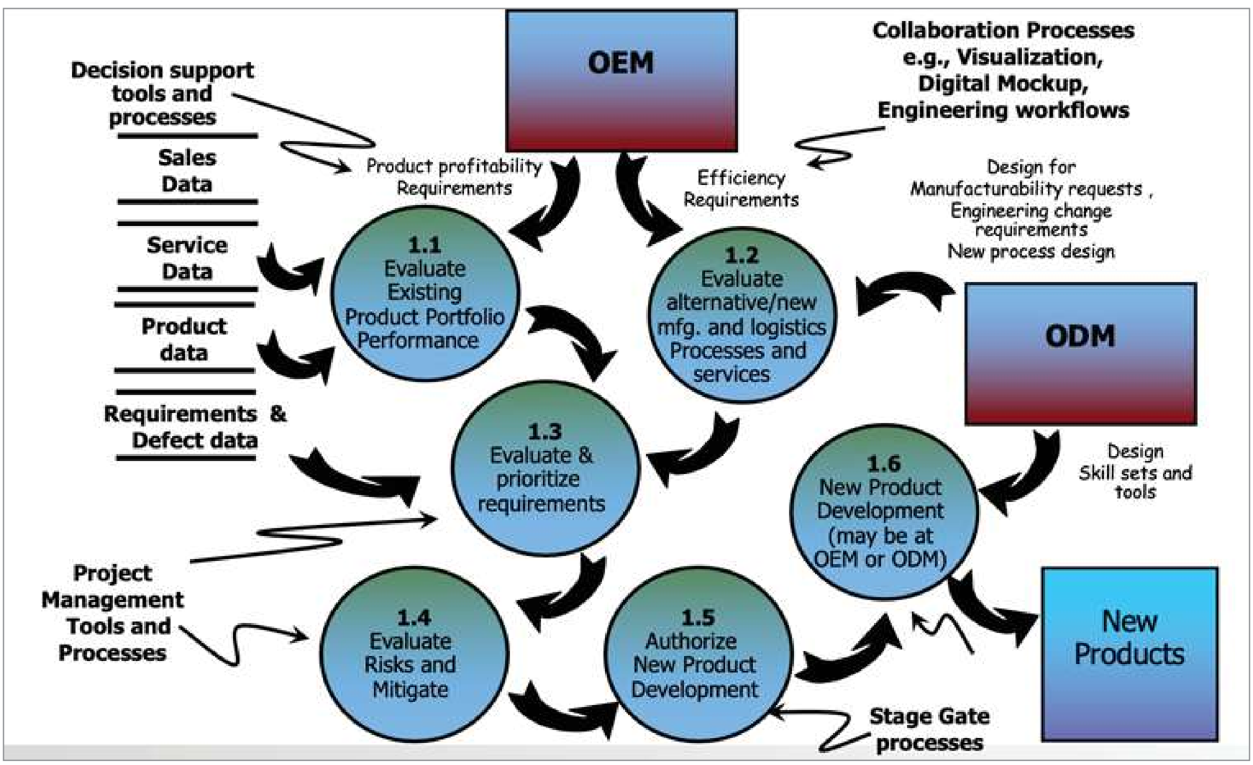
- Reworking newly manufactured products at the ends of assembly lines, delaying shipment and running up costs
- Iffy, on-the-fly workarounds that turn into repetitive do-loops producing nothing but frustration

Both are good places to launch process re-engineering and easily win user support.

Re-engineering any process starts with a deep dive to pinpoint where and why

"The way we have been getting things done" no longer keeps up with the speed of innovation in today's marketplaces. And it is product and process innovation that helps fend off competitors, hang on to demanding customers and shore up profit margins.

things go wrong. Once the problems and their causes are clearly identified, address them one by one. So a big part of process re-engineering is developing new capabilities to reconfigure the tasks and sub-tasks that make up the process. Once these new capabilities are



The complexities of how business units and enterprise processes fit together make re-engineering almost unavoidable. It also can lead to a reduction in those complexities. *Image: CIMdata Inc.*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chosen, test and verify them. Though tedious, testing and verifying must be done with care.

Processes usually generate predetermined outcomes that support decisions or feed additional processes. Poorly planned changes to a process, or even to just a few of its tasks, could blindside workers elsewhere in the business unit.

In the enterprise's high-level business processes, the impacts of re-engineering run even deeper. These processes include concept to design, design to manufacturing, orders to cash and others that must not be overlooked.

A typical scenario for CIMdata clients takes shape while the processes are being re-engineered. After the process changes

What Does Re-engineering a Process Really Mean?

PROCESS RE-ENGINEERING involves reviewing the existing operations, starting with the most badly broken processes to identify:

- Business objectives, clearly stated and understood
- Learning why, when and by whom the process was created
- Required process outputs
- Inputs that are still valid and verify with users
- Process steps to be added or dropped
- Outputs to be verified with users
- Process changes to be prototyped
- Changes to be validated
- Whether better tools are needed
- Changes in processes to be prototyped
- Processing changes to be validated
- Effectiveness of process connectivity
- Impacts of changes on connected and dependent processes

When undertaking change, they key ideas are:

- Validating processes being scaled up to production status
- Communicating all planned changes
- Establishing effective governance with a framework to manage organizational change
- Evaluating alternative tools, systems and technologies
- Evaluating lesser included subtasks
- Assembling, finalizing and verifying new processes, then running tests
- Implementing new processes—initially next to legacy processes
- Reverifying process transparency
- Establishing a help desk

have been verified as viable, CIMdata continues to help the client while the re-engineered processes are put into use and, equally importantly, integrate the changes with other processes that are closely connected.

At this point, several crucial decisions must be made, and the synergy of outside expertise and knowledgeable staffers comes into force. These decisions focus on ensuring user buy-in as well as how best to gain the support of all those whose work is tied to the process(es) being re-engineered. Other key decisions cover lining up in-house technical resources and securing financial support.

Changing the Work Process

A big part of the value of process re-engineering lies in helping the workforce grasp the benefits in letting go of obsolete processes. If the workforce is to welcome change and embrace innovation, make sure that decisions about re-engineering are clearly communicated.

An alternative approach to these communications is budgetary—putting business issues first. This means linking anticipated re-engineering costs to projected revenue gains.

To help with building your case for re-engineering a process, here are a few realities that must not be overlooked:

- Processes are linked in countless ways, even without the bidirectional and end-to-end (E2E) connectivity essential for maximum efficiency
- Process changes occur fast and often, prompting users to modify their processes themselves
- Process changes at the business-unit level are triggered by innovation such as augmented/virtual reality and advanced analytics
- Process changes also impact users directly—artificial intelligence and machine learning, for example
- At the enterprise level, processes are disrupted by model-based engineering, system-of-systems thinking, predictive analytics and agile software development

As the skills of the workforce are upgraded and transformed, new and better ways will be found to connect people, data, technologies and tools. As these are implemented, process re-engineering will grow in value—and inevitability.

Perhaps the best approach to process re-engineering is to undertake it together with workforce transition and skills upgrades. None of these crucial initiatives can achieve its full potential without the others. Transitioning workforce skills while re-engineering their processes can go a long way assure the ultimate success of digital transformation and, in turn, help secure the sustainability and long-term competitiveness of the enterprise. ■

Gauging Attitudes on SUSTAINABILITY

A survey of company engineers, executives and sustainability managers looks at how sustainability is being pursued.

by **Stephen J. Mraz**, Senior Editor

Managers at Protolabs, a company that offers manufacturing services such as 3D printing, CNC machining and injection molding to designers and manufacturing firms, were curious about what the companies were doing with their sustainability initiatives.

To find out, the company commissioned EGL ACE Research to do an online survey of executives, sustainability leaders and product developers across the medical, automotive and aerospace industries. The goal was to uncover what they and their companies are doing to succeed at sustainability, how product design is affected and how manufacturing can help meet sustainability goals.

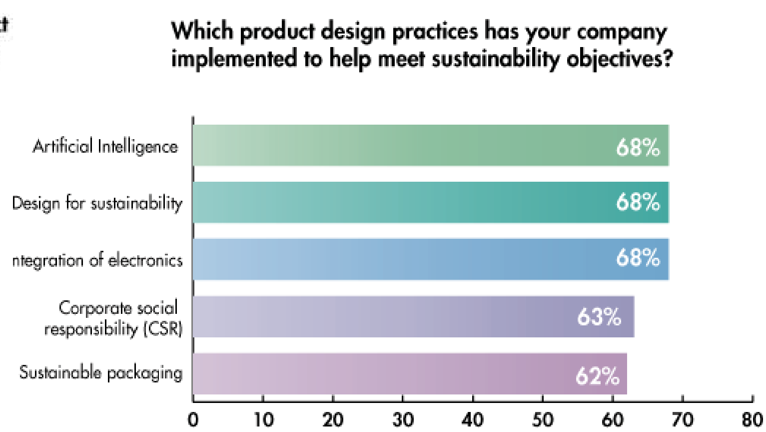
They received replies from 200 people, 50 of whom were company executives, 50 were sustainability managers and professionals, and 100 were product designers and engineers. 75% of the respondents were between 36 and 55 years old, with 60% at least 46 years old. 90% worked at companies with at least 100 employees and 30% worked in firms with 1,000 or more employees.

Most respondent had significant exposure to the concept of sustainability. 68% had been involved with the concept for at least six years and 21% have been working with it for 11 years or more.

Defining Sustainability

It would seem that most engineers include several aspects of sustainability when doing their jobs. They look for the least expensive methods and materials to accomplish a task or build a product. They strive to reduce scrap and not waste energy. They also adhere to environmental regulations.

"Engineers *are* focused on efficiency in their work," says Paige Marie-Morse, a sus-

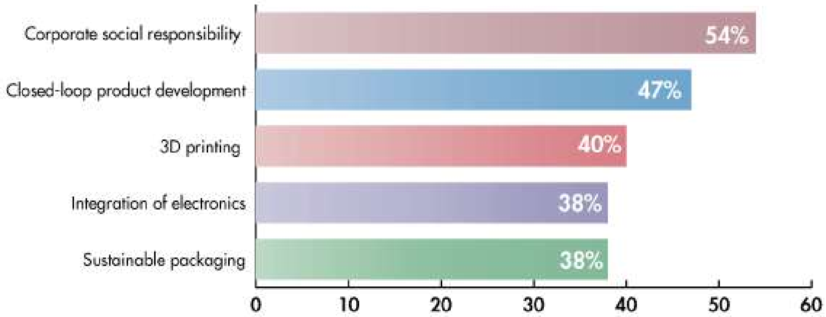


tainability manager at AspenTech, a firm that assists companies in monitoring and managing assets. Its asset management software helps organizations streamline engineering and maintenance to reduce downtime and increase operational efficiencies. "But at AspenTech, we align our definition of sustainability with the United Nations Brundtland Commission. It defines sustainability as 'meeting the needs of the present without compromising the ability of future generations to meet their own needs.'"

"What has changed for engineers are the metrics used to evaluate projects and designs. Industrial organizations have broadened their performance metrics beyond only financial performance and ROI in product design to increasingly account for environmental metrics such as emissions and waste reduction, and the impact of manufacturing processes on local communities. It's the balancing of these factors, as well as tracking less obvious measures, that makes efforts toward sustainability more challenging."

"Industrial organizations have broadened their performance metrics beyond only financial performance and ROI in product design to increasingly account for environmental metrics such as emissions and waste reduction, and the impact of manufacturing processes on local communities."

Which product design practices is your company considering to help meet achieve sustainability objectives?



COMMENTS ON SUSTAINABILITY

Rating	Comment
7.88	Management here believes promoting sustainability efforts is the right thing to do. Good ethics is good business.
7.86	I am proud to work at my company because of its investment in sustainability.
7.84	It's easier to get financial approval for initiatives that increase productivity than initiatives related to sustainability.
7.82	The sustainability focus of our company has a positive effect on day-to-day operations and productivity.
7.65	Our company has an active program for reprocessing materials as part of our sustainability initiatives.
7.53	Our company actively seeks to make products that contain at least some recycled content.
7.33	The sustainability movement is creating external pressure that is forcing organizational change in our company.
7.26	Fiscal responsibility trumps altruistic concerns for issues such as sustainability.
7.25	Our sustainability initiatives are driven by government requirements rather than being the "right" thing to do.
7.06	Our company only focuses on sustainability practices where there is no additional costs or investments required.
6.96	The focus on sustainability hurts the quality of our products.

The Results

For most, their organization's involvement with sustainability were based more with an eye on the bottom line and improving the company's reputation than on a commitment to any idealistic goals.

Regardless of why they support sustainability, most companies did make changes in product design in response to it.

According to the survey, respondents say 88% of companies have made changes in product design and sustainability in the last two years. So, it seems companies are doing a lot to achieve sustainability in product design.

Current and future emphasis appears to focus on mission-driven efforts such as corporate social responsibility (CSR). For this survey, CSR is how companies adapt product development so that it has a positive effect on society and considers more than just the economic consequences. We know more than 60% of respondents report they prioritize this approach in product design, and more than half expect to increase CSR initiatives in the coming years.

The survey also indicates that sustainability initiatives have positive momentum among product design and engineering companies.

Respondents were then asked which product design/development areas in their company would benefit most by implementing sustainability initiatives. 51% said materials engineering and 50% said sourcing and procurement.

They were also asked how confident they were that employees understood and could recite how company sustainability initiatives align with the overall company strategy. On a scale of 1 to 10, with 10 being very confident, executives and sustainability professional said 8. Product designers and engineers came in a little lower at 7.

When asked how confident they were that company investments in sustainability will lead to significant value, revenue gains, cost savings and enterprise value, answers were similar. Executives and sustainability professionals said 8, while engineers and product development designers rate their confidence a 7.

Here are some comments on this survey question from respondents arranged according to their ratings.

So, according to the survey results, those responsible for setting sustainability strategies are more confident about its implementation being successful than those responsible for implementing it.

Those setting and carrying out sustainability strategy also have a list of top priorities.

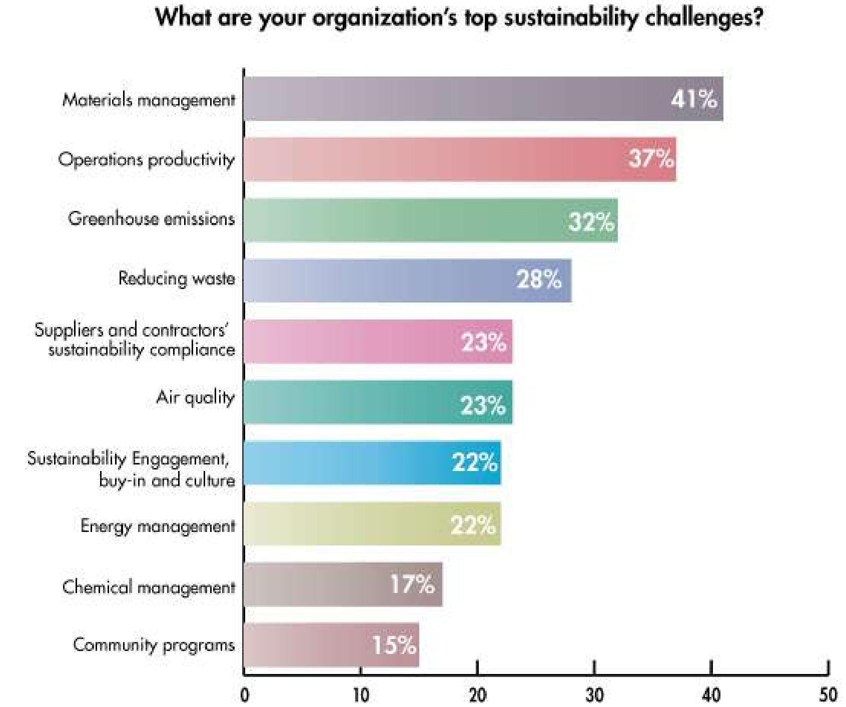
Respondents indicate that sustainable materials management is expected to be the top challenge today and into the future. Overall, companies expect to be working toward these same goals two years from now.

Respondents indicate that sustainable materials management is expected to be the top challenge today and into the future.

Sustainability seems to be such a broad umbrella that it is taking up a large percentage of employees' time. As the accomapanying graphic shows, respondents say they are working on a variety of sustainability initiatives.

There are a lot of initiatives competing for organizational time and resources, which could divert the company's focus from more profitable pursuits.

For a copy of the report, visit *https://get.protolabs.com/sustainability-trend-report/.* ■



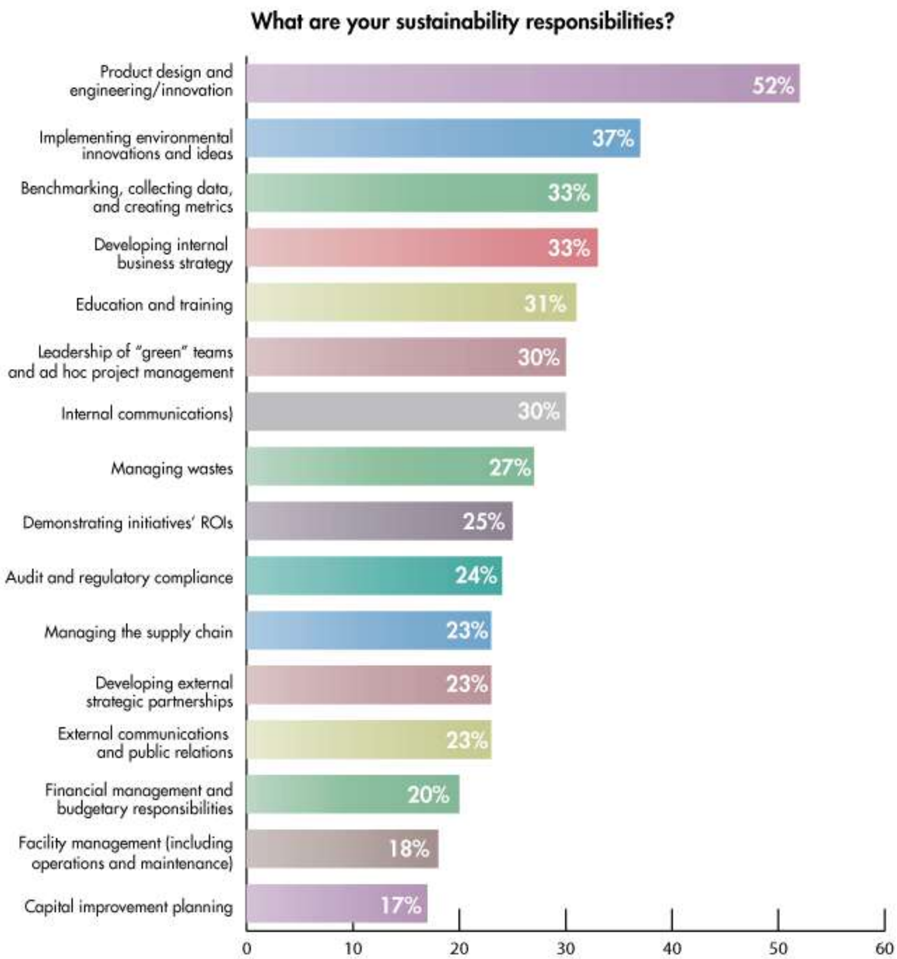


Image: Pavel Shlykov | Dreamstime

Engineering Your Career, Part 4:

Networking and Being Mentored

Career advancements come to engineers through the support of many others.

by Tricia Hatley, Immediate Past President, National Society of Professional Engineers

What does career success mean to you? For some, it is being highly compensated and able to comfortably take care of yourself and family. For others, it means power and control. It could also mean continuing the legacy of a family business.

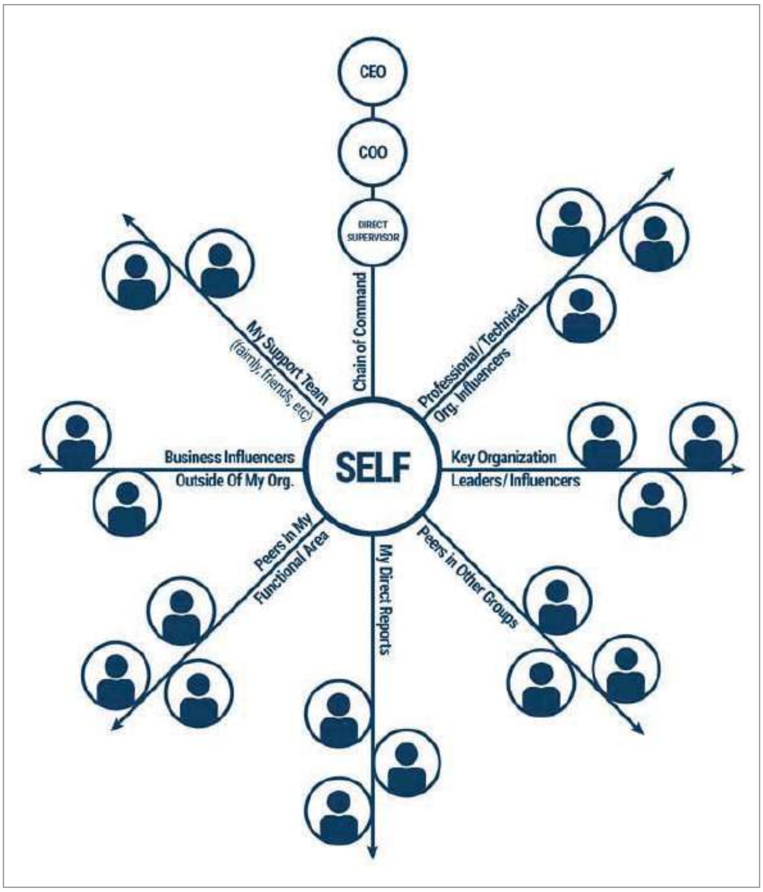
Many engineers and technical professionals define success as working on challenging projects and creating technical innovations or being considered a technical expert. You may have an entrepreneurial mindset, so success could be building a new business or service line. Or it may simply mean you have found fulfillment in your work, and you are happy.

As you look for ways to advance your career, understanding your drivers and motivation is critical. And be aware that these can change over the course of a 40-year career. But if you can picture what success looks like, you have taken the first step toward a successful career.

In the early stages of your career, you should seek out those in your firm or organization who are effective based on your definition of success. Once you identify these individuals, seek out opportunities to work with them. Try to position yourself so you can watch them work, see how they organize their days, and learn as much from them as you can. If working directly for these individuals is not possible, maybe you can volunteer for a committee or team project that lets you to interact with them. If nothing else, ask them to be your mentor. Most of these people are eager to mentor and develop younger engineers.

In the early stages of your career, watching and learning is key. Soak up the good you see and take note of the things you don't like. No one is perfect and everyone has their own style. Watch others and learn which style works best for you.

As your career progresses and you begin mastering the technical aspects of your work, consider building your network. For most, advancement comes through the support of many others, and you will need them to back you along the way. One useful tool for this is a network diagram. It can help in growing your support team. The diagram should contain people you interact with at work, including your supervisor, those in key leadership positions and your peers across the organization. It should also contain personal and family friends who are important to you.



Once you have the diagram roughed out, look at relationships that need strengthening. Where do you need to invest more time? Are there people in the diagram you don't know as well as you should? For each person, consider what you know about them and how they like to get information prior to meetings or discussions. Keep a copy of the diagram and a page for each key person at work. Make notes of what you learn about your contacts and how best to communicate with them. For engineers, this may all sound too touchy-feely, but organizational politics is all about relationships, and healthy relationships are crucial to success.

Another aspect of career growth is self-awareness and being honest about your strengths and weaknesses. Several tools can help identify blind spots, including 360 reviews and profile assessments. It is always helpful to invest in your strengths while also understanding your weaknesses. Learning about your weaknesses and what may be holding you back lets you focus on one or two key improvement areas. But it is equally important to find ways to leverage your strengths. These strengths are the assets you bring to the table, so invest in them to reach your career goals.

Taking opportunities offered to you shows a commitment to the organization. If you take the steps discussed so far and are intentional about your career, you will have opportunities. Some of them will clearly be a great fit and easy for you to assess. Others may not seem to be a good fit or may look like a lateral move.

But evaluate each opportunity carefully and find a way to say yes. That doesn't mean you can never say no, but you should avoid turning down opportunities without carefully evaluating them or offering suggestions for modifications that might make your answer positive.

Sometimes opportunities look like lateral moves, but consider them as improving your chances for advancement. A move within the organization may let you learn different segments of the business and prepare you for a promotion. Taking opportunities offered to you shows a commitment to the organization. At the same time, turning down a move that isn't right for you (or your family) can be a positive, so don't mistake this advice. But look at them from all angles and seek advice from a mentor or friend before turning them down. Careful consideration and clear articulation of why you are saying no is important and can help pave the way for future openings.

So, what risk are you willing to make for your future? Do you have the vision to see that a step sideways—or maybe even backward, but in a new location or service line—will provide the experience for driving your career forward? Do you have the network and relationships needed for successfully navigating these and other important life decisions that will come your way? Now is the time to reflect on these questions and chart your path to career success. ■

This is the last part of a four-part series on how engineers must adapt in these changing times. Part 1 covers the challenges facing today's engineers, Part II covers PE licensing and Part III covers personal and professional development.

Smaller Parts, Bigger Challenges

Advanced parts manufacturing demands advanced measurement technology.

by **Tsuyoshi Aomi**, Chairman and CEO of Aomi Precision

Innovative cutting and machining processes continually make more intricate features and precise geometries possible. *Image: AOMI Precision*

When it comes to creating miniature parts, innovative cutting and machining processes continually make more intricate features and precise geometries possible. Although advanced machining can create small parts with previously unattainable features and shapes, the systems and equipment used to measure them must keep pace.

Small-scale manufacturing irregularities may not affect larger parts, but they may present major issues for micro-sized parts. Small part sizes also bring measurement challenges. A part design may have, depending on how it will be used, intricate shapes as well as micro-sized features or hole geometries. The advanced machining tools that make it all possible have impressive capabilities. For example, a manufacturer with advanced machining capabilities can:

- Process a thin-walled product with a thickness of 0.1 mm and roundness of 0.01 mm or less.
- Create parts with outer diameters smaller than Ø160 to strict geometric tolerances.
- Cut parts to a geometric tolerance as low as 0.002 mm and surface roughness of under 0.6S.
- Achieve hole dimension tolerances down to ±5 µm or less.
- Specialize in ultra-fine processing of 1 mm or less.

For manufacturing technology progresses to deliver smaller parts with more sophisticated features and geometries, it pays to work with a fabricator that uses leading-edge metrology systems and equipment. This is especially true if the complex part is intended for critical applications like medical devices and instruments. These challenging part measurement elements demand top-notch metrology expertise and capability.

Accurate Clearance Measurements

Precision machining shops often encounter assemblies in which the constituent parts must fit into a space with virtually no clearance, such as when a shaft and hole have the same diameter. That means the tolerance—the maximum permissible variance between dimensions—can be as low as thousandths of a millimeter.

One such assembly involved a spool with an outer diameter of φ8 (0.000/–0.002) and a sleeve inner diameter of φ8 (+0.002/0.000). With such a tight clearance accuracy requirement, AOMI Precision employed an air micrometer and a CNC roundness measuring machine to achieve a proper fit. The air micrometer—which requires extensive operator training and meticulous calibration—injects a fixed amount of air and converts the returned air volume into electrical signals, providing dimensional measurements with sub-micron-level accuracy.

This contactless measurement method is well-suited for inspecting the surfaces of critical devices such as hemolytic pumps. This machine provides a rotational accuracy of 0.015 + 0.0003 µm per millimeter to measure the inner and outer diameter of a workpiece with high repeatability. It can also measure the straightness, parallelism and taper angle of a tapered surface. To ensure uniform measurements, the test equipment used to inspect the assembly is kept in a constant temperature room at all times (20 ± 0.5°C, 50% ± 5%).

Measuring Surface Roughness

If there's a potential problem during

the machining process, the part's surface finish is likely to provide an early clue. Changes to the roughness or texture of the surface—sometimes called "chatter"—can indicate tool wear, unexpected or improper tool speeds or temperatures. For these reasons, surface measurement is an essential step to ensuring part quality. Many parts have holes that are too difficult to access using traditional surface roughness measuring devices, so a non-contact measuring approach is necessary.

For example, AOMI employs a high-speed, non-contact 3D optical profiler. Its 1,024 × 1,024-pixel array provides a large field of view, and its data specifications include 0.1Å rms resolution, <0.2Å rms repeatability and 0.1% step height repeatability.

Using this scanner, a custom part with a hole-bottom surface roughness of Rzmax0.4 Wz0.3 and hole side surface of φ12.917 mm was measured. The hole depth was 43 mm—out of reach for most surface roughness measuring devices.

Comprehensive Hole Measurements

Another obstacle to accurate hole measurement is identifying differences between the measured value of a measurement point and the design values specified in the CAD data. Coordinate measuring machines can visually check the error of each measured value obtained to evaluate flatness, roundness and cylindricity in order to examine the unevenness of the plane at a glance. The machines also should include a function to evaluate free-form surfaces.

Not all machining companies have the experience and capabilities to apply advanced metrology when measuring parts. When selecting a precision machining partner, here are some of the things you should look for:

- **High-end inspection equipment.** A full-service precision machining shop will have a comprehensive roster of high-accuracy, high-precision CMMs to measure various geometric points on a part in real time, along with CNC roundness and concentric shape instruments, non-contact and optical measurement instruments, contour shape measurement systems and a wide range of measurement probes.
- **Temperature-controlled inspection facility.** Environmental conditions can have an influence on the dimensions of the part being measured as well as the precision and accuracy of measurement instruments themselves. To ensure repeatable measurements, inspections must be conducted in a room in which the temperature is continuously controlled at a high level.

- **Quality standards.** Approvals and certifications are another indicator of a machining company that delivers high-quality products. Be sure to look for a company that carries an ISO 9001:2015 certification. ISO 9001:2015 is a quality management system for companies with demonstrated ability to consistently meet customer and regulatory requirements. A similar certification—ISO 13485—covers quality management systems for medical devices and related services. Medical customers should also ask about a company's license for medical device manufacturing.

Measure it Before Making it

As precision cutting and machining processes create smaller and more sophisticated parts for medical and other critical devices, micro-size dimensions and tolerances are pushing the limits of traditional measurement instruments. If a part manufacturer can't measure the part, they can't make the part. In order to be sure your miniature part can be manufactured with uniform and consistent quality, select a precision machining partner with robust and top-quality metrology capabilities. ■

This CNC roundness measurement machine measures workpiece diameters to an accuracy of 0.015 +0.0003 µm per millimeter. *Image: AOMI Precision*

High Voltage Connectors a Solution for Medical Devices

The REDEL 2P Multi-Contact High Voltage Connectors are available in 2, 5 and 8 contact configurations. They are for use in medical applications where compliance to user safety IEC60601-1 (Rev. 3) is required. The connectors significantly increase the air clearance and creepage distances to guarantee user safety, all while maintaining a small connector size. Building on the 2P series legacy in medical applications, the connectors are a solution for PFA (Pulsed-Field Ablation) and PEF (Pulsed Electric Field) catheter and cardiac applications technologies. They feature push-pull positive latching with an audible click, are triple keyed for blind mating in low light conditions, and have alternate mechanical key and color-coding options.

LEMO

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Data Cables Offer a Variety of Styles, Applications

The Murrelektronik data cables are high-flex shielded Ethernet Cat5e cables offering various connector styles, including D-coded M12 to M12, M12 to RJ45, RJ45 to RJ45, and M12 to pigtail. These cables are flame-retardant and chemical resistant with a tough TPE (thermoplastic elastomer) jacket for typical industrial applications. A selection of RJ45 IDC field wireable connectors and adapters have also been added to provide custom terminations for specific applications. Supporting Cat5e and Cat6a Ethernet with a variety of cable outlet options, these connectors and adapters are an easy solution for complex field-wiring needs. Another addition is the M12 L-code power cables, couplers and adapters. Power cables are available in 14 or 16AWG with current ratings up to 16A. Adapters and couplers provide an easy way to convert the different connection options to match the job at hand.

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Compact Power Unit Offers Unique Features

The INKA intelligent compact power unit is equipped with many standard technical highlights. The attached electronic communication box with integrated real-time operating system enables the acquisition and storage of operating data, extensive diagnostic options and a self-test for all measuring functions. The measured values of the integrated multi-sensor, including the motor speed, can be transmitted to the higher-level machine control system via an IO-Link interface. In the software, the calculated volume flow, the running time of the unit and much more can be displayed via the motor speed. The software also enables the digital creation of variants of the INKA with switching outputs, which is very interesting for flexible adaptation to different machine types by the OEM himself. The status messages of the integrated multi-sensor on oil temperature, fill level and general condition of the unit are also displayed at all times via the LEDs on the communication box.

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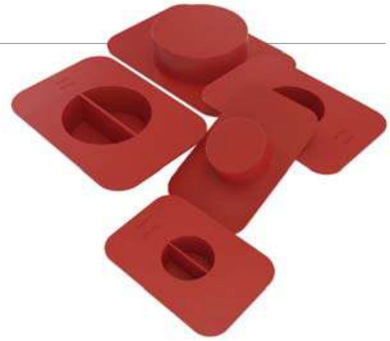
Split Hydraulic Flanges are Easy to Install



The SHF Series split hydraulic flange plugs are designed for use on SAE 3000 lb, four-bolt split hydraulic flanges, allowing for maximum flexibility. Designed to protect the port, flange surface and bolt holes from damage and debris during transit, handling and storage, the SHF series Split Hydraulic Flange Plugs are easy to install and remove and are molded in red LDPE plastic to fit 3/4-12 thru 2-1/2-40 nominal flange sizes.

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Electronic Circuit Breaker Embeds Intelligence into System

The CAPAROC electronic circuit breaker system uses data-driven power modules to customize overcurrent protection. With numerous feed-in power modules, circuit breakers, potential distribution modules and current rails, CAPAROC makes it easy to design an intelligent system with communication. The power feed-in module, available in status reset or PROFINET versions, is the "brain" of the system. The status reset uses standard digital input/output to communicate the status of the breakers and to reset tripped channels. The PROFINET power module allows complete control and monitoring of the breakers.

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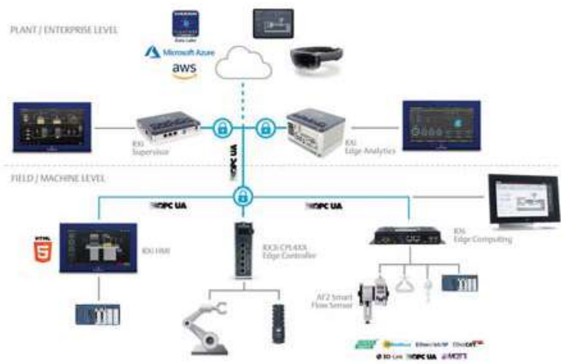

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The PACSystems Edge Solutions are a new portfolio of turnkey industrial edge hardware and software solutions. Edge Solutions simplify selection and deployment, helping original equipment manufacturers (OEMs), systems integrators and end-users significantly reduce the time spent integrating, developing and validating digital transformation projects. From low footprint connectivity and computing to plantwide analytics and supervision, the portfolio delivers a scalable range of edge capabilities in fit-for-purpose packages.

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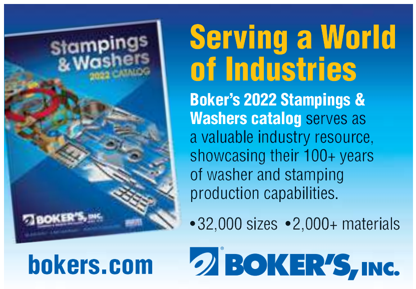
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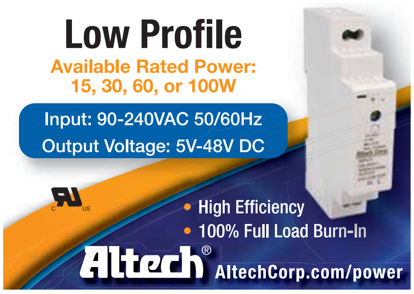
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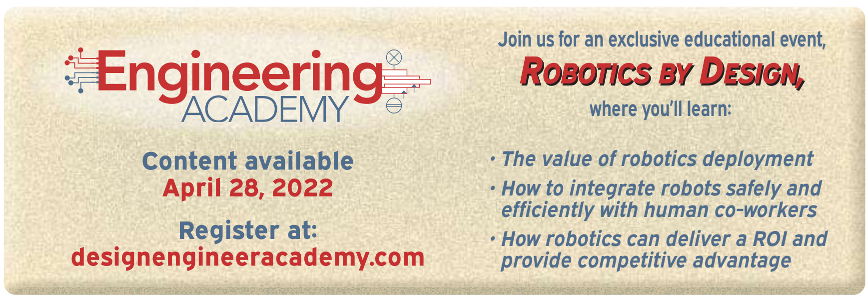
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• How robotics can deliver a ROI and provide competitive advantage

Ad Index

Book Review:
Hot Tech Cold Steel

The tale of a pioneer in computer-aided manufacturing and NC machining.

by Stephen J. Mraz, Senior Editor

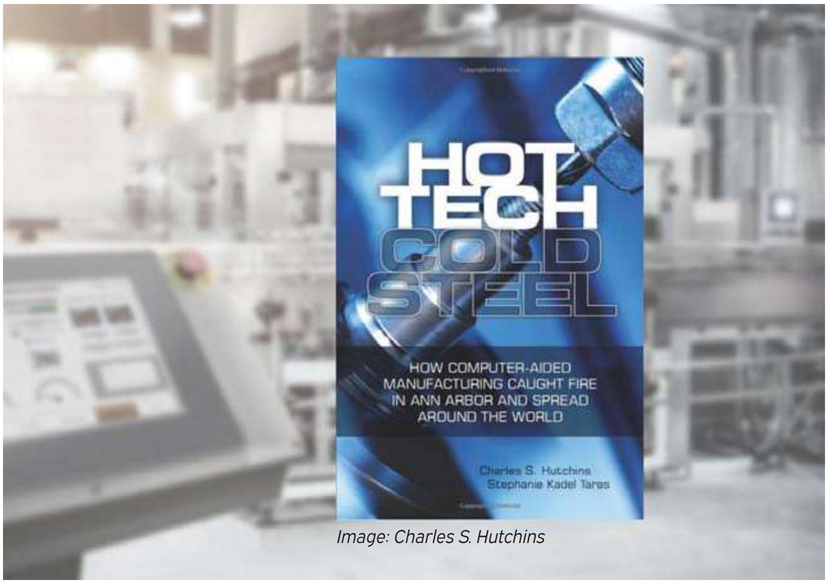

Image: Charles S. Hutchins

Hot Tech Cold Steel is an autobiographical look at the engineering and entrepreneurial side of Charles Hutchins' life. With a mechanical engineering background and education, along with a self-taught mastery of software and management, Hutchins describes a textbook case of leveraging the latest in technology and knowledge of an industry—machining parts and product—to build a world-class company, Manufacturing Data Systems Inc. (MDSI).

Together, he and his well-chosen partners back in the 1960s and 1970s took numerical control (NC), which is now better known as computer numerical controls (CNC), and made it accessible and profitable for small and mid-sized manufacturers and machine shops. No longer would it be confined to deep-pocket companies making airliners and military platforms.

From a historical perspective, the book is a window on a time when computers were strictly mainframes, there was no internet or email, and good software coders were hard to find. It traces the changes in hardware and software as Hutchins and MDSI served as a midwife to computer-aided manufacturing, truly an industrial revolution that continues to evolve today.

Some of the innovations they birthed include computer timesharing over modems in the 1970s, the forerunner of today's internet-based cloud computing. MDSI was also one of the first companies that pushed software as a service (SaaS), letting companies with few computing capabilities and little experience enjoy the latest technological advancements. In addition, the firm pioneered the business model of letting third parties develop value-added software that could be easily integrated into its core platform. And if clients had trouble with that integration, MDSI stepped in and provided all the help they needed.

MDSI and its clients profited handsomely. MDSI had one of the most successful IPOs of the 1970s, according to Venture Capital Assoc. The global firm was eventually sold in 1981 for $210 million.

The book also outlines a gameplan for today's engineers and entrepreneurs who dream of starting and running a highly successful tech firm. From staffing it with hard-working and capable engineers to treating clients like partners, MDSI seemed to make all the right steps. And most importantly, Hutchins and the MDSI team first understood the technology and the industry they wanted to serve and had a vision of how to make things better for all involved.

Engineers and technologies will appreciate the details the author provides on going from punch cards to data tapes to modems, detailing the various hardware that was once high-end and its limitations in terms of speed and memory, as well as cost. They might also find themselves envying the engineers and others hired at MDSI and then pushed to learn and develop in an atmosphere that recognized and rewarded performance over politics.

Hot Tech Cold Steel, by Charles S. Hutchins and Stephanie Kadel Taras (2021). You can find it online for $18. If you are interested in winning a copy, please send an email to smraz@endeavorB2B.com with HTCS in the subject line. A winner will be randomly chosen on April 15th to receive the copy the publisher sent to *Machine Design*. ■