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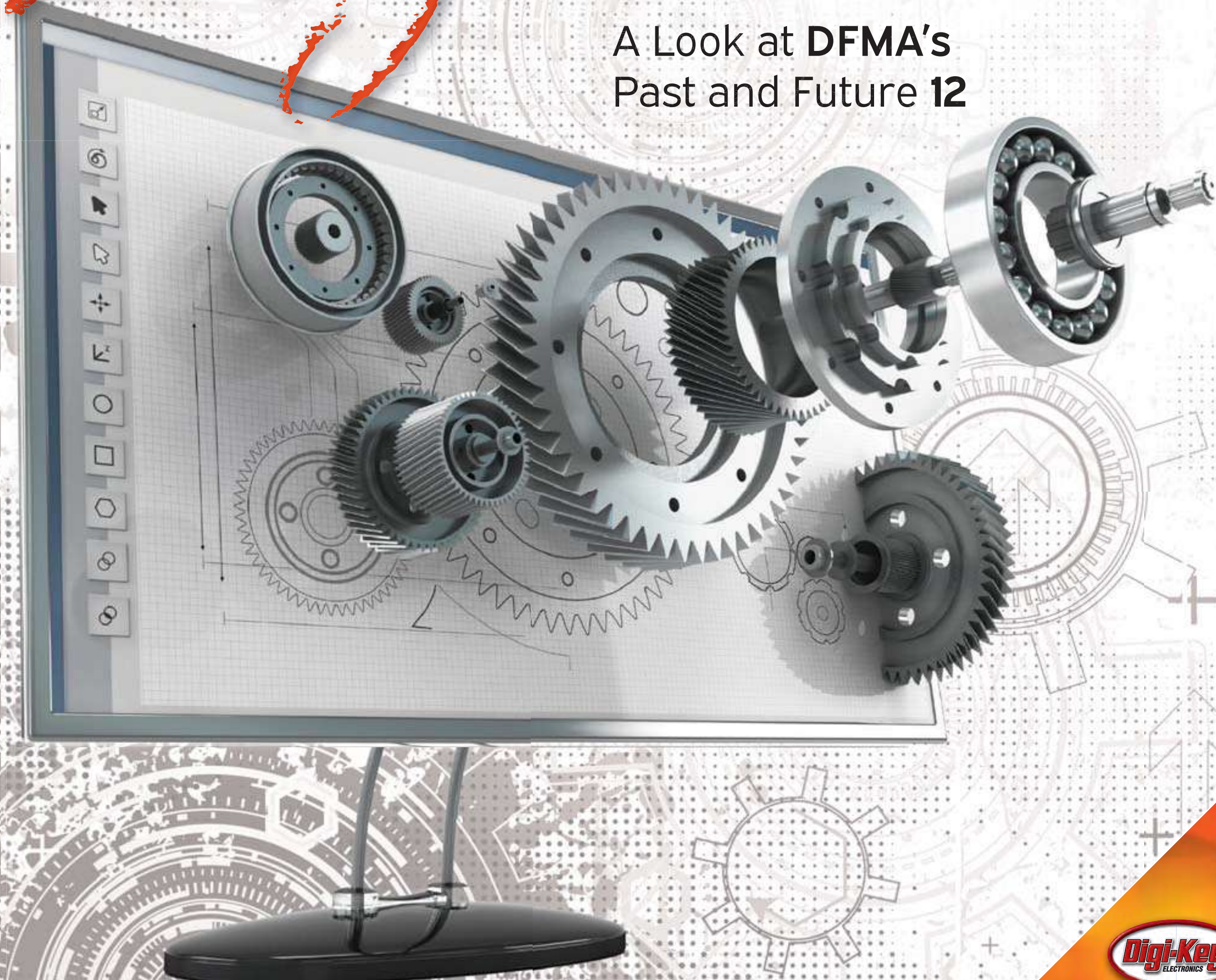
## Design FOR MANUFACTURING:

A Look at **DFMA's** Past and Future **12**



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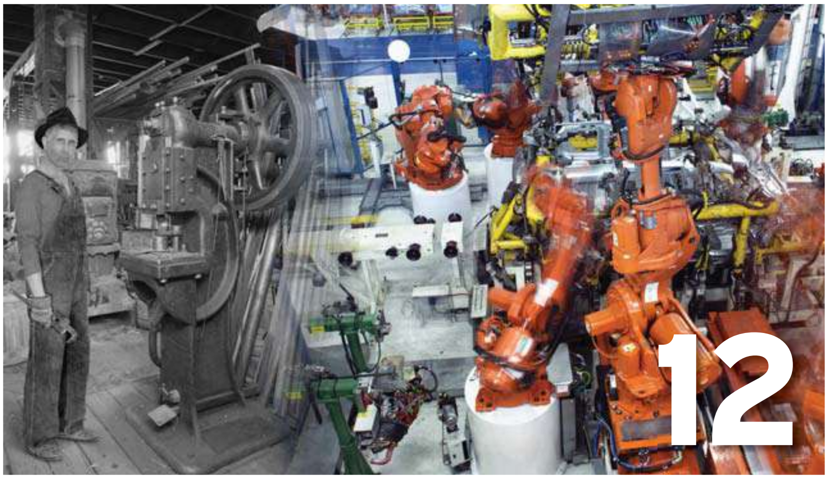
# INSIDE

MachineDesign
FEBRUARY/MARCH 2022
Volume 94, Issue 2

*"Companies that minimize the number of parts that must be assembled into products enjoy lower costs, smaller inventories, less handling costs, decreased working-capital requirements, faster times-to-market and higher profit margins."* — Bradford Goldense, Goldense Group Inc.




## COVER STORY

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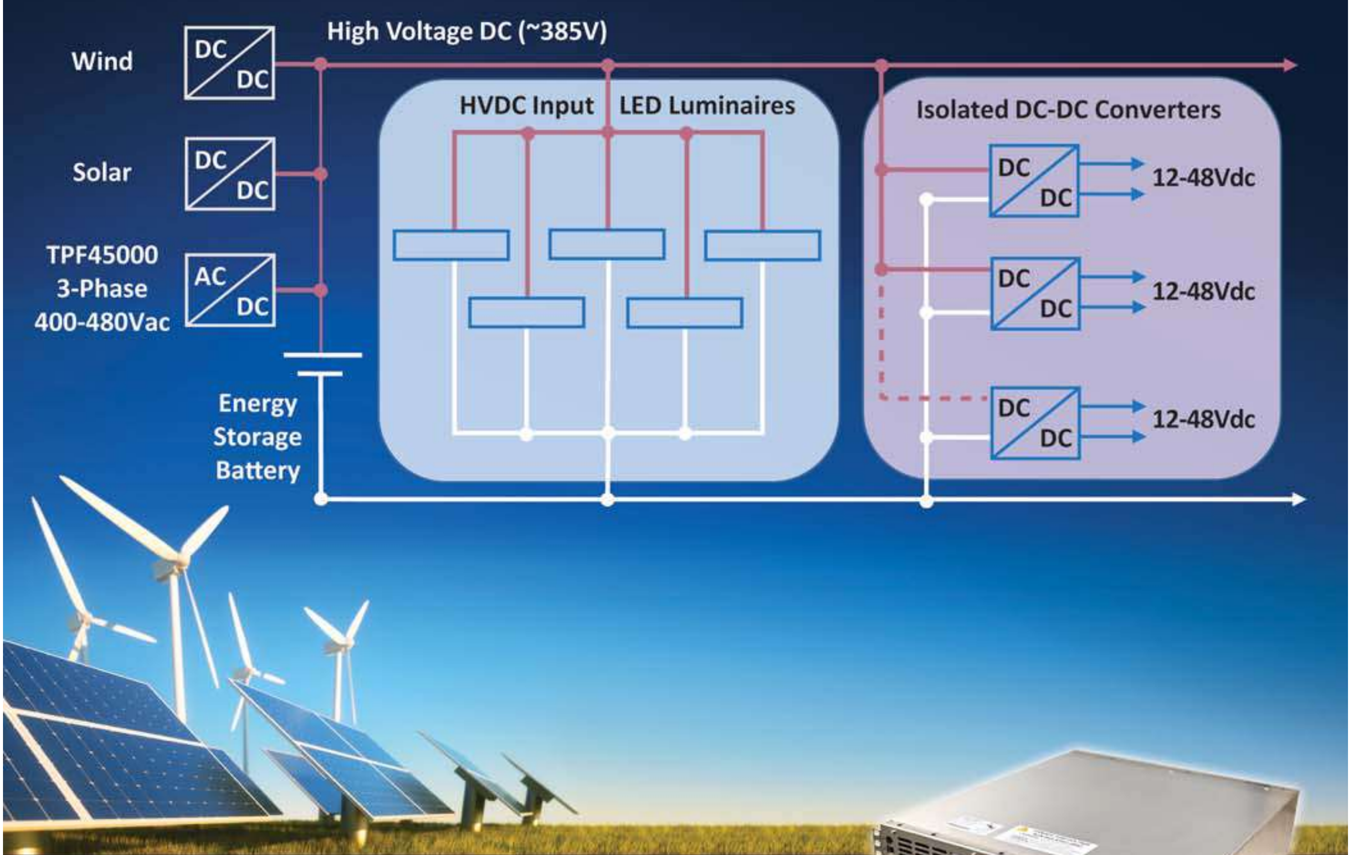


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**From the Editor**

By **Bob Vavra**, Senior Content Director

# **Demolishing** the Silos

Even in the modern workplace, effective communication between design and operations teams remains imperative.

**IN THIS WONDERFUL** and interconnected age of information, perhaps the best thing to come from all of it is the ability to deliver information to the right person at the right time in the right context. We can target our message and deliver our information to just the right person. That makes information more useful.

Sometimes we've depended too much within our organizations on these tools. The information can lack context, or what we used to call "the human touch." And with the events of the last couple of years, the human element has had to take a back seat to our need for safer conversations.

But that still shouldn't get in the way of making sure we continue to make valuable connections with other parts of our organization. One area we've focused on this month with our cover story—and one that will be the focus of a great deal of coverage throughout this year and beyond—is the relationship between the design and operations teams. The traditional silos that have existing in several parts of an organization are being demolished not just with better communication tools, but also with a better understanding of how connected enterprises can be more efficient and effective.

This is especially true for the design and operations teams. System design is only effective when it produces products that meet all the expected quality, safety and productivity standards. Yet that is not a fixed standard; there's always room for process improvement, both at the initial design stage as well as at regular review intervals. The operations team can influence effective design from conception, but it also can provide real-world feedback on how that design has performed.

The design team also can better create and optimize process design with a fuller understanding of the capabilities and limitations in operations. They can design a system that takes full advantage of those skills and delivers the best version of efficiency on Day 1.

Such an outcome isn't accomplished simply with communications, however. It's achieved through understanding the message being communicated. Whether through the use of our modern tools or across a table, gaining a deeper insight into the challenges and opportunities within the entire design-to-operate process is a worthy aspiration.

And as we seek to communicate this month, it's also a competitive advantage. ■

*Image: Orest Lyzhechka and Niderlander*

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# Sara Jensen to Lead *Power & Motion*

A veteran journalist in the fluid power space, she will direct editorial coverage for the recently expanded brand.


*Power & Motion*, sister brand to *Machine Design*, announces Sara Jensen has been hired as its technical editor, directing expanded coverage into the modern fluid power space, mechatronic and smart technologies.

"Sara joins us with more than a decade of experience covering the advancing fluid power industry. She specializes in onboard vehicle applications, which brings excellent balance to our existing competencies," says Bob Vavra, senior content director.

"Her active presence in the fluid power industry brings with it a strong network of established contacts and relationships that will help us further integrate ourselves into the fluid power and motion control markets," continues Vavra.

Jensen joins *Power & Motion* and the Design & Engineering Group at Endeavor Business Media after a successful career leading OEM Off-Highway, covering fluid power technology extensively as it has progressed from components to an integrated system, to a smarter and connected part of an optimized vehicle.

"Sara has a long history of creating exceptional industry coverage in a multitude of delivery platforms, from print magazine to digital content, including video and podcast formats. Her experience is exactly what *Power & Motion* needs to bring the next level of industry coverage to its audience," says Michelle Kopier, group content director for the Design & Engineering Group.

"I'm thrilled to be given a chance to lead the new *Power & Motion* brand at Endeavor Business Media," said Jensen of her appointment. "My interest in the fluid power industry has only grown as the technologies have advanced over the years, and I can't wait to dive even deeper into the industry." ■

## ARC Forum, Hannover Messe Postponed


**AFTER CANCELLATIONS OF** live events in 2021, two of the most prominent global trade events have been postponed until late May and early June. Show officials said the postponements were made to get past the current COVID restrictions.

Officials for ARC Advisory Group and Hannover Messe announced that their events have been delayed in 2022. ARC Advisory Group has postponed its 2022 Industry Forum to June 6-9 at the Renaissance Orlando at SeaWorld in Orlando. Hannover Messe will be a four-day event in 2022, scheduled for May 30 to June 2 in Hannover, Germany.

The ARC event was originally scheduled for Feb. 14-17 at the same location, but the event was delayed "to ensure the safety of our customers, partners, and employees," ARC officials said in a press release.

"We believe that the COVID situation will be much improved in June for us to have a more meaningful learning and networking experience," ARC officials said in the press release. "Those of you who have already registered for the Forum, your registration will be valid for the June Forum, and you do not need to register again."

The ARC Industry Forum's online event also has been postponed until June 20-23.

Officials at Hannover Messe, the world's largest industrial trade show, had a similar message in postponing the event from April 25-29 until later in the year. ■

# Self-Replicating Fab Lab Brings Innovators Closer to Self-Sustained Future

**IT'S NEVER A BAD IDEA** to give back.

But it's just part of a message Paul Altidor, former ambassador of Haiti to the U.S., hoped to convey when he announced his intention behind locating a state-of-the-art fab lab in the town of Jérémie. The project potentially closes the gap between local makers and advanced global digital fabrication tools and skills.

The announcement was made during a media session at 3DEXPERIENCE World 2022 (Feb. 7-9). Altidor joined Sherry Lassiter, president & CEO of The Fab Foundation, and Suchit Jain, vice president of Strategy and Business Development for 3DExperience Works, Dassault Systèmes, in broadcasting the announcement during the virtual event.

"The Center for Bits and Atoms at MIT has been working closely with The Fab Foundation, which has a mission of providing means and ways by which communities in different parts of the world can essentially sustain things—so giving power and democratizing the idea of creation," said Jain.

In essence, fab labs provide a platform for capacity building, knowledge sharing and integration of hardware and software disciplines.

The Haitian fab lab will be the fifth in a series of facilities set up jointly by Dassault Systèmes and The Fab Foundation. The other four are located in Rwanda, Bhutan, Chile and Nepal.

## Self-Replicating Fab Labs

Fab Lab Jérémie differs from the other four because it is planned as the first in a series of "self-replicating" fab labs. In other words, this facility will be equipped to make machines that can create the entire set of other machines, components and utilities needed to function a fab lab in a second community.



**Paul Altidor, former ambassador of Haiti to the U.S.** *Dassault Systèmes*

"We call this Fab Lab 2.0," said Lassiter. "We've partnered with MIT's Center for Bits & Atoms on a project called 'Machines that Make,' and can now produce the machines for a fab lab, in a fab lab."

## The Goal is to Provide Access

Locating the pilot in Jérémie will enable the Haitian community to build new economic opportunity locally, and to scale opportunity across the country," Lassiter said. She described the project as a nexus of innovation and a network for the larger additive manufacturing community.

The fact that the facility can be set up at 1/10th the price of off-the-shelf technology is a strong motivator. The cost of setting up a typical fab lab is around $150,000 in materials, equipment and shipping. "It's really hard for many communities around the world to have access to that kind of money, and these kinds of resources," said Lassiter. "But when you make it yourself, you're probably talking about $15,000. Now that becomes a lot more accessible to the community and to a business. And it makes it very scalable."

Altidor explained that the project not only brings access to cutting edge technology to the community, but will serve to "reduce our dependency on a number of issues with the world" and open "a set of doors that were historically closed to people."

Altidor, who is also native to the city of Jérémie, explained that 70% of the population is under the age of 25 and that locating the lab in Jérémie would be tantamount to building the future.

"We're talking about designing, thinking, innovating for the future," said the MIT graduate and guest lecturer. "Once you put these kinds of tools in the right hands, with the right guidance, the sky's the limit in terms of enabling Haitian innovators—young folks in the country, engineers, designers. I do feel that this can be a catalyst for something that can happen." ■

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Cover Story

# A History of Design for Manufacturing and Assembly

The specialization of engineering and manufacturing disciplines drove industry to formalize the cross-functional knowledge needed to re-integrate the specialties.

**by Bradford Goldense,** President of Goldense Group Inc.

Image:: WisconsinArt/Dreamstime and iStock

The need for Design for Manufacture and Assembly (DFMA) began shortly after the dawn of the Industrial Revolution, but it took a hundred years for it to ultimately come into focus in the 1960s, and it did not really blossom until the 1980s.

**The road to high volume:** Frederick Winslow Taylor and Henry Ford, co-creators of the assembly-line process of manufacturing, began tearing apart the centuries-old Master-Apprentice Model as the Model A was being designed in 1903. Masters knew how to do everything, from concept-to-customer, and intuitively designed products so they could make them efficiently. But, taking 8 to 15 years to train Masters in all the required skills simply didn't cut it when it came to meeting the immediate and large demand for cars and trucks that arose in the early 1900s.

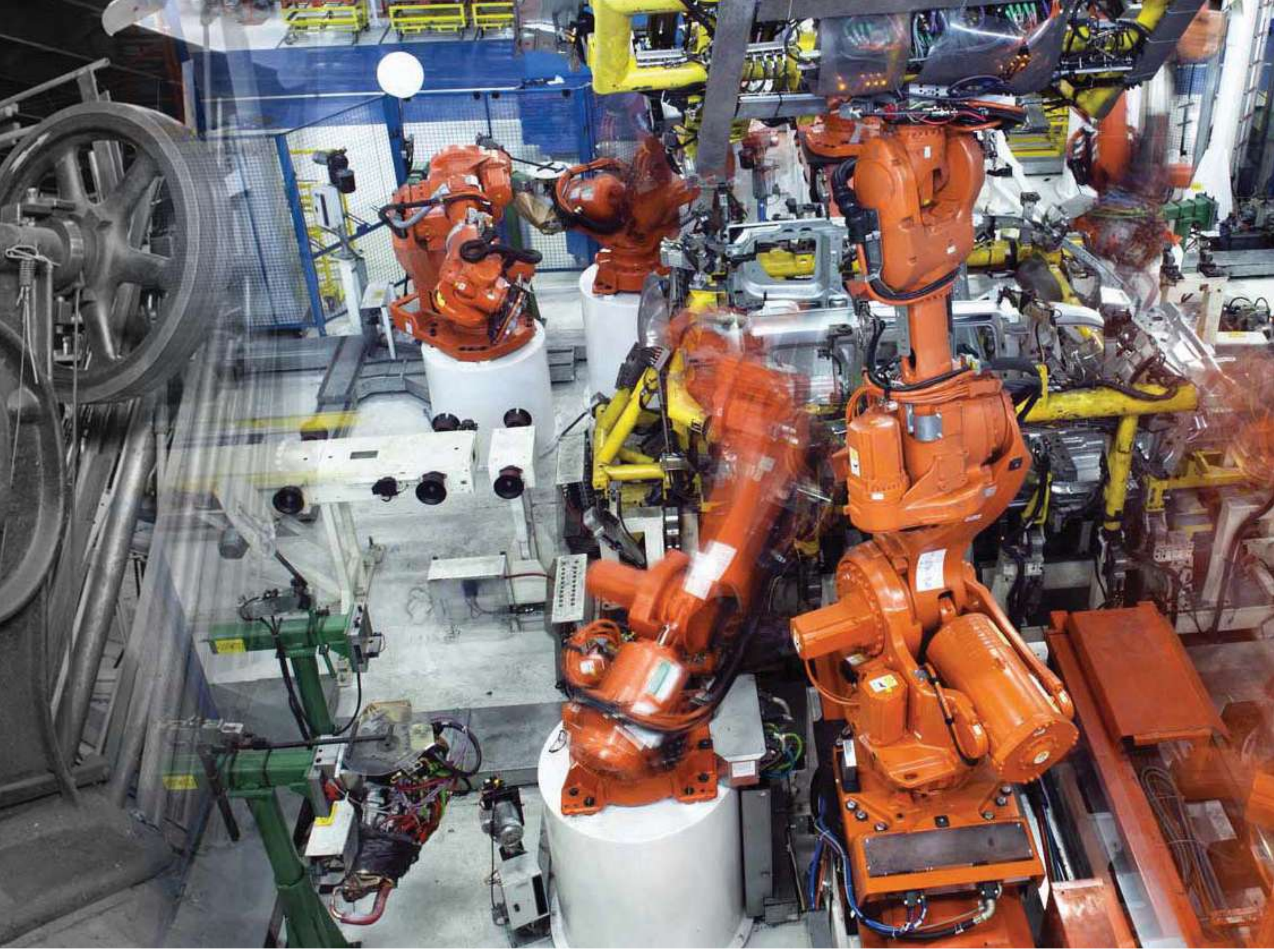
So, while transitioning from the Model A in 1903 to the Model T in 1908, Taylor and Ford introduced task specialization at every step of the design and manufacturing process. With specialization, each person could be trained to do their piece of the overall process in a few weeks to a few months, which led directly to high-volume manufacturing.

The underpinnings of manufacturing specialization had been in the works since the 1870s, as Taylor's productive approaches grew and spread. The underpinnings of engineering specialization actually began earlier, in the 1850s. The Second Industrial Revolution led to completely utilitarian product designs. Aesthetics had never been important.

Like Taylor, Christopher Dresser was on a mission to improve the way products looked. As the first person credited with improving the look of new products, Dresser helped many companies in the late 1800s. The founding of The Rhode Island School of Design in 1877 affirmed the importance of good-looking products. As Dresser aged and finally passed in 1904, Joseph Sinel became the recognized expert and further refined the approaches and processes of product design.

The first attributed use of the term "industrial design" was in 1919 and is credited to Sinel. When The Carnegie Institute of Technology created a formal product-design curriculum in 1934, the final milestone for the specialty of Industrial Design was set.

**Organization evolution:** As task specialization spread across industries, company-wide organizational structures quickly evolved to accommodate this new and improved method of work. Soon, there were departments for each specialized capability. Today, at the macro level, we think of them as the level-one blocks such as Marketing, Engineering,



Purchasing and Manufacturing on most companies' organizational charts. Of course, each of these level-one blocks houses its own respective sub-specialties.

For the first several decades, with most companies and industries staying small and designing and producing for their own countries, this all worked fine. Assembly-line business and organizational structures certainly proved faster than the Master-Apprentice approach. However, as globalization started and products were designed and manufactured all around the world and global companies emerged, the flaws in task specialization became increasingly evident.

**Departmental optimization:** By the late 1970s, driven by the need for speed as global competition accelerated, departments were under so much pressure to complete tasks quickly that managers began optimizing their department at the expense of optimizing the company.

## AT A GLANCE:

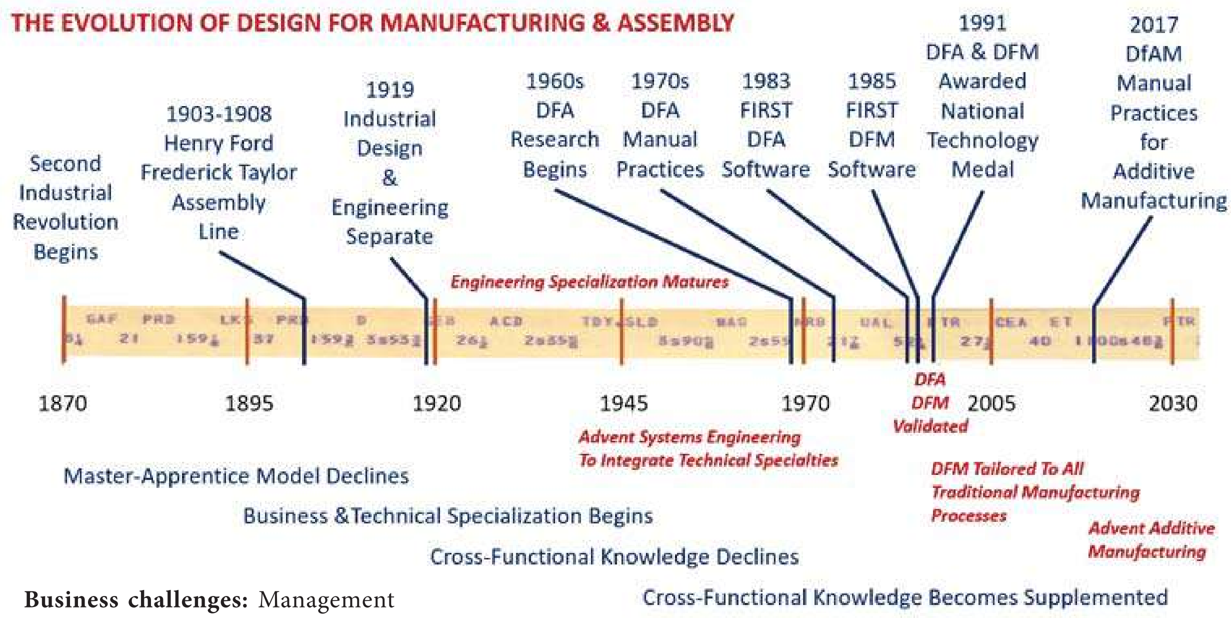
- The need for DFMA traces back to the Industrial Revolution, but it took until the middle of the 20th Century to come into focus.
- As globalization took hold, with products being designed and manufactured all around the world, the flaws in task specialization became evident.

Department self-optimization became widespread.

This problem appeared in just about every department. For example, Marketing and Product Management pushed for a long list of unique features which would make it easier for Sales to generate revenues. They hoped to dazzle customers by out-featuring the competition, regardless of the time Engineering would take to design a product that met all the extraordinary requirements.

**Engineering monomania:** Engineering's self-optimization, analogous to Marketing and Product Management, resulted in highly elegant design packages that manufacturing simply couldn't produce—or took too long to do so. Tight specifications and tolerances often exceeded the manufacturing equipment's capabilities. Components were not optimally designed for the tooling, equipment and processes actually available to manufacturing.

Designs were also unnecessarily complex. They had many parts, each designed by engineering specialists, and that drove part and material costs through the roof. Parts took so long to manufacture and then assemble into final products that the profit margin targeted in the approved business plans were missed or erased. Tensions between Engineering and Manufacturing steadily began to rise.




Source: Goldense Group, Inc., Dedham, Massachusetts.

**Business challenges:** Management began blaming Manufacturing for not keeping up with customer demand, while the real problem was that Engineering was not designing products for fast and profitable manufacture and assembly. "The product design was thrown over the wall from Engineering to Manufacturing" became the mantra in just about all companies.

By the time Engineering and Manufacturing hammered-out the design problems, the development budget was through the roof. Products were late compared to the planned schedule. Actual product cost greatly exceeded the planned product cost, thereby reducing planned profit margins. Worse yet, products often missed the market window and had to be canceled.

**Specific solutions:** As long as companies all endured the same task-specialization problems, none suffered disproportionately in the marketplace. Soon, though, some companies realized they could gain a competitive advantage if they reduced excessive costs and avoided the missed schedules caused by Engineering throwing designs over the wall to Manufacturing.

Leading companies developed an array of proprietary management procedures. Westinghouse, using a slide ruler analogy, developed the "Westinghouse Wheel" to help engineers create manufacturable designs. It helped determine "assembly difficulty" and "acquisition difficulty." Hitachi came up with the Assembly Evaluation Method (AEM). Fujitsu devised the Productivity Evaluation Method. Xerox developed the Producibility Index, XPI and something called Pumpkin Books. Lucas Engineering (UK) created engineering methodologies to improve designs for British military and commercial purposes, as did Draper Labs in the U.S.

All these approaches were specific to each competitor's situation. A non-proprietary and more general application methodology was needed, a methodology that could be documented and automated through software and used across industries.

**General solutions:** Enter a group of professors at the University of Massachusetts Amherst including Corrado Poli, Robert Graves, Laurence Murch and Geoffrey Boothroyd in the mid-1960s. They didn't set out to create DFMA. They were focused on better product designs that would feed parts faster through the state-of-the-art robotic parts-feeding and assembly processes of that time. By 1970, a handbook on feeding and orienting small parts had been published.

The next step was coming up with a way to code those parts with desirable and undesirable characteristics. If a coding system could be developed, engineers could quickly reference it when designing parts. Boothroyd and his graduate student C. Ho published their coding system in 1976. Dozens of visiting scholars, graduate and undergraduate students, and exchange students contributed across the years.

By the late 1970s, there was a working methodology for Design for Assembly. In 1978, Boothroyd and colleague Bill Wilson at Amherst obtained a three-year grant from the NSF to study the broader topic of Product Design for Ease of Manufacture. A final report was produced in 1981, entitled Design for Manufacturability.

The University of Rhode Island (URI) was quite interested in what was going on at UMass and the next thing you know, Boothroyd was on his way to URI. The details of this sudden research and intellectual property break-up are scant and hard to come by, and remain the lore of DFA and DFM historians and aficionados. Boothroyd was soon to team with colleague Peter Dewhurst who

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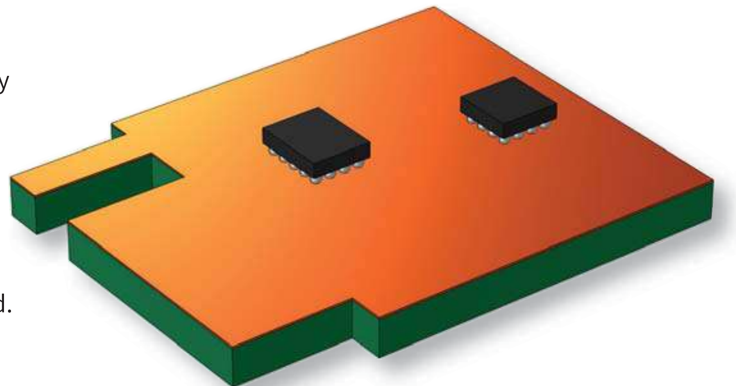
# *Thermomechanical Fatigue of Electronics Products*

**Electronic devices** are abundant, ranging from cellphones and computers to household appliances and automobiles. Ever-increasing demands on energy efficiency, performance, and prolonged service life present significant challenges to design engineers. In operating these devices, temperatures in the electronic circuitry vary over time, and this cyclic thermal loading produces mechanical stresses and strains that can cause fatigue damage. The product fails when sufficient fatigue damage has accumulated.



**Multiphysics simulation software** can be used to assess the risk of fatigue failure for electronic products. A multiphysics simulation computes the cyclic thermal loading, including the heat generated by the electronic components. In addition, the simulation include the effects of surrounding airflow and the radiative heat transfer. The simulation uses computed temperatures to calculate stress and strains in the component. The simulation then calculates the fatigue damage produced by this thermomechanical loading.

**In this presentation,** guest speakers Kyle Koppenhoefer and Joshua Thomas from AltaSim Technologies will discuss the development of a thermomechanical fatigue model for electronic devices subjected to a complex thermal environment. The webinar will also include a live demonstration using the COMSOL Multiphysics® software and a Q&A session.

**SPEAKER: Kyle Koppenhoefer, Altasim Technologies**

Kyle Koppenhoefer is the president of AltaSim Technologies. He and his business partner founded AltaSim 20 years ago. He works with customers to identify how computational analysis can be used to provide solutions to their products and manufacturing processes. Prior to cofounding AltaSim, Kyle worked for the Department of Defense and the Edison Welding Institute. He holds a PhD in civil engineering from the University of Illinois.

**SPEAKER: Joshua Thomas, Altasim Technologies**

Josh Thomas is a senior engineer at AltaSim Technologies. He has provided consulting and training support in COMSOL Multiphysics® over the last 10 years. He is a lead instructor in many of AltaSim's classes and has worked extensively with structural mechanics problems and multiphysics problems involving thermal and structural analysis. Josh received his bachelor's degree in aerospace engineering and master's degree in mechanical engineering from The Ohio State University.

**SPEAKER: Akhilesh Sasankan, COMSOL**

Akhilesh Sasankan is a technical sales engineer at COMSOL. Before starting at COMSOL, he received master's in mechanical engineering from Arizona State University. Akhilesh's areas of interests include CFD and high-performance computing.

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quickly embraced Boothroyd's rapidly solidifying methodologies for both Design for Assembly and Design for Maufacturability.

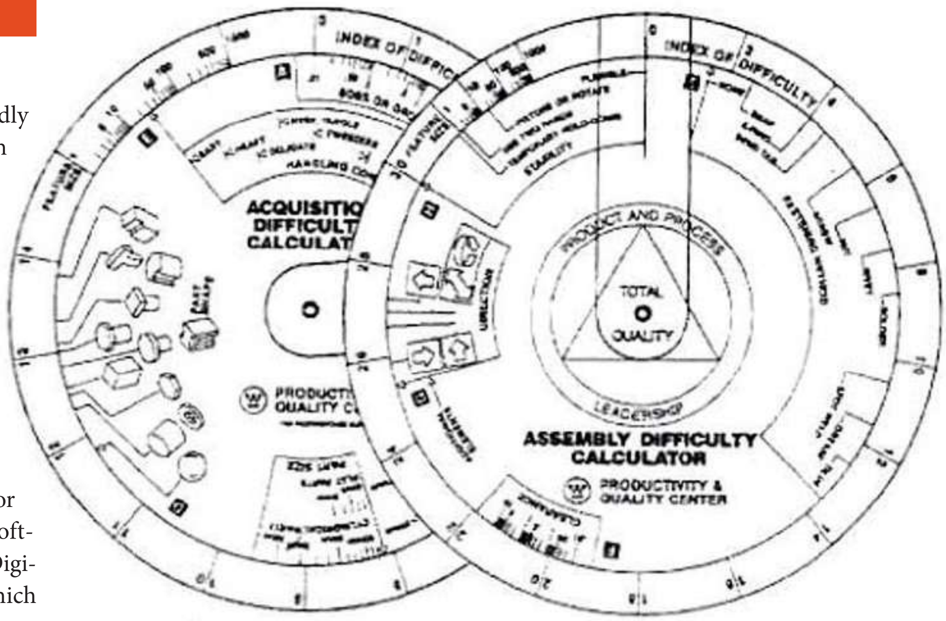
Joining forces in 1980, along with Professor Winston Knight, they were soon recognized as the international experts on these emerging DFA/DFM methods and were highly sought after by the world's largest companies.

**The Advent of DFA & DFM:** Their first DFA/DFM product was Design for Automatic and Manual Assembly software for the Apple II Plus. IBM and Digital Equipment expressed interest, which quickly led to the funding of a PC version and the incorporation of Boothroyd Dewhurst Inc. (BDI) in 1983. With URI resources and outside corporate support, additional research was conducted that led to the first Design-for-Manufacturing module being added in 1985.

Industry-leading companies, such as GM and Ford, quickly recognized the value of DFA and DFM and were using them to save billions of dollars annually. BDI quickly rebranded their intellectual property and its capabilities as DFMA. Both founders received the National Medal of Technology from President George H.W. Bush in 1991. Today, thousands of companies around the world practice DFM and DFA and many use BDI's software to help apply them.

BDI's founders' greatest contribution, as history will write, was not creating the software. It was something more profound that can be used every day by any product designer, engineer or manufacturing professional. Their concept of "Theoretical Minimum Part Count" was revolutionary and changed how everyone in manufacturing thought. Fewer parts to design, fasten together and quality check made sense. Fewer design change orders to fix tolerances so assemblies fit snugly together would save time. Fewer items to purchase or manufacture, handle and stock would save money.

Specializing engineering disciplines had led to optimizing product




The Westinghouse Wheel.

design at too low a level in engineering organizations and the product bills-of-material they generated. Specialization had also resulted in a parts and fasteners nightmare that no one really noticed had happened over the years.

The theoretical minimum count can rarely be reached; there are too many performance trade-offs to do so. But forcing a discussion that questions if every part and fastener is needed to meet the specified product performance is a discussion management should want to have in smart and efficient companies.

**Business results:** Companies that minimize the number of parts that must be assembled into products enjoy lower costs, smaller inventories, less handling costs, decreased working-capital requirements, faster times-to-market and higher profit margins. Companies that can also lower each part's manufacturing cost through better material selection, improved tooling strategies and more rapid fabrication processes garner even more profit.

DFA part optimization, followed by DFM on the fewer resultant parts, improves overall corporate speed and profit margins. After 40 years, no other company has accumulated a greater resource than the research underpinning BDI offerings and is still being built upon.

**What lies ahead:** The next chapter in DFA's and DFM's evolution is now unfolding. 3D printing has come of age and the advent of additive manufacturing is at hand. Additive design and production approaches differ from traditional approaches for both engineering and manufacturing. Just as happened before BDI created generalized cross-industry DFA and DFM methods and software, corporations are again creating their own company-specific DfAM or DFAM methods for additively manufactured parts and assemblies.

Will there be another incarnation to include 3D-printed designs from BDI, or will there be an entirely new generalized approach for additive DFA and DFM that emerges elsewhere? The next decade is sure to be exciting as additively manufactured part volumes increase. And, of course, most future products will combine additive and traditional parts. DFA and DFM solutions of the future will need to address these new hybrid product approaches. ■

Bradford L. Goldense, NPDP, CMfgE, CPIM, CCP, president of Goldense Group Inc. (GGI; www.goldensegroupinc.com), has advised over 300 manufacturing companies on four continents in product management, R&D, engineering, product development and metrics. GGI is a consulting, market research and executive education firm founded in 1986.


Image: ipopba/iStock

# A Quick Look at DFMA

Industry experts talk about DFMA advances and benefits, as well as the stumbling blocks standing in the way of its principles being more widely applied.

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

## AT A GLANCE:

- It is imperative for DFMA to be kept in mind from the first design concept, and its use depends greatly on the forecast of production quantities.
- DFA takes a "big picture" approach and DFA software helps to visualize those savings.
- Applying a DFA analysis to an assembled product is only beneficial if there is an intimate knowledge of the available design options.

A trio of manufacturing experts with years of experience applying Design For Manufacturing and Assembly (DFMA) principles take a look at how companies should use them, advancements in the methodology and what engineering students are learning about it.

### The Panel

**Scott Baxter** has spent over 13 years as business development manager and proposal writer at PEKO Precision Products. He has a bachelor's degrees in manufacturing engineering and economics.

**Jon Freckleton** has decades of manufacturing DFMA experience and has worked for and consulted with a wide range of companies. He has also taught DFMA workshops and provides DFMA advice to innovators.

**Christopher Kehoe** has 15 years of experience using DFMA. He also earned a master's degree in manufacturing and mechanical systems integration and product development.

**What have been the most significant advances or findings regarding DFMA over the last five or 10 years?**

**Scott Baxter:** One of the most significant advances in DFMA are the CAD software plug-ins that let designers see how much parts from suppliers might cost as they are designing those parts. These programs are not without hiccups, but they can help designers see what kinds of features have major effects on manufacturability.

**Christopher Kehoe:** There is now more of a focus on cost realization at earlier stages of design. Project Management and Product Development processes, for example, are requiring DFA/DFM analysis at earlier stages in design. Having it as a checked off requirement rather than part of a culture of design efficiency is the toughest part to achieve. Establishing an engineering culture that embraces DFMA requires quantifying successes to show value. Software can help the collaboration, but programs must be easy to use and understandable to several parties.

**Is DFMA used more often to lower production costs for products already being made or when designing new products? Why? Wouldn't it make sense to use it starting early in the design phase?**

**Jon Freckleton:** Once a company is tooled and in production, it is too late for DFM. Therefore, it is essential to have DFMA in mind from the first design concept. How a firm uses DFMA greatly depends on the forecast of production quantities. It is also important that firms have design and advanced manufacturing departments working together.

**Baxter:** That depends on the OEM. My guess is that DFMA is being used mostly on second- and third-generation products. By that time, OEMs have some real data on which to base DFMA decisions. DFMA at the early stage is always best for cost down initiatives, but there is a huge disparity in the DFMA skills of design and manufacturing professionals, so it makes sense that some companies are less fluent in DFMA for early designs.

**Kehoe:** I would agree that DFMA is used more for cost reduction after production as opposed to cost avoidance during the design phase. That is because product development has historically been linear. But using DFMA requires back and forth collaborations between design and manufacturing. That back-and-forth helps designers better understanding the manufacturing processes and helps manufacturing better understand the designs they are building.

**Which has the biggest economic return, DFM (how to improve the manufacturing of parts and components) or DFA (how to improve the processes of putting together parts and components into assemblies and then completed products)?**

Scott Baxter

Jon Freckleton

Christopher Kehoe

**Freckleton:** They are not separate; they must be considered together and must include repair if that is a factor, and recycling, which is always a factor unless it is an expendable item such as a bomb. A non-repairable item can be ultrasonically welded or have a permanent snap fit, but not if it needs to come apart for maintenance or repair.

**Baxter:** This depends on a host of factors, but a good rule of thumb would be to Pareto lower cost ideas and first attack high-fliers with the lowest risk. Sometimes the two are intertwined, such as when redesigning a part to make its assembly easier (like adding a keyway) but increasing the part's price. It also depends on how quality is affected at either the manufacturing or assembly levels.

**Kehoe:** Both. DFA takes a "big picture" approach and DFA software helps "visualize" those savings. DFA analysis is best done with product *and* manufacturing knowledge. Simply applying a DFA analysis to an assembled product is only beneficial if there is an intimate knowledge of the available design options from the design and manufacturing perspectives.

**What key features are companies adding to DFMA software?**

**Baxter:** There are some DFMA platforms that give real-time feedback about features that can be really handy, such as locations or relations of features, and hole sizes as compared to nominal drill sizes. These are very powerful. Once these platforms can analyze and compare DFMA features against production volumes and make process suggestions, DFMA software packages will make huge leaps.

**Kehoe** There are some DFMA packages that provide on-the-fly cost feedback from CAD models and how changes can affect cost.

**Is DFM well-covered in undergraduate engineering curriculums? If not, how should it be taught—as one major course (and lab) for all engineering students, or as part of several required courses in a student's chosen field of engineering? As an aside, are there enough people qualified to teach college-level DFMA to handle all the engineering undergrads?**

**Baxter:** Luckily for me, I took a DFMA class with a lab at Rochester Institute of Technology, and I am glad they offered it. It taught me the principles of DFMA and in our final project each of us applied those principles to a real product and developed new designs and cost estimates. It taught me a lot.

But based on what I've garnered from designers I've met, college-level DFMA courses are not well-staffed. DFMA courses also require real-world interaction (for getting prices, for example) that most colleges cannot offer.

"Luckily for me, I took a DFMA class with a lab at Rochester Institute of Technology, and I am glad they offered it. It taught me the principles of DFMA and in our final project each of us applied those principles to a real product and developed new designs and cost estimates. It taught me a lot."
— Scott Baxter

**Freckleton:** First off, a Ph.D. who has never worked in product development and production cannot teach it. Ideally it should be covered in many engineering courses and also covered in a course devoted to DFMA. It should also be an important part of any appropriate capstone senior design project. Hose senior projects should be industry sponsored and involve actual design problems and challenges. They should also be multi-department or multi-discipline projects where appropriate, as this is usually the case in the real world.


THERE'S A KEYSTONE
IN EVERY GREAT INVENTION.
OK

I cannot answer as to how well it is covered these days, but as a hiring manager at several tech companies, I never found a properly prepared B.S. grad.

Since industry lacks enough people with this background, they are in demand. And since colleges look down on—and usually will not hire—anyone lacking a Ph.D., it is often taught by adjuncts who cannot present a demanding-enough course, and do not have daytime office hours and availability to students for project support.

**Kehoe:** No. Undergraduates do not have enough design or manufacturing knowledge to apply DFMA. I would support the influx of DFMA any time critical thinking of product development is part of a curriculum. Dedicated DFMA classes can be considered specialized since engineering undergrads would need to do significant research to understand design factors and manufacturing factors of cost.

That is a major challenge for a younger student. Mostly this can only be substituted with practical experience. The principles of DFMA are questioned throughout the curriculum and then reenforced with research. Only then can this become a tool for use in practical application.

I cannot speak the state of education at this time, but I can attest to the fact that through six years of graduate work, the education department was not able to embed DFMA principles into programs of study. I took a dedicated class as a graduate student, but also had close to 20 years of experience. I was able to absorb the principles and apply them from my extensive knowledge of manufacturing and design.

**What industry seems to be the best at using DFMA and enjoying significant benefits from it? Why is this industry doing so well?**

**Baxter:** One thing I know is that every industry wants DFMA. I'd guess that automotive and electronics are the best at using DFMA based on their deep pockets, R&D commitments and predictable, high-volume forecasts. They also have lots of weight with their suppliers so they can easily get pricing and cost ideas from the supply chain to verify their DFMA concepts.

**Why haven't other branches of DFMA taken off, such as Design for Reliability, Design for Serviceability, Design for Environment, Design for Recyclability, Design for Disassembly and so on?**

**Freckleton:** Idiots in management.

**Kehoe** There needs to be culture or paradigm shift in a company to where these approaches are infused into the design while it is being developed, not after the design has been completed.

**Baxter:** Usually cost is the first thing I hear regarding DFMA efforts. The costs in DFMA efforts are immediate and less theoretical. In other words, DFMA costs seem to be more tangible, so they get more consideration from decision makers. ■

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Cover Story

# A Look Inside the DFMA TOOLBOX

Here are some tools and technologies that let companies apply DFMA principles to their products.

**by David Meeker,** Consultant, Neoteric Product Development


*Image: David Meeker*

Over the last decade several design methodologies and manufacturing processes have appeared that, when employed, lead to automatic DFMA results.

Here's look at several* of them that have been shown to help designers and engineers achieve several DFMA goals—the primary one being reduced part count, which saves money and simplifies assembly.

### Electronic Packaging Assembly Concept

In the 1990s, steadily decreasing market prices and shorter life cycles crippled Hewlett-Packard's workstation business. The company decided it suddenly needed faster production processes.

Hewlett-Packard's workstation design team, needing to reduce the cost and time it took to building its workstation, had an epiphany. As one of the designers recalls, "The team could not get out of their minds the idea of fixing parts so that they are enclosed and held by their by geometrical forms. The idea is similar to children's games that require players to put differently shaped blocks into matching hollows."

For the workstation, the blocks would be the workstation's electrical and mechanical components, while the hollows would be spaces inside the workstation's enclosure. The critical step turned out to be finding a suitable material in which to carve out spaces for components inside the enclosure. The material would need to:

- Be pliable and bouncy.
- Be 100% recyclable.
- Be nonconductive.
- Hold tolerances.
- Attach components to substrates without fasteners.
- Resist heat, chemicals and moisture. The material that seemed most suitable was expanded polypropylene (EPP).

Creating the prototype with EPP foam required two days to fabricate the parts and assemble the workstation. With a few minor alterations required for air flow, the workstation not only ran, but passed all environmental tests as well. Compared to the traditional workstation, the Electronic Packaging Assembly Concept (E-PAC) workstation needed:

- 70% fewer housing parts.
- 95% fewer screw joints.
- 50% less assembly time.
- 90% less disassembly time.
- 30% less transport packaging.
- 50% less time and cost in developing the housing.

Moreover, the E-PAC workstation included these additional benefits:

- Fewer chassis parts.
- A one-step process to make molded parts.
- Simple, fast, cost-effective assembly.
- A lighter final product.
- Shock and vibration protection.
- Cooling from air channels in the foam.
- 100% recyclable materials.
- Fewer tolerance issues due to material flexibility. ■

*For the full text of this article, including additional images and DFMA principles on 3D Molded Interconnect Devices, Electronic Magnetic Assembly Bonding, hydroforming, 3D printing and friction stir welding, please visit www.machinedesign.com/21216271.

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# DFMA Redesign
## Leads to Reusable Parts That Withstand the Heat

This redesigned part performs better, lowers cost and shortens lead times.

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

Engineers at Nieka Systems in Canada design x-ray equipment that determines the compositional makeup of ore and cement samples. They also design and manufacture the equipment needed to mix and dissolve samples in molten borate at temperatures over 1,000°C to make the material samples compatible with the analysis process.

The materials and borate are mixed and heated in platinum crucibles which are suspended by thin metal clips. Nieka System's founder, Louis Croisetière, wanted to redesign the clips using DFMA principles to lower costs.

There were several goals for the clip's redesign. The new clip would need to:

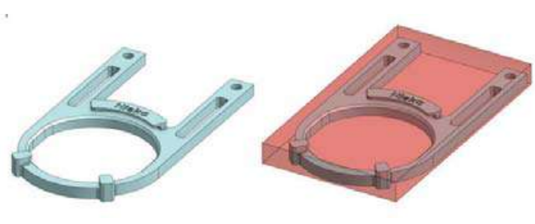
- Hold the crucible in place throughout the mixing and pouring operations.
- Minimize heat transfer from the crucible to the rest of the machine.
- Keep its strength and durability despite high temperatures.
- Have lower manufacturing costs.
- Make lead times shorter and more predictable.

Deciding the clips' material was relatively simple. The high temperatures and rapid temperature changes made the nickel-based superalloy Inconel 625 a natural fit. Choosing that exotic metal introduced several manufacturing complications.

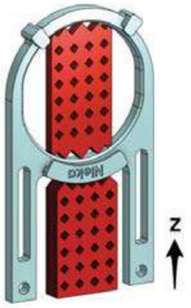
The crucible clips can be seen holding platinum crucibles over gas burners in one of Nieka's sample-making machines. The clip's design is relatively simple. But it took the company several DFMA steps to get to the final design.

At first, Nieka wanted to use CNC machining to prototype and manufacturing the clips. The company designed a clip that met the mechanical requirements and had a slot in each of the clip's legs to minimize heat transfer. A design evaluation concluded this would be difficult to manufacture using CNC machining and lead to steep costs, long lead times and machine shops declining to take on the job.

CNC machining also meant the clip had to be cut from a much larger volume of Inconel 625 stock, so much of it was lost to waste. Inconel 625 also can quickly wear down slotting tools required



An early design for a CNC-machined crucible clip (left) and the bounding box of the Inconel 625 sheet stock from which it would have to be cut (right). Note the large amount of extra material that must be removed to create the clip.




A clip orientated for DMLS production shows the supports needed during the 3D printing process in red.

to cut the overhangs that hold the crucible. Keeping the clip in position while it was machined was also a challenge: It took several set-ups, and the clip tended to bend under the forces from the vice holding it.

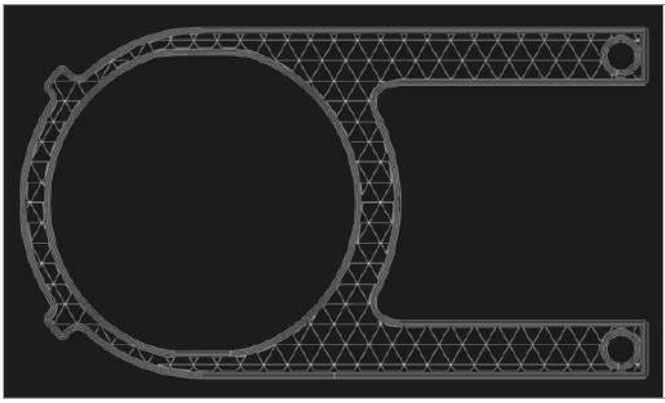
To lower the cost for complex parts made in low-volume production, Nieka turned to direct metal laser sintering (DMLS) and an outside vendor. Although the original CNC clip design was already DMLS-compatible, there were other complications. The clip was 3D printed upright to simplify removing it from the build platform. In this upright orientation, support structures were needed to anchor the part during fabrication. Although an outside DMLS vendor agreed to remove these structures, it added lead time and occasionally left rough surfaces that required post-processing.

More significantly, Nieka did not have enough orders to fill an entire build platform. To keep costs down, the vendor delayed making the clips until it had enough orders to run a full build. This led to inconsistent and unpredictable lead times varying from 14 to 40 days, which hindered R&D and production planning. These supply chain constraints led Nieka to seek an in-house metal AM technology, leading to a new design for the crucible clip.

### A Flexible Manufacturing Solution

Nieka needed a more flexible manufacturing method that could be done in-house. The company eventually chose metal fused filament fabrication (FFF) on a Metal X printer from Markforged. Of course, this also called for a redesign of the clip, as the FFF process involves 3D printing using a polymer and wax filament which contains metal powder, then removing the wax and polymer and sintering the metal powder into a metal clip.

FFF let Nieka engineers create complex clip geometries to meet their design goals. They also used Eiger slicing software from Markforged to create a hollow triangular infill in the clip's CAD model. This eliminated the need for the cooling slot and meant that less heat-transmitting Inconel was needed to make each clip. The new design prevented much of the heat from escaping the crucible, and the new leg was stiffer than the DMLS version.



A screenshot from Eiger slicing software shows the sparse triangular infill structure within the crucible clip printed using FFF.

The crucible clip 3D printed using DMLS (left) and FFF (right).

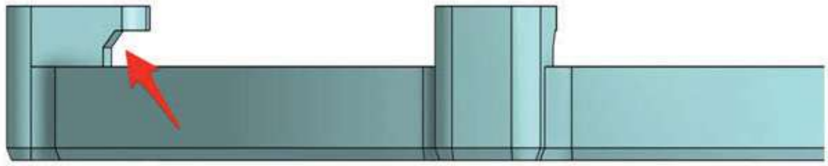
Eiger slicing also creates a "raft" underneath printed parts to improve geometric stability during sintering. This normally has minimal impact on process costs, but the crucible clips are so small that printing the raft doubled the print time and material cost. Nieka's engineers chose to forgo the raft, doubling daily production capacity but also causing the legs of the clip to go slightly out-of-parallel during sintering. This was a classic engineering trade-off—a small reduction in dimensional accuracy increased production capability.

Fortunately, the resulting problem of legs that were out of parallel also had a simple fix. The clip's legs always bent outwards by a repeatable angle during sintering, so they were redesigned to angle inwards by the same amount and they would be straight and parallel after sintering.

Subtle modifications created efficiency improvements in processing FFF parts after sintering. A small chamfer added to the lip that retains the crucible flange reduced the amount of support material used in that region. This created a bigger gap between the support material and the part and made it easier to remove any remaining support material.

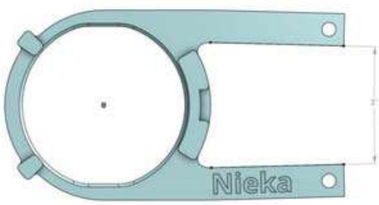
Redesigning the crucible clip for the Markforged FFF printer lets Nieka


FFF parts are usually printed on a raft (in red) which helps maintain dimensional accuracy during sintering.



A small chamfer added to a flange made it easier to slide a tool in to remove the part from the build platform.

Systems consistently deliver lead times and cost savings at least an order of magnitude better than CNC machining or DMLS could, while improving the clip's performance.




3D printing the legs so they are canted slightly inwards offsets sintering's warping effects without using a raft.

> *"Some of our new designs are based on the fact we can print parts, so it's changed the way we work. It's reduced our assembly time and we have none of the design limitations of traditional methods."*
>
> *— Louis Croisetière*

It also has changed the way that Nieka designs its products. "Some of our new designs are based on the fact we can print parts, so it's changed the way we work," says Croisetière. "It's reduced our assembly time and we have none of the design limitations of traditional methods." ■

# Redesign of Medical Imager Gantry Cuts Costs, Eases Installation

Replacing heavy welds with bolts for the main gantry saved considerable time and money.

**by Scott Baxter,** BD Manager, PEKO Precision Products

A medical company had been making and marketing a multi-million-dollar cancer imaging and treatment system, the company's flagship device, for a few years. Management then decided to upgrade portions of the technology in the device, not the least of which was changing the dosing subsystem. The original model, the one they had been selling, relied on cobalt for dosing.

The company wanted to move to linear accelerators, sometimes known as linacs. It also wanted to lower the cost of making the imager. But such a major redesign would make it mandatory to requalify the machine, and requalification is a long and arduous process. Nevertheless, it would open a window to some interesting possibilities.

When the company first designed the machine, it had partnered with an engineering team from PEKO, a contract design and manufacturing firm. PEKO manufactured the machine the OEM had designed. While the machine was being qualified, PEKO engineers brainstormed some Design for Manufacturability and Assembly (DFMA) ideas for it. Implementing them at the time of the original design would require a new requalification which could take over a year and cost tens of thousands of dollars. The company was anxious to get the machine on the market, so the DFMA ideas were shelved.

Since the upgrade would require requalification anyway, the two companies decided to apply DFM principles to the device and lower the cost of making it at the same time.

One of the machine's main assemblies is a gantry, a large donut-shaped ring into which the patient is placed, much like an MRI machine. Changing the dosing subsystem would affect the gantry the most, so the DFMA principles of "eliminate, combine and optimize" were applied to its redesign.

The gantry, an electro-mechanical assembly, stands roughly nine feet tall and is composed of large aluminum components, all on a heavy base. The aluminum sections are joined to strengthen the gantry. A chain drive rotates the gantry when the machine is operating. The gantry's main function is to position and hold the imaging and dosing subsystems that are paramount to proper treatment.

The original gantry was assembled using heavy 3/4-in. welds joining the aluminum components. It took 100 hours to weld, but the aluminum parts had to be heated to 300°F during this process. This type of welding presents several challenges. It is prone to warp and shrink parts in unpredictable directions, which can push parts out of tolerance and lead to low yield rates and repeatability problems.

Another issue is the high cost of welding thick beads on large structures followed by post machining. Lastly, inspection time was lengthy due to the manufacturing method and the size of the components. The original design was also more likely to be rejected during inspection of the entire unit, and at that point the gantry could not be dissembled to make easy corrections.

### New Calculations for Old Issues

The DFMA redesign used bolts rather than welds to assemble the gantry. This would maintain the gantry's strength and durability while reducing assembly and inspection times and increasing manufacturing throughput. Using bolts also slashed the amount of time parts spent on large CNC machining centers, a costly and unwieldy machining method.

The design team also calculated that the heavy aluminum welded structures could be replaced by smaller components. The components would be precision machined to ensure the positioning of critical features was accurate and could be performed on smaller, less-expensive CNC machines. Holes for fasteners could be drilled and tapped using CNC and all the parts could be delivered to the assembly line in a kit for technicians. The new assembly process benefits from the accuracy of the features machined into lower-level components.

As in any DFMA initiative, results are what matters most. Once the work is performed, measuring the outputs against the expectations reveals success or failure. In this case, PEKO used DFMA to lower the overall unit cost and increase manufacturing capacity and throughput by eliminating welding and large machining. The redesign saved thousands of dollars and removed process uncertainty from this gantry project. The time needed on large mills was reduced by 50%. Across the board, the gantry's price was reduced by nearly 22% and throughput rose to more than double that of the original gantry. ■

Special Report


# Engineering Your Career, Part 3

## Professional Societies and Community Groups

Professional societies and community groups can help build networks of design professionals that help engineers stay technically relevant.

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

Engineers who invest time and energy in professional associations and community groups will quickly find that those investments pay dividends in terms of building networks of engineers and design professionals and staying technically relevant. Both of these can be critical to an engineer's career success.

### Investing in Your Profession and Community

When you decide to join a professional association or a community group, you've taken an important first step in boosting your career. But that membership likely won't pay dividends until you engage. Being a member typically includes access to various benefits, but actively engaging in the organization often leads to real career growth and acceleration of an engineer's professional development. For example, associations are leaders in post-college training and professional development for engineers of all disciplines.

My own story serves as a good example. I first joined the National Society of Professional Engineers as a young engineer fresh out of college after being invited to a meeting by a co-worker. At that first meeting I learned about an opportunity to volunteer at the local Mathcounts competition. Mathcounts, a STEM program for 6th, 7th and 8th graders, encourages the pursuit of high-level math courses, a prerequisite for any engineering program. I participated in Mathcounts in grade school and knew how fun it is, so I wanted to be a part of the effort. Through that engagement, I had the opportunity to be a Mathcounts coordinator for my local NSPE chapter. I also moved through the various officer positions in NSPE, including chapter president.

Serving as a chapter leader and then at the state and national levels, I learned vital leadership skills and had the opportunity to put those skills into practice. Certainly, on-the-job training is a great way to learn and grow, but learning and practicing leadership skills in the safe and relatively harmless context of a volunteer organization or professional association has a lot of benefits. I found my fellow members and officers to be extremely supportive and forgiving when I made mistakes or missteps. This is not always the case in the work environment. The experiences in Mathcounts and NSPE helped build my confidence along with my skills and networking base.

For example, serving as a committee chair in a professional association or community volunteer organization lets you work with small groups to accomplish a task or series of tasks. You have no real authority over your other members, so you must flex your skills of persuasion to achieve results beyond what you alone could accomplish.

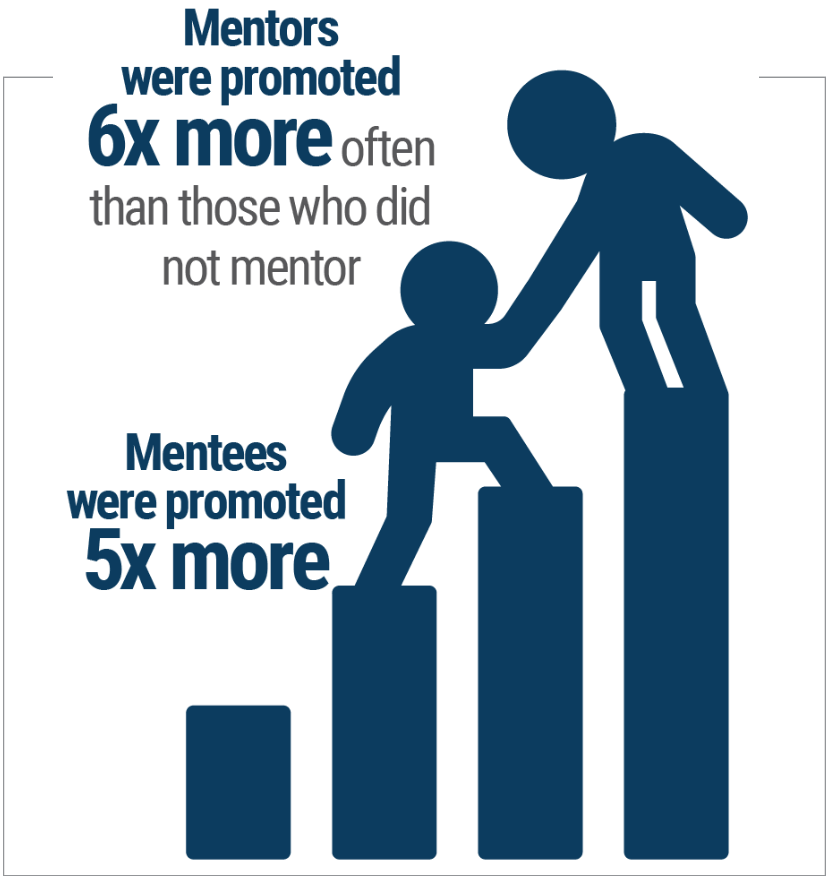
Associations are leaders in post-college training and professional development for engineers of all disciplines.

To effectively influence team members to take action and help with various tasks, you have to paint a picture of what the team is trying to achieve and then organize the team with task assignments and a schedule for completion. This closely parallels what project managers in engineering organizations do when developing a project or product. Team members don't usually report directly to the project manager, and they have other responsibilities within the organization and outside of it. So, these skills of influence or persuasion, along with planning, organizing and scheduling, are critical to the team's success. And mastering those skills is critical to your development as an engineering leader.

In addition to skills development, engaging in professional associations and volunteer community organizations requires that members learn to focus on what is important to them, their careers and their mental/physical health. In other words, members learn to balance work and outside activities, which can be a challenge for any engineer.

As a young engineer working my way up the corporate ladder, I was also a wife and mother. I didn't have a lot of spare time, but I found a way to make time for professional and community activities while also excelling as an employee and caring for my family. These things are not mutually exclusive; they are complementary. The skills learned in one situation are helpful and applicable in the other.

Granted, balancing all of this might not be easy, but it is certainly possible. It's also fulfilling and enriching, which is a huge motivator when it comes to maintaining the focus necessary to push forward daily.




### Giving Back Gives Back

We often talk about the desire to "give back to our profession," an old-school way of looking at the world and our responsibilities. But maybe we need to rephrase it to be more in tune with today's thinking. For me, it means working as hard as possible to improve the engineering profession for future generations. Or in other words, to leave things better off than how I found them.

Whether it's sustainability, resiliency and green approaches to our work, or improving processes and procedures for the future, it's all about making a difference and changing things for the better. That's a worthy goal, and one that fits the calling of a professional engineer. So, to have a rewarding and successful career, many engineers feel the need to make positive changes and "give back."

Mentoring young professionals, for example, is one way to give back to the profession and pass on the wisdom we have learned to future generations. According to a June 2019 *Forbes* article, about 70% of Fortune 500 companies offer mentoring programs to employees, a sure sign those companies value mentoring.

Whether through formal mentoring programs or informal settings, spending time mentoring or being mentored can be fulfilling and enlightening. Ironically, I often leave mentoring sessions with more than I brought to the table. Spending time with people who may differ in age or background can enrich an engineer's career while also helping others.

Committing time to mentoring and being mentored can be a challenge in today's busy world, but the time spent is worth it. In a July 2019 *Forbes* article, a Sun Microsystems case study illustrated this point. Mentees in the program were promoted five times more than those who were not. And mentors were promoted six times more often than those who did not mentor anyone. On top of that, retention rates were significantly higher for mentees (72%) and mentors (69%) than for employees not participating in the program (49%). It seems investing time in mentoring is critical to career growth and development.

### Building a Network

Having an effective network is more than just meeting folks, having casual conversation and connecting on social media. To illustrate this point, engineers can create a bubble diagram of their network. It starts with a circle in the middle of the page that represents the engineer, and then bubbles are drawn representing various people in their life including friends, family and co-workers. This lets engineers "see" their various relationships and then focus on strengthening those important to career advancement and other goals. For me, that includes family and professional relationships. Over the years, I have revisited and updated my network's bubble diagram, which has benefitted me.

Engineers who are exploring their networks should consider not only their


company and family, but also volunteer organizations, alumni and community groups, and others who influence their lives. They will likely find that a rewarding engineering career is about more than designing great projects; it is truly about the people in their lives.

### Staying Technically Relevant

Engineers are technical professionals and staying up to date on technical advances in their fields is vital to their career development. I have sat across the table from numerous young engineers who talk about wanting to be project managers and leaders in their field. But they don't seem to understand the value of their technical knowledge and problem-solving abilities as they apply for advancement.

Engineers should focus heavily on developing their technical skills in their first five years after graduating from college. Then, as their career progresses, they may shift the focus to leadership, management and business skills. At the same time, however, it's advisable to pick a technical niche they find compelling and continue to take classes, read books and articles, and attend webinars in that area. Young engineers can easily become experts in their field if they put in the time. Fulfillment as a technical professional requires continual learning throughout your career.

Investment in your career development is essential to success. So use professional associations such as NSPE to achieve your goals and take advantage of the many opportunities that will come your way. ■

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This is the third part of a four-part series on how engineers must adapt in these changing times. Part I covers the challenges of engineering, Part II covers licensing and Part IV looks at risk taking.

# Heavy Metal:
## PC Control Guides Steel Forming

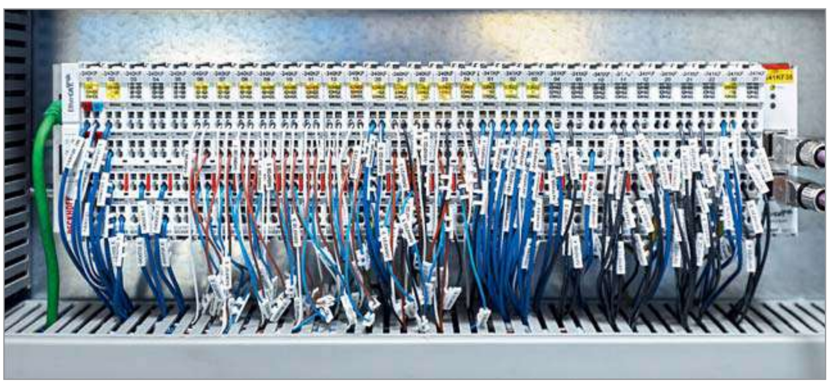
A Swiss machine builder uses automation technology to form 45-ton tanker hull plates.

**by Peter Reinstadler,** Area Sales Manager, Beckhoff Switzerland

Haeusler AG, based in Duggingen, Switzerland, is a leader in implementing large-scale facilities for forming metal plates. Haeusler is a specialized machine manufacturer that employs around 120 staff today. Since its founding in 1936, the company has developed a wide variety of machines and production lines, including customer-specific designs, for processing sheet metal for use in applications such as wind turbine towers, pipelines, the Ariane rocket, shipbuilding and enclosures within power plants and reactors.

At the end of 2020, the machine builder delivered a giant 1,245-ton straightening machine to one of the largest shipyards in China. One of the largest of its kind in the world, the machine is used in the oil tanker hull production. After an 18-month design and construction period, the latest RI 4000 X 87 straightening machine was delivered to the Chinese customer.

**The 12-meter forming machine just before delivery.** *Images courtesy of Beckhoff*



**The C6920 control cabinet Industrial PC is used in two machine control cabinets.**

### Proven Machine Expertise

Haeusler's RI machine series is fitted with five, seven, nine or 11 straightening rollers, depending on the technical specification. This includes the latest, gigantic forming system, the RI 4000 X 87, which draws on the company's 80 years of experience in the field.

Standing 12 meters high, coming in at a dead weight of 1,245 tons and equipped with five large straightening rollers, this most recent system can apply up to 19,000 tons of force during the forming processes. It is capable of machining 120-mm-thick, 4-m-wide and 12-m-long high-strength steel plates (1,000 N/mm2 yield strength) weighing up to 45 tons. Haeusler officials said the capacity to process these huge metal plate dimensions provides significant advantages compared to traditional straightening solutions.

Machining this kind of steel plate is simply not comparable with forming typical sheet metal that is just a few millimeters thick. Here, it is more a matter of evenly aligning the plates as a rule—which are sometimes slightly wavy after manufacturing—for the subsequent work steps. Another task is to homogenize the stresses occurring in the sheet through several passes of cold rolling.

For these purposes, the RI series offers a number of features, such as special individual roller adjustment for optimal straightening of both thin and very thick sheets. The direct roller drive provides automatic speed compensation and integrated overload protection. For this need, Haeusler turned to PC-based control technology from Beckhoff to ensure the enormous forces for precisely forming steel parts are guided in the right direction.

### Intelligent Machine Control

Another feature of the RI series is its intelligent machine control system, according to Haeusler. The Beckhoff control technology allows users to achieve optimum machining results within a short amount of time. The modular components are distributed and networked with the high-performance EtherCAT communication system, which can be ideally adapted to the special requirements of the straightening machine.

"The strength of Beckhoff lies in the breadth of the portfolio and in particular in how open PC-based control and EtherCAT technology is," said Patrick Stadler, deputy head of the electrical department at Haeusler. "This means that if third-party components such as position measuring systems are required, they can be integrated without a huge amount of effort.

"What's more, a second control computer was installed in the plant for a downstream measuring application, which enables quality inspections to be performed after straightening," Stadler continued. "Using the EL6695 EtherCAT bridge terminal, both controllers could be connected to allow real-time data communication with minimal effort. We also use ADS to transfer process parameters between the controllers via TCP/IP and to the HMI that we developed ourselves, and we appreciate how open the interface is in this respect, too."

As another example, Stadler mentions a highly precise laser used for measuring the flatness of the straightened steel plates: "The laser has an RS422 interface, and could be easily integrated with the EL6021 serial interface and the corresponding TwinCAT library without painstaking project planning.

"A complex hydraulic system is fed from an 8,000-liter oil tank, which transfers up to 3,500 liters of oil per minute," he added. "Hydraulic torque control of seven axes simultaneously has been implemented, with torques of up to 10 million Nm. The system is supplied with up to 2,500 A power (at full load), the majority of which is used for the hydraulics."

Stadler also sees another advantage in the TwinCAT OPC UA Server (TS6100): "With this OPC UA interface, we provide the end customer with the option to efficiently integrate the machine into their shop floor management," he said. ■

## Continuous Jumpers Reduce Vibration Interference

The introduction of 3-way and 5-way continuous jumpers has expanded TOPJOB S uses. As with previous jumper introductions, these versions utilize the exclusive jumper retention spring designed into TOPJOB S terminal blocks to ensure a vibration-proof connection every time. This offering provides additional options when circuit designs need to use the second row of jumper slots on TOPJOB S terminal blocks for other purposes (for example, testing). Combined with staggered jumpers, they are able to cover a wide variety of end-use applications.

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An upgraded line of IEC Pilot Devices features pilot lights, push buttons, selector switches and E-Stops, with a wide range of variations and options available within each product group. All new Series GT products are compatible with the discontinued Series B products, all while keeping the same mounting and assembly dimensions and specifications.

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## Heavy-Payload Robot Improves Reach, Output

The M-1000iA robot is capable of handling very heavy products, including automotive components, construction materials and battery packs for electric vehicles. The M-1000iA's serial-link construction gives the robot a wider range of motion in every direction. It can extend its arm upright or rotate it backwards, which is not possible for typical heavy-payload robots with a parallel-link mechanism. With a 1,000 kg payload, a 3,253 mm horizontal reach and a 4,297 mm vertical reach, the M-1000iA is ready to go to work for manufacturers looking to increase output and maximize their production line's efficiency.

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## Graphical Panel Helps Connect Legacy Equipment

Legacy equipment in plants can make it difficult, time-consuming and costly to extract data from the machines to help improve performance. Red Lion's newly launched graphical panel meter, PM-50, is designed to change that. Available through Allied Electronics & Automation, the new wireless smart panel meter makes it easier for machine operators to unlock and use data from their factory floor. The PM-50 can be used in industrial factories, food and beverage, water/wastewater and packaging plants, and anywhere else panel meters are currently used.

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# Owl Wings
## Inspire Airfoil Design and Noise Suppression

Owl wings enlighten researchers on novel ways to suppress the aerodynamic noise of an airfoil.

**by Rehana Begg,** Senior Editor

A new sound-suppression study provides fresh insight for airfoil design and noise control for micro-aircraft and fluid machinery.

The research focused on the concept of trailing-edge noise by using the characteristics of owl wings to inform airfoil design and significantly reduce the trailing-edge noise.

Trailing-edge noise can be characterized as the dominant sound emitted from aeronautical and turbine engines, such as wind turbines and marine propellers, but is also prevalent in drones and automobile fans. Suppressing noise pollution from take-off and landing is a major environmental goal in urban areas. The FAA has set the day-night average sound level (DNL) 65 dBA as the threshold of significant noise exposure, below which residential land uses are compatible.

Noise—whether of the engine or aerodynamic variety—is a perpetual by-product of air travel and impels a continued review of noise mitigation at the source.

Researchers from Xi'an Jiaotong University, based in Xi'an, Shaanxi, China, had good reason to take their cue from nocturnal owls. "Nocturnal owls produce about 18 decibels less noise than other birds at similar flight speeds due to their unique wing configuration," said Xiaomin Liu, a co-author of the paper, which is published in *Physics of Fluids*, by AIP Publishing. Moreover, Liu added, when the owl catches prey, the shape of the wings is also constantly changing, which underscores the significance of studying the wing edge configuration during owl flight.

### What Exactly is Trailing-Edge Noise?

Trailing-edge noise is broadband sound. It is generated when airflow passes along the back of an airfoil, such as the wing or blades of the propeller, rotor or turbine. The flow forms a turbulent layer of air along the upper and lower surfaces of the airfoil. The researchers explain that when that layer of air flows back through the trailing edge, it scatters and radiates noise. It plays a significant role in the overall airframe noise.

Previous research on the effects of serrated trailing edges showed that serrations effectively reduce the noise of rotating machinery. But these studies also showed that noise reduction could not be generalized—the measure of noise diffusion depended on the final application.

"At present, the blade design of rotating turbomachinery has gradually matured, but the noise reduction technology is still at a bottleneck," said Liu. "The noise reduction capabilities of conventional sawtooth structures are limited, and some new non-smooth trailing-edge structures need to be proposed and developed to further tap the potential of bionic noise reduction."

### Suppressing Noise in Rotating Machinery

The researchers used noise calculation and analysis software to conduct a series of detailed theoretical studies of simplified airfoils with characteristics reminiscent of owl wings. They applied their findings to suppress the noise of rotating machinery.

They found that they could suppress the noise when they improved the flow conditions around the trailing edge and optimized the shape of the edge. The researchers also pointed out that symmetric trail-edge serrations reduced the noise more so than conventional trailing-edge serrations.

Since the level of noise reduction was dependent on operating conditions, the researchers emphasized that the airfoil designs should be further evaluated based on the specific application.

For example, wind turbines have complex incoming flow environments, which require a more general noise reduction technology. The researchers said that examining noise reduction techniques under the influence of different incoming flows would make their conclusions more universal.

The owl wing research, noted the authors, will serve as an important guide for airfoil design and noise control.

The article "Aeroacoustic Investigation of Asymmetric Oblique Trailing-edge Serrations Enlightened by Owl Wings" was authored by Lei Wang and Xiaomin Liu. Read the full article in *Physics of Fluids*. ■

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