

# machine design

BY ENGINEERS FOR ENGINEERS

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APRIL 2016  
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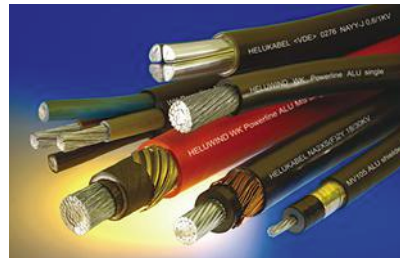
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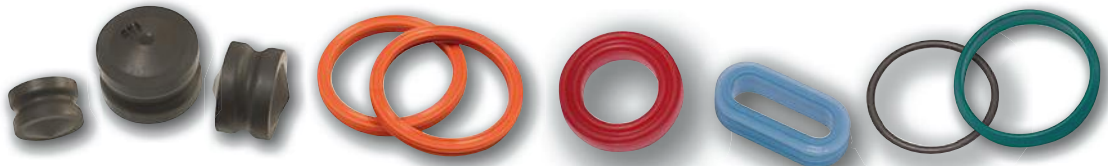
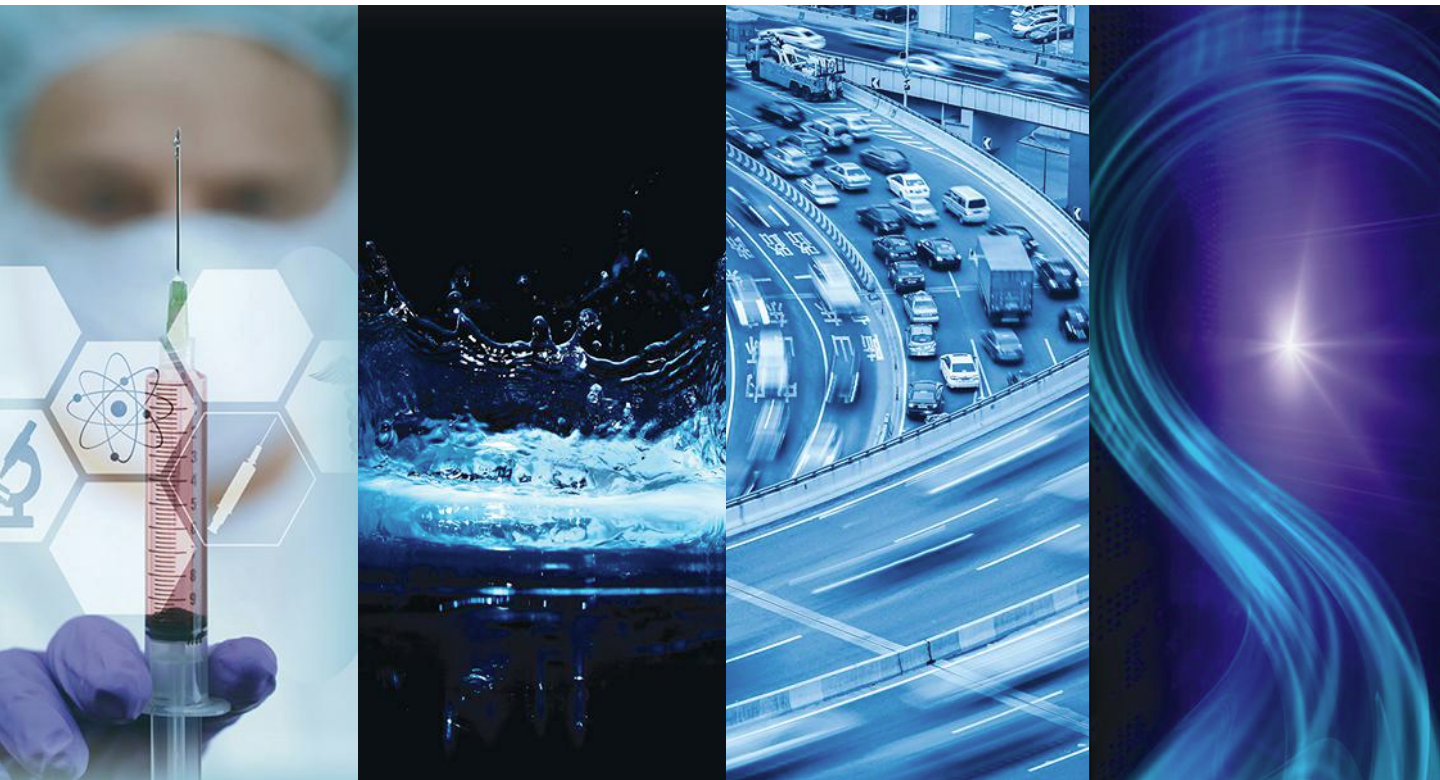
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<http://machinedesign.com/motorsdrives/motors-and-drives-leading-way-robots>

If you missed our March issue, go online for this in-depth roundup of the latest motors and drives and the push for more innovation in that sector to meet the challenges of a rapidly growing robot business.

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## COMPANIES ARE BRINGING MANUFACTURING BACK TO THE U.S.A.

<http://machinedesign.com/blog/4-reasons-companies-are-bringing-manufacturing-back-us>

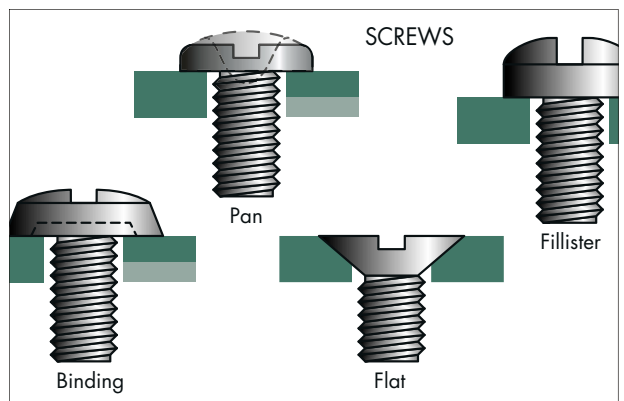
After a decade of significant offshoring, the cost savings American firms had chased began to erode. Labor and transportation costs increased, eating into much of the savings manufacturers had previously enjoyed. And many companies uncovered the hidden costs a few consultants warned about. Those costs often outweighed any benefits of manufacturing overseas. Suddenly there is a surge in industry returning to the United States.



## “APPLE VS. FBI” AND THE INTERNET OF THINGS

<http://machinedesign.com/blog/apple-vs-fbi-and-internet-things>

The highly publicized case comes down to one critical issue: How is the future of security in our technology compromised as we become more and more dependent on it? The implication of compromising security also threatens the future of the Internet of Things (IoT).



## HARDWARE FOR ELECTRONICS AND PCBs

<http://machinedesign.com/fasteners/hardware-electronics-and-pcbs>

Many prototypes and even final products suffer failures due to poor selection of common items such as screws, standoffs, bushings, and nuts. Here's an illustrated look at some of that hardware and some tips for getting the most out of it.



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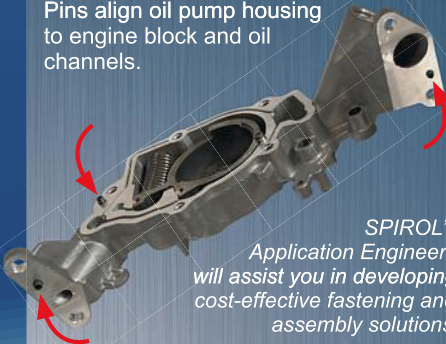


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### Editorial

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## A Thin Line between Engineering and Toys

I had the privilege last week to attend the 113th International North America Toy Fair in New York City. For me, the show is a personal thrill to attend. As I have mentioned in a previous blog, “Did My Engineering Major Prevent Me From Getting a Job?,” I partially owe my pursuits in engineering to the toys I owned growing up. I was amazed to see the amount of STEM and STEAM toys at the fair this year. I had attended the show last year, but in just one year I would say that the amount of STEM-focused educational toys doubled. But what is even more surprising is how many engineering concepts I saw in today’s toys.

Right before attending the Toy Fair, I was in Anaheim for the Pacific Design Show. Many companies in attendance had on display their new lines of products and this year robotics was a dominant theme, along with 3D printing and assembly automation. At the Pacific Design Show, there were pick-and-place robotic arms like Baxter and Swayer from Rethink Robotics, programmable collaborative robots like the robotics arms from Universal Robots, and autonomous robots like the ones from Omron. So when I got back from Anaheim and headed to the Toy Fair in New York, what did I see but the same exact technology in kids’ toys?

There were toys that had the same program functions as a Universal Robot, allowing for place and record movements via a tablet app. In today’s toy market, there are robotic arms, modular robotic assemblies, 3D printing toys, code-teaching robot games, and autonomous robot toys. In particular, the Jimu robot from UBTECH impressed me the most. This robot is completely collaborative. The child is placing the robot in specific positions and recording them via their tablet. The robot then interpolates the required transitions between positions to reach the end of its programming. This style of toy is teaching kids how to program modern robotics like Universal Robots’ robotic arms, which is programmed using the same exact method.

The reason I’m so impressed is that these are fundamental engineering principles being taught at a younger-than-ever age. I always played with LEGOs, K’NEXs, Erector Sets, etc., and each included engineering fundamentals naturally built into them. But none of them explained gear ratios or how to define torque like the Motorblox Vehicle Lab from Smart Labs or how to build my own electric gadgets like littleBits does. The new generation of toys not only entertains, but is focused on showing kids the governing engineering formulas and principles that make those toys tick.

And ultimately the goal is to have kids be familiar with engineering principles at a younger age so that when they encounter more complex STEM ideas, they are not afraid. One of the reasons many students leave engineering majors in college is due to the overwhelming nature of the material. Yet if they are exposed to STEM and engineering concepts earlier on in life, they will be more likely to stay and help create a new wave of young engineers. **md**

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## What's Inside

# Sensor Leverages Thermodynamics to Measure Gas Flows

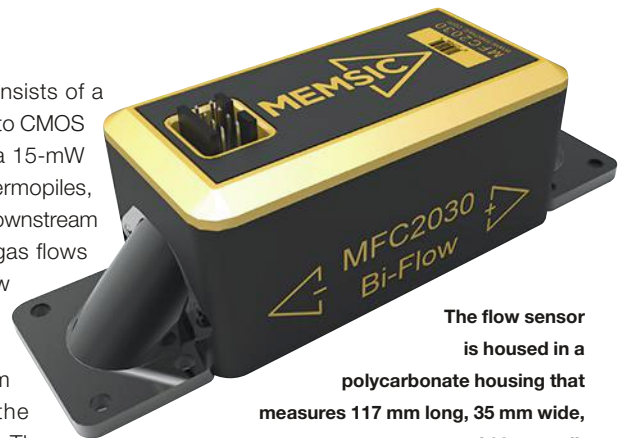
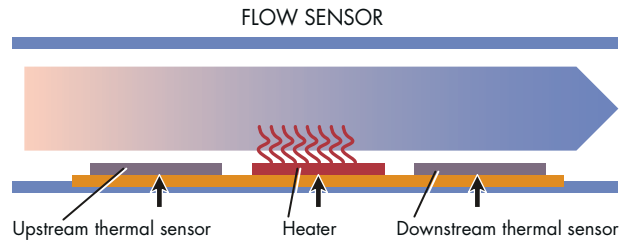
### THE MFC2000 SERIES

gas-flow sensor from MEMSIC Inc. ([www.memsic.com](http://www.memsic.com)), Andover, Mass., can measure up to 70 liters per minute of gas flow (in either direction) while creating less than an 18-mbar pressure drop.

The actual sensor consists of a small cavity integrated into CMOS circuitry equipped with a 15-mW heat source and two thermopiles, one upstream and one downstream from the heater. When gas flows through the sensor's flow path, which is parallel to the rest of the flow, the incoming and upstream thermopile measures the temperature of the gas. The downstream thermopile detects more heat since the gas has traveled over the heater. An algorithm then calculates the flow rate using the temperature readings and timing data to determine the flow rate of the gas. Accuracy is to within 3%; repeatability is  $\pm 0.8\%$ .

The heater's output is a function of flow—the higher the flow, the more heat is generated. This minimizes power to the heater when flow is low or nearly zero. Other heat-flow paths, such as through the substrate or electrical leads, have been minimized by designers so that they don't upset the thermal-mass readings. The meter works on some flammable gases and has been tested with natural gas.

The lack of moving parts makes the device durable and long-lasting. It is also economical in terms of power, operating on less than 5 mA. When in sleep mode (no flow), it needs only 100  $\mu$ A. It requires 2.5 to 5.5 V of external power, but typically runs on 3.3 V. The output is digital, but other types are available. **md**

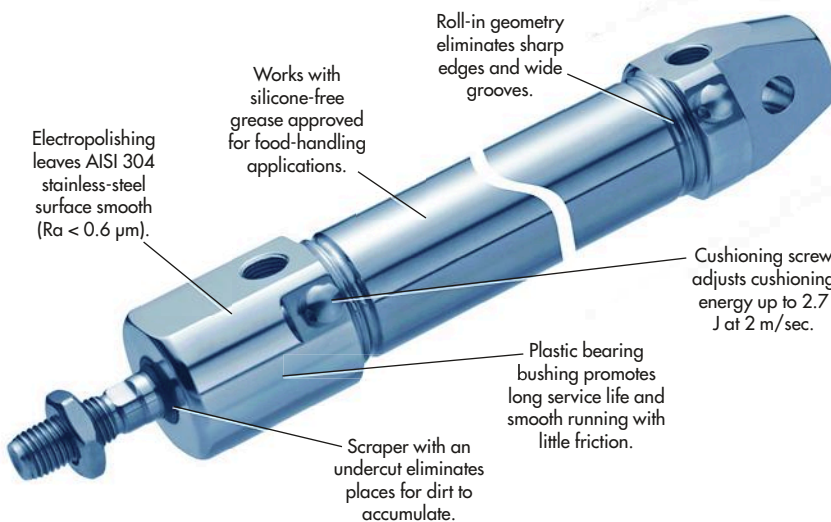


The flow sensor is housed in a polycarbonate housing that measures 117 mm long, 35 mm wide, and 33 mm tall.

# Pneumatic Cylinder Designed to Stay Clean

**THE CSL-RD MINI** pneumatic actuator from Aventics Corp. ([www.aventics.com/us](http://www.aventics.com/us)), Lexington, Ky., was designed with hygiene in mind. For example, its tube/cover was made using roll-in geometry, which reduced the width of gaps between housing components and eliminated sharp edges and grooves. There's also a new scraper without an undercut. All of these features prevent accumulation of dirt.

The stainless-steel housing, plastic slide bearing, and other components are built with materials that resist corrosion and harsh chemicals, an advantage for parts exposed to frequent washdowns. The cylinders also meet ISO 6432 standards. These characteristics make the cylinder well-suited for the food and drink companies, as well as the chemical industry.



The cylinders also come with sensor holders that are easy to assemble and attach. Designed to fit ST4 and ST6 series sensors, they are made of light, high-strength plastic that resists all common industrial cleaners. The cylinder also features pneumatic cushioning that can be adjusted using a hex-headed screw designed to minimize dirt accumulation.

The cylinder can withstand temperatures from  $-20^{\circ}\text{C}$  to  $80^{\circ}\text{C}$  with PUR seals or  $-10^{\circ}\text{C}$  to  $150^{\circ}\text{C}$  with FKM seals. The cylinder's pressure range is 1.5 to 10 bar. Bore sizes are 16, 20, and 25 mm, and strokes can be up to 1,200 mm. **md**



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# News

## A Trip to Mars:

### Playing Pretend Could Get Kids Interested in STEM

In a commentary published at the end of last year, *Machine Design* Senior Editor Stephen Mraz proposed that outer space become an integral part of STEM education. His belief was that presenting kids with opportunities to explore space technologies (such as those needed for colonizing Mars or the moon) would boost kids' interest in general engineering, math, and science.

Though it would require extensive funding to send students on a real field trip to the moon (think of the children's show "The Magic School Bus"), a new STEM academy at Westminster College creates an imaginary scenario where kids are preparing to take a trip to Mars. Based off concepts in the book and movie *The Martian*, it explores a range of technologies and applications that would be necessary to inhabit the red planet.

The STEM academy will take place from 8:30 a.m. to 5 p.m., June 27-30, when Mars is in its prime position for viewing. Led by Westminster scientists and professors, students will perform hands-on experiments during the day and look out at their hypothetical destination at night. The class will also give students an opportunity to learn in a college setting with advanced resources.

The first segment in the four-day session will teach how to analyze the microbiology of soil. They will discuss the importance of microbes in vegetation and their pivotal role in the nitrogen cycle.

Next, the mechanisms of photovoltaics will be explored. Professors will show the students how to apply testing conditions that maximize energy production. Finally, they will create their own working dye-sensitized solar cell.

At night, the kids will learn stargazing skills in the Planetarium Theater and Observatory. They will examine the motion



of planets and stars, and the professors will offer a discourse on the challenges of surviving on Mars. In addition, they will investigate the thermodynamics and kinetics of heat flow associated with temperature regulation.

The class is open to the first 30 students who register, and is aimed at students entering grades 9 and 10. The class costs \$250 for the week. Students who qualify for financial aid should contact Dr. Peter Smith, event coordinator and professor and chair of chemistry, at (724) 946-7299 or [smithpm@westminster.edu](mailto:smithpm@westminster.edu). Registration is available at [www.westminster.edu/stemacademy](http://www.westminster.edu/stemacademy). ■

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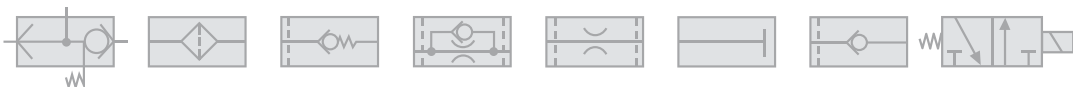
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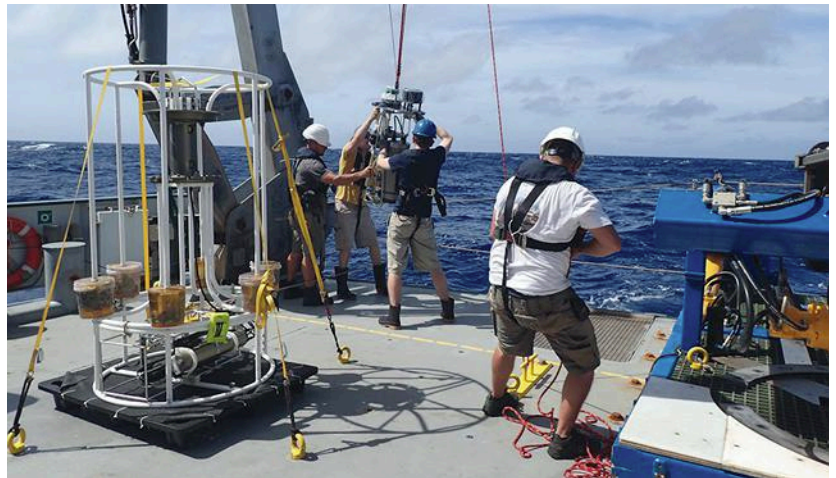


Hexapods

News

## ANALYSIS OF MICROBE Metabolism Could Reveal Clues about Atmosphere

**WHAT CAN WE** learn from the various microbial populations that span our oceans? Protozoa, archaea, and bacteria are very sensitive to their surroundings, changing various aspects of their metabolism to survive with the nutrients available to them. The organic materials used in these metabolic cycles, along with their byproducts, directly affect the levels of organic materials (e.g., nitrogen, hydrogen, oxygen, and carbon) in the water, sediment, and atmosphere. Furthermore, changes in microbial metabolism may offer a different perspective on the health of our oceans and the effects of temperature, current, and water composition.



To this end, the Woods Hole Oceanographic Institution (WHOI) is studying the biochemistry of microbes in low-oxygen maritime regions—also known as dead zones—where aerobic lifeforms that depend on free oxygen in the water cannot survive. The scientists plan to collect various population samples of microbes to analyze a large database of anaerobic mechanisms throughout Atlantic Deadzones. They hope to gain insight on current cycles of organic materials in dead zones and their effects on the Earth's atmosphere.

During its 22-day "ProteOMZ" exhibition, WHOI scientists traveled through dead-zone regions between Hawaii and Tahiti aboard the Schmidt Ocean Institute's R/V Falkor research vessel. They used a rosette to collect thousands of microbial-population samples by pumping seawater through collecting filters as they traveled the ocean. The method allowed them to accumulate microbial samples at various depths up to 1000 meters, and subsequently examine the effects of water pressure, underwater currents, and temperature on oxygen levels and microbial metabolism.

The next step is to use a range of new techniques at WHOI's Saito laboratory to map out the enzymes and functions in different anabolic and catabolic mechanisms. Using an established targeted metaproteomics (a type of protein analysis) approach, the team will analyze the structure and functions of several enzymes that catalyze metabolic reactions. With such a wide sample size, thousands of mechanisms will be investigated above and beyond those we already know, such as Krebs and Calvin cycles. Since high-temperature waters tend to have low levels of dissolved oxygen, the study also expects to uncover the effects of global warming on our atmosphere and maritime biomes.

Finally, the study should also provide clues about hurricane effects on ocean waters, since the expedition occurred during a strong El Niño year. ■

## MAGNETIC LEVITATION TO Elevate Independent-Cart Performance

### AFTER ACQUIRING MAGNEMOTION

Inc., a manufacturer of intelligent conveying systems, Rockwell Automation expects to advance automated conveyors and processing technologies into the next generation. Specifically, the company plans to incorporate the unique magnetic-levitation capabilities of MagneMotion conveyors into its iTRAK independent cart solutions.

Previously purchased in 2013 from Jacob Automation, iTRAK motion solutions apply magnetic propulsion techniques in automotive and general assembly, packaging, and material handling. By incorporating complementary MagnetMotion technologies into its product, Rockwell anticipates capabilities such as independent transfer of products between machines.

"MagneMotion expands our existing capabilities in independent cart technology," says Marco Wishart, vice president and general manager of Rockwell Automation's motion control business. "This acquisition continues our strategy to build a portfolio of smart manufacturing technologies that brings next-generation performance to our customers today."

"As the market continues to realize the benefits of applying independent cart technology, Rockwell Automation's global organization will be a tremendous asset," adds Todd Weber, president and CEO of MagneMotion.

MagneMotion's integration into the Architecture & Software segment of Rockwell Automation's motion business will likely be completed by the end of this quarter. ■



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**News**

**1-V CdTe SOLAR CELLS Rival Silicon  
as Industry Standard**

**A NEW METHOD** for manufacturing high-efficiency cadmium-telluride (CdTe) solar cells was revealed as part of the SunShot Initiative by the U.S. Energy Department's National Renewable Energy Laboratory (NREL), which teamed with researchers from Washington State University (WSU) and the University of Tennessee. The project shows advances in an industry-wide, six-decade effort to improve the efficiency of CdTe solar cells. It has potential to push CdTe solar cells to the forefront of the photovoltaic-cell (PVC) market, ahead of silicon PVCs.



Known for their low manufacturing cost, quick energy-payback time, and robustness in hot or humid conditions, CdTe PVCs rank as the second-most-used solar cells behind their silicon counterparts. But their low open-circuit voltage, which had never surpassed 900 mV, limited the devices' applicability. However, in a *Nature Energy* journal article published this February, the authors claim that the final product surpasses the 1-V mark.

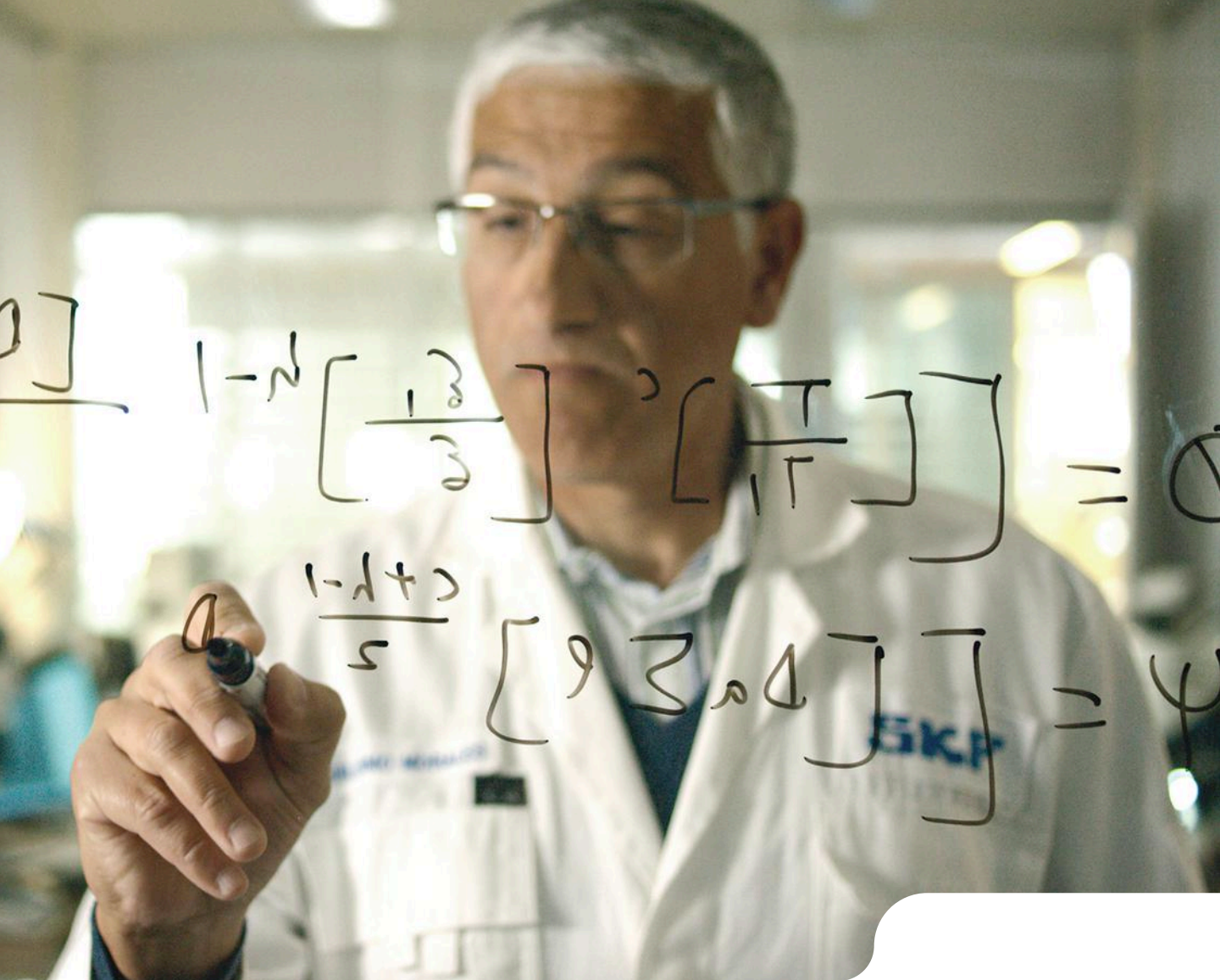
"It's a significant milestone. It's been below 900 mV for decades," said Kelvin Lynn, Regents professor in WSU's School of Mechanical and Materials Engineering and Department of Physics, who led WSU's effort.

According to the report, the method eliminates the use of cadmium chloride. Instead, small amounts of phosphorous at tellurium lattice sites create ideal interfaces between materials with different atomic spacing to complete the solar cell. The method led to better conductivity and carrier lifetime by orders of magnitude, and opens new research paths for efficient solar cells.

While the NREL treated the crystals, in addition to building and characterizing the solar cells, WSU researchers developed the crystal material used in the cell. In a technique called melt-growth, the researchers mixed, prepared, and vacuum-sealed the materials in a clean room to achieve maximum purity. The crystals were then synthesized in a furnace above 1,100°C and cooled from the bottom up at a rate of 1 mm per hour. Subsequently, the crystals were cut into polished wafers to make solar cells.

"Others have tried dopants, but they didn't have the control and purity that we have. And, the purity matters," said Lynn. "WSU is known for growing really high-quality and -purity crystals. You have to control every step."

Lynn also expects that by using WSU's established techniques, CdTe-cell efficiency could improve up to an additional 30%. ■



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## Commentary

BERNARD HEUCHMER | Vice President of Motion Control  
Siemens Industry, [www.usa.siemens.com/motioncontrol](http://www.usa.siemens.com/motioncontrol)



# Setting the Record Straight on Industry 4.0

It seems every trade magazine I pick up nowadays has an article on Industry 4.0 or big data or the Internet of Things or the digital factory. These terms are being pitched around like a rugby ball and almost always with a decided lack of clear definitions.

So, as the saying goes, let's set the record straight.

German Chancellor Angela Merkel, along with her ministers of industry and education, ordered a study about the manufacturing environment. In response, the National Academy of Science and Engineering, which represents the interests of German scientific and technological communities at home and abroad, drafted its vision of Industry 4.0, which was to be a coordinated initiative between the IT world, universities, and various manufacturing associations to reshape industry. It would seek to combine the physical, virtual, and IT worlds with cybersystems, thereby creating a new working environment between workers and machines.

The 4.0 part of the name, incidentally, derives from it being the fourth industrial revolution. The predecessors were the mechanization of industry through steam and water power, applying electricity to mass production, and the invention of the computer, which has led us to the modern concepts of IT and automation.

Industry 4.0 has been adopted worldwide as a functional goal in industry, especially the manufacturing world and, specifically to our purposes, the machine-tool market. The metrics of performance and goals will differ by industry and end product. And the information-management jobs it will create will be unlike anything seen so far in industry.

Industry 4.0 represents a high point, where every company—whether a large OEM, major tier supplier, or smaller job shop—can implement and benefit from the technologies and communications platforms available today. One factor holding back Industry 4.0 is the mindset of management. That needs to change—they must be more proactive in supporting the changes among market leaders.

Without question, this vision is less a look into the future and more a vibrant collaboration between IT, machine-tool builders, industrial automation integrators, and especially

motion-control suppliers. They will all benefit when machine control can take information needed to make the final products from the design, CAM, and PLM sides, and then send data on production, metrics, and machine-to-machine comparisons to evaluate the performance of machines, different shifts of technicians, and even entire plants—all at speeds measured in nanoseconds.

To work effectively, this concept requires standardization of both the communications and language used. For example, the MT Connect effort, which focuses on machine tools, has been a good start here in the United States. It strives to standardize the data, so that all types of machines with a host of different control brands on board can seamlessly transmit data up the line for evaluation and adjustment in real time.

The goal is to make the first part or batch faster and better, then improve that performance by using actual production data and feedback control to make the needed adjustments and compensations. This also applies to handling raw materials and components, and the logistics of moving incoming and finished products into and out of the plant.

Although this big-data idea overwhelms most managers, technicians, and operators, the key is to manipulate that data in a hierarchy of need, to borrow a term from the psychology world. Mobile devices, tablets, cell phones, and now CNC screens themselves can be useful tools for transmitting the most important data from the shop floor to the top floor, or just down the hall to the front office.

Small-shop owners would be well advised to heed this trend and respond appropriately. For example, they could use an integrator to tie all of their machine functions and outputs together for the day when demanded by their OEM or upper-tier customer. In many industrial sectors, that day has already arrived.

Lastly, the cybersecurity issue cannot be understated, as data storage in a factory or shop network will shift from the open cloud to the closed cloud. Protecting your intellectual property remains paramount, on a global scale. To overlook that reality is to compromise the stability and security of your company.

Welcome to the future, folks. **md**

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## What's the Difference?

JEFF KERNS | Technology Editor  
jeff.kerns@penton.com

# What's The Difference Between Aluminum and Copper in Electrical Applications?

**Are myths and misinformation leading designers to use the wrong material?**

**T**here are obviously material property differences such as capacitance, weight, and cost between aluminum (Al) and copper (Cu) to consider for an electrical application. Al was more prevalent in the past for products such as bus bars, fuses, and breakers. Over time, some designers have changed components from Al to Cu. Today, due to cost stability and coating, some designers are switching back.

### MATERIALS

Misconceptions about the properties between Al and Cu can arise due to different grades of metals used in different electrical applications. The Cu used in wire and electrical equipment is nominally pure. Pure Al, however, is often not strong enough for electrical applications. Also, keep in mind that different alloys have changed over time and on account of evolving applications.

Different Al alloy properties will also change, depending on processing. For example, Al 6101 is stronger than Al 1350. Yet heat-treating Al 6101 hardens it and improves its strength. Different grades of metals, such as Al 6101 and Al 1350, will



Aluminum cables with fine-wire stranding help flexibility to enhance installation and their use in applications where a small bend radius is required.

vary in comparisons with Cu. During the design process, it is therefore essential to have the material properties for the specific material used.

### PROPERTIES

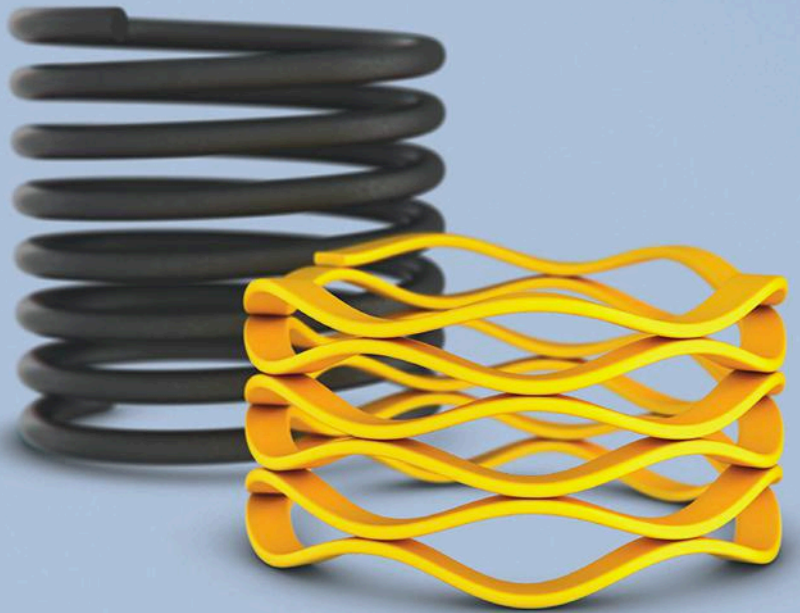
Weight, electrical capacity, and cost are major considerations when selecting Al or Cu for an electrical application. Yet others can loom just as large. For example, resistance in electrical connectors can increase if a material's strength and expansion are not considered. As a connection undergoes thermal cycles, the expansion can increase the clamping force that can deform contact points and promote creep in materials. This will be a larger concern with Al because its coefficient of thermal expansion, depending on the alloy, is about 42%

# SMALLEY WAVE SPRINGS: FORCE WITHOUT THE FOOTPRINT.

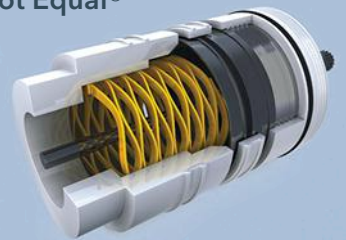
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## What's the Difference?

greater than Cu, but Al may be able to dissipate the heat faster.

Taking advantage of the lower modulus of elasticity since the 1990s, extruded Al bus bars have increased the surface area, helping to keep temperatures low. It is important when designing in either material that connections are robust to prevent poor connectivity over time, owing to deformation from thermal expansion, as well as creep.

A common misconception is that Al is soft and must use compression connectors. However, with some design and plating changes, mechanical pressure connectors and compression connectors are no longer required. In some cases, alloys or processing are used to make aluminum almost on par with Cu. In addition, coating and plating will often include tin or silver. These materials reduce corrosion in both Al and Cu, as they are prone to oxidation when exposed to the atmosphere.



Relays, sensors, switches, and small motors can use control cables for on/off control applications for signal and control equipment.

Corrosion is also a problem when there are two dissimilar metals in one system. Al will electrochemically react with the Cu if moisture is introduced (moisture that would act as an electrolyte). Al to Cu cable lugs are connectors that have been friction welded and capsulated to prevent corrosion from

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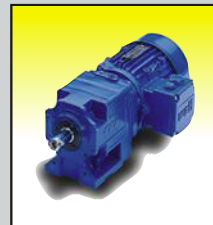
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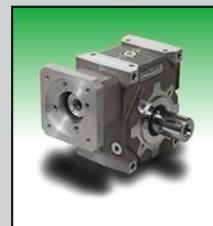


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## APPLICATIONS

### AL APPLICATIONS

**Transmission and distribution lines:** The lighter Al wire means fewer support towers, leading to most of the world using Al for high-voltage overhead transmission lines.

**Lighting applications:** Many light bulbs and other connectors in the past used brass connectors. Today, many lighting connectors use Al.

### CU APPLICATIONS

**Telecommunication wires:** Cu's higher ductility works well to provide flexibility and less breaking to the telecommunications industry.

**Motors:** Size and capacity are important factors in designing motors and as a result, many manufacturers use Cu for their designs.

### BOTH CU AND AL APPLICATIONS

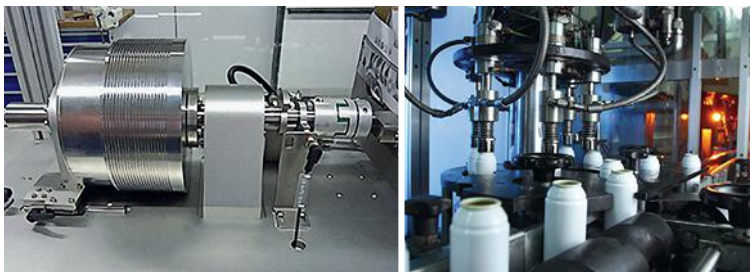
**Large building wiring:** Al is in many of the wires for large buildings. It offers price stability over the long time it takes to build them. In addition, if space is not a problem Al can reduce the price for large buildings that can contain miles of wires. However, Cu's ductility and smaller size work well for conduit inside the buildings. Hence, both offer advantages in large buildings.

Other applications in which both Cu and Al are used include bus bars, transformers, and low- and medium-voltage underground cables.

damaging an Al-to-Cu connection. Proper connections are important, as corrosive wear is also a concern. Al and Cu are compatible metals, so contact can create bonding that could promote wear. While corrosive wear is more of a problem for parts that move, it's possible a technician may need to take more time in the field if wires are stuck to the bus bar.

### WEIGHT AND ELECTRICAL CAPACITY

Arguably, the main material property in deciding between using Al or Cu in an electrical application is its capacity. Cu offers a better electrical capacity per volume. However, Al has better capacity per weight. According to Uwe Schenk, global segment manager at Helukabel, "As a raw material, Al is approximately 70% lighter than Cu. For wires, Al can be up



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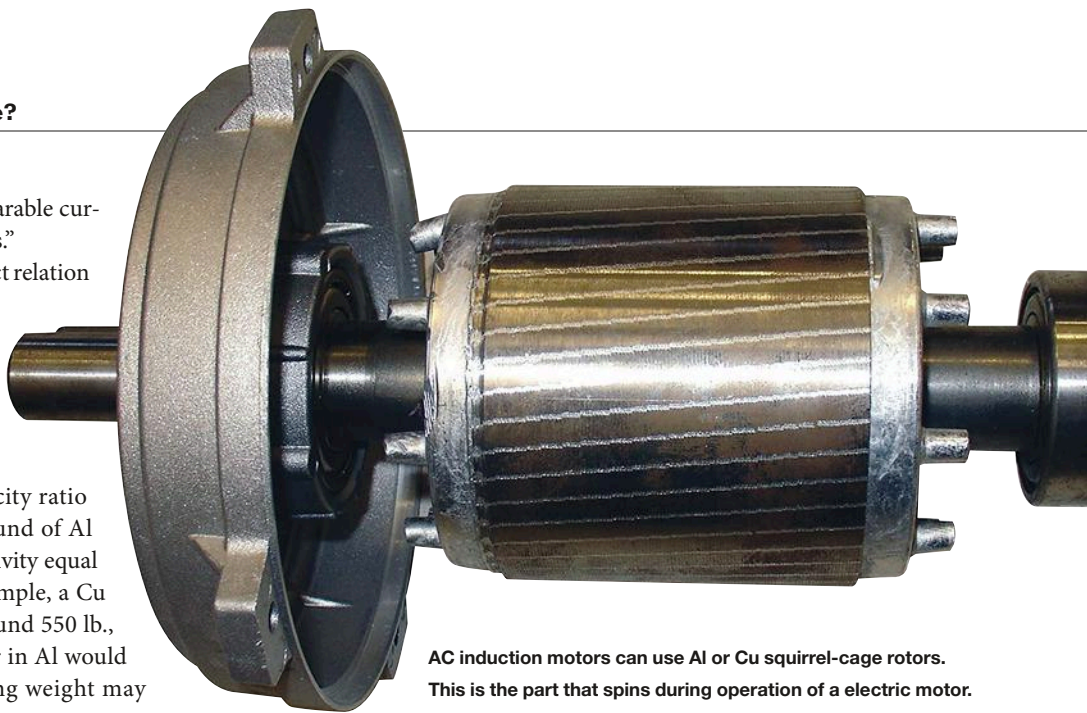
## What's the Difference?

to 60% lighter than comparable current carrying copper wires.”

The weight is not a direct relation as more Al is necessary to match the capacitance of Cu. Al carries about half the capacitance of Cu (56% in Al 6101). The difference in the weight to electrical capacity ratio means generally, one pound of Al has the electrical conductivity equal to 1.85 lb. of Cu. For example, a Cu bus bar could weight around 550 lb., whereas the same bus bar in Al would be about 300 lb. Reducing weight may help shipping or even labor cost.

### OTHER CONSIDERATIONS

Although labor is not a material property, it does affect cost. Some projects may be more cost-effective if weight is able to be reduced—whether this translates into shipping, installation, or other costs. However, lighter may not be better in all applications. Consider the added diameter in an Al wire to match the



AC induction motors can use Al or Cu squirrel-cage rotors. This is the part that spins during operation of a electric motor.

capacitance of Cu. The National Electric Code (NEC) gives rules for how much a cable can fill a piece of conduit.

There are more rules than this, but, generally speaking, when dealing with three or more cables, pipe fill has to be 40% or less. However, NEC Article 501 says if the conduit is in hazardous locations, only 25% fill, or less, is accepted. This means the increased size of Al might increase the cost

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of labor for the extra or larger conduit that now needs to be run to satisfy the NEC.

For a general example, if switching from 14 AWG Cu cable to Al, the increased cable size (12 AWG) will reduce the maximum amount of wires allowed in ¼-in. conduit by three (max fill: Cu = six wires, Al = three wires at 40% fill). If this application needs four cables, you can reduce the fill by running two pieces

of conduit or a larger size—which will use more energy to bend. Either of these solutions could increase labor.

There have been other problems with Al in electrical components. Historically, Al was prevalent in switchgears (fuses and circuit breakers). Unfortunately, in the past, welding was often necessary to fasten switchgears. Al welding in the field may have been what pushed designers to switch to Cu. Since this time, they have offered bus bars with holes or dovetail-like grooves that allow for easier installation and do not necessarily have to be welded.

Despite addressing these processes, manufacturers like GE reported that many customers started requesting Cu bus bars over Al. Manufacturers will produce based on what designers order, so Cu was produced in higher volume. Some of Al's past problems, while corrected, gave Cu manufacturing momentum.

Despite this trend, cost and planning remain key factors when estimating projects. Al is the third-most abundant material in the Earth's crust, while Cu is the 26th. This has Cu prices fluctuating while the cost of Al is more stable. If a designer is planning a long-term or future project, Cu prices might be hard to predict. If Cu prices become higher than projected, it can hurt or even bankrupt a project. This is one of the reasons why large wind projects have been using Al. Often they plan over long periods of time, and need a stable price for accurate estimates. In addition, wind turbines can be up to 328 ft. high and use a heavy gauge wire to transmit electricity to the ground. Reducing the weight of a cable, such as this transmission wire, could

help reduce supports and unnecessary stress on connectors, and make it easier to install.

Large projects requiring massive amounts of wiring might find Al to be cost-effective. Currently, the Nasdaq shows Cu at \$2.14/lb. and Al at \$0.73/lb. (3/16). As cost is such a driving factor—not negating the aforementioned—if an increased size isn't a concern and you need a large amount of it, Al might be a better choice. **md**

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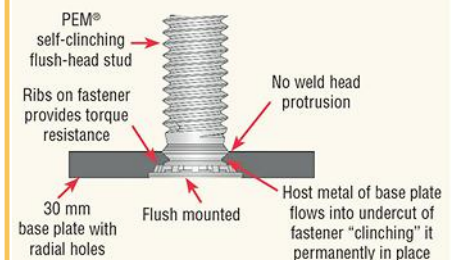
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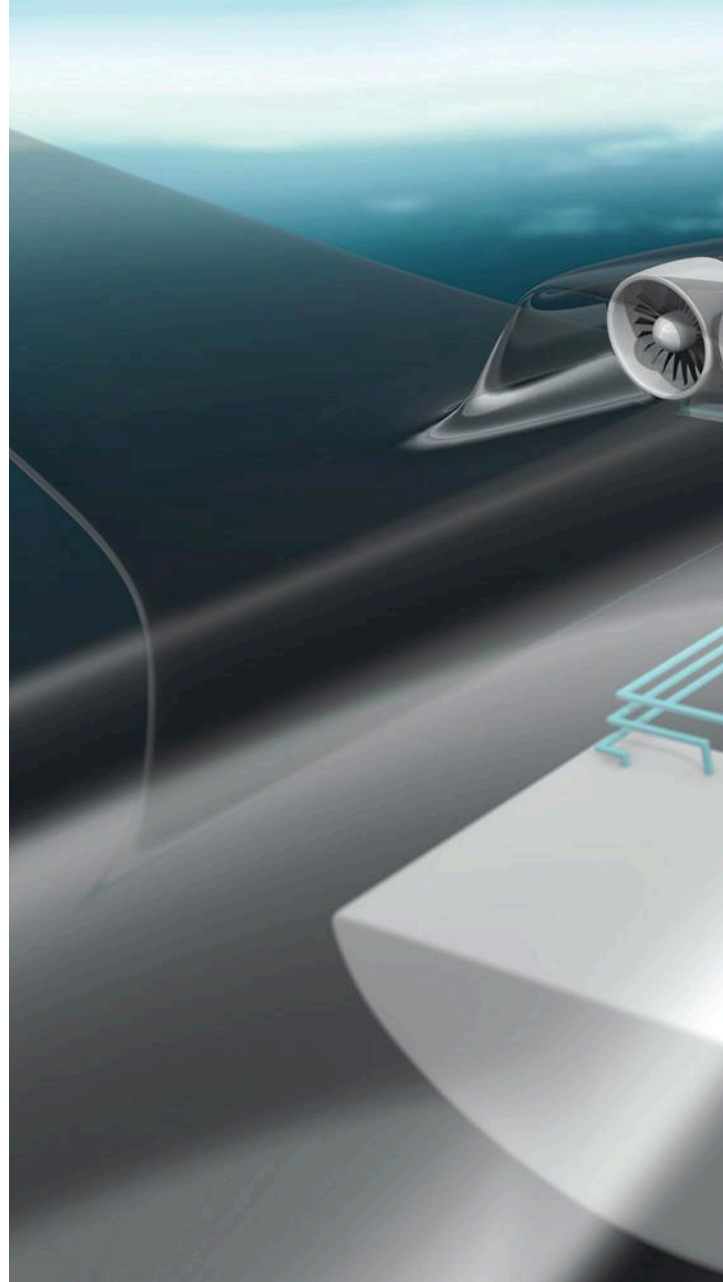


# The Future of Electric Hybrid Aviation

**NASA and Airbus are leading the way in cleaner aviation by designing purely electric or hybrid aircraft.**

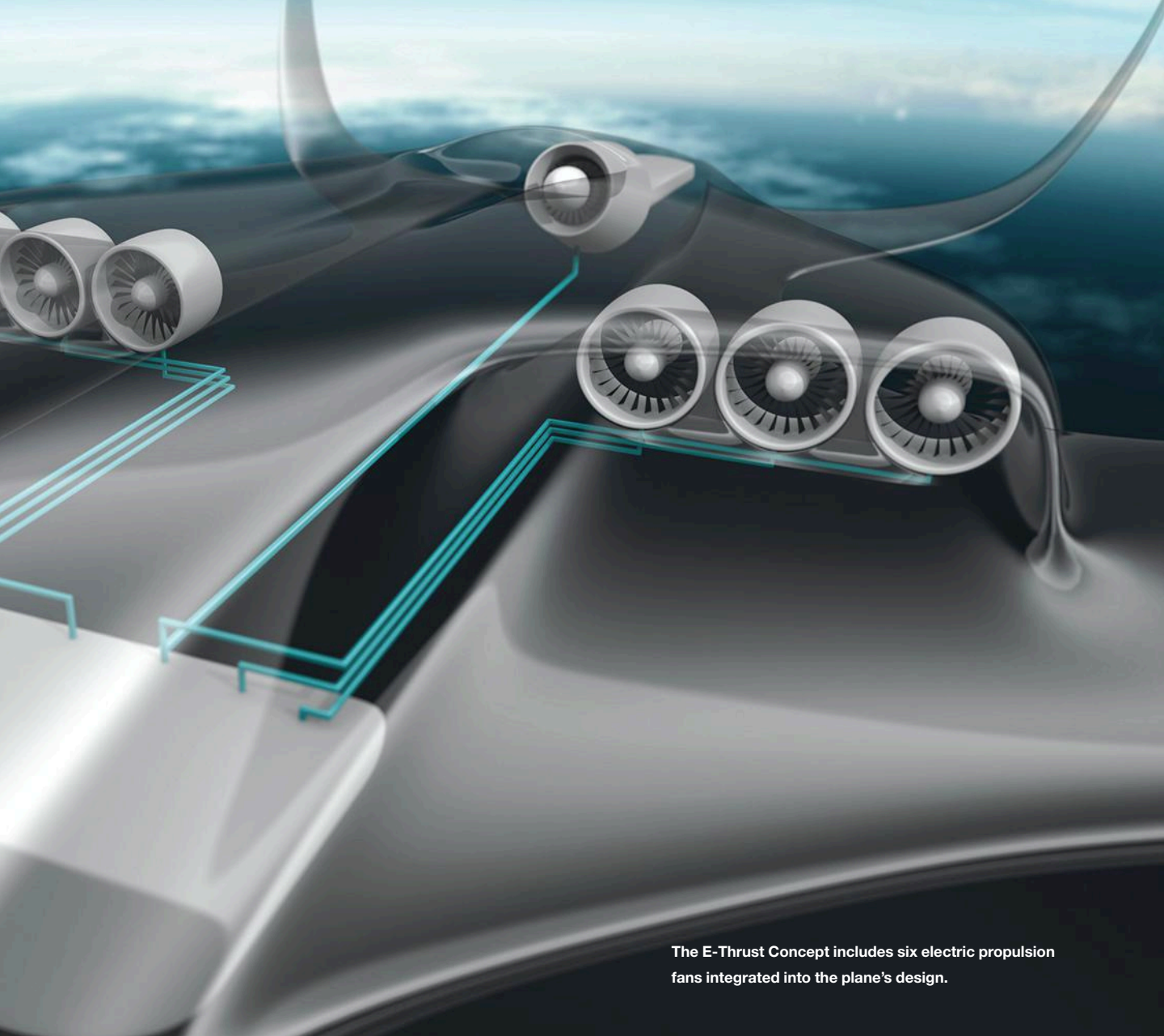
**P**art of the push toward electric-hybrid aircraft is to cut carbon emissions produced by aircraft. According to the Natural Resources Defense Council (NRDC), in 2012, 98% of all apparel items imported came from abroad and mostly through air transport. The NRDC reports that when a plane is used instead of a cargo ship, 4.5 times more particulate matter and 25 times more nitrous oxides are added to the environment. National Geographic reported in April 2015 that airplanes contributed 700 million metric tons of carbon dioxide to the air in 2013. The number, if changes do not occur, is set to triple by 2050.

The 1997 Kyoto Protocol climate pact delegated responsibility to the United Nations' International Civil Aviation Organization (ICAO) for controlling aviation emissions. In the United States, many environmental groups have sued the Environmental Protection Agency (EPA) to push for harder regulations under the Clean Air Act. Last year, *The New York*



*Times* reported that according to the EPA, American aircraft in the United States' transportation sector contributed 11% of greenhouse gas emissions and 29% of all aircraft emissions worldwide.

Finally, this past February, ICAO announced the first-ever international agreement to cut carbon emissions from commercial airplanes. There are 23 countries onboard with the new agreement, including the United States. The agreement calls for a 4% reduction in fuel consumption from new commercial aircraft built after 2028 and from aircraft in current production that will be delivered after 2023. The new standards plan to cut carbon emissions from airplanes by more than 650 million tons between 2020 and 2040. According to a White House statement about the agreement, this is equivalent to emissions from 140 million cars. These regulations are driving the United States and other manufacturers to design more efficient aircraft.



The E-Thrust Concept includes six electric propulsion fans integrated into the plane's design.



The Sceptor demonstrator design is based on a Tecnam P2006T light aircraft.

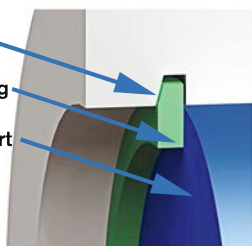
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## Electric Hybrid Planes



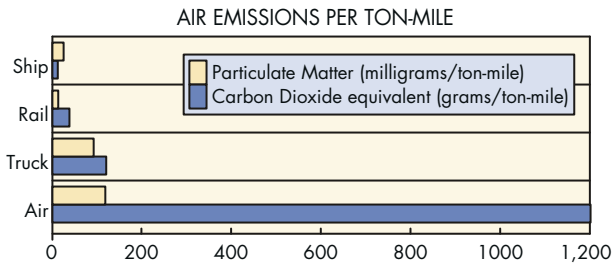
### NASA, EFFICIENT AIRCRAFT, AND NEW X-PLANES

The advancements of hybrid or electric power to improve automobiles serve as the base technology being applied toward aircraft. Currently, the engineers and scientists at NASA's Glenn Research Center are actively researching the next generation of efficient aircraft. One of their current objectives is to help shift the industry from solely using gas turbines to start implementing hybrid or turboelectric propulsion. The benefits of this are reduced energy consumption, emissions, and noise. Jim Heidmann, manager for NASA's Advanced Air Transport Technology project, notes that "moving toward alternative systems requires creating new aircraft designs as well as propulsion systems that integrate battery technologies and electromagnetic machines like motors and generators with more efficient engines." The researchers at Glenn are looking at alternate power systems that generate electricity in place or in addition to thrust at the turbine engine,



LEAPTech is the ground-based testbed created to work out the challenges of having multiple propellers on a single wing.

and then the electricity is converted into thrust using fans at other aircraft locations. Along with this, they also are investing research into lightweight alternative materials, wire insulation, conductors, and the improvement of magnetic materials and semiconductors to make motors and electronics lighter.



The graph above compares air emissions against different types of travel used for transporting commerce goods.

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## Electric Hybrid Planes



Sceptor, which stands for Scalable Convergent Electric Propulsion Technology Operations Research, is NASA's distributed electric propulsion testbed. It is part of the next generation of X-planes and is the first step in NASA's plan for a megawatt-class electric propulsion commercial aircraft. The goal is to create an aircraft that can fit nine passengers with a 500 kW power system (nearly 700 horsepower) by 2019. The plane weighs 3,000 pounds and is scheduled to fly in early 2018. The aircraft will have multiple electrically powered propellers evenly distributed on its leading edge to increase lift by up to five times at low speed and enables the use of a smaller and more efficient wing, optimized for cruising speeds. Joby Aviation has been working with NASA on Sceptor with its Leading Edge Asynchronous Propellers Technology (LEAPTech) program.

The LEAPTech program mounts 18 electrically powered propellers on its leading edge, which is then mounted above-truck. Initial tests have shown that distribution of power among the 18 motors has doubled the lift at lower speeds when compared to traditional systems (max speeds on the truck beds have been around 73 mph). With a wing aspect ratio of 17, the wing used for the LEAPTech program is very slender and does not have much room available inside for motors, controllers, wiring, and instrumentation. The area of the test wing is about half of the original P2006T wing. The initial motor controller did not fit in the pod and was not fast enough, according to Starr Ginn, deputy aeronautics research director at NASA Armstrong Flight Research Center. "EMI created havoc on the communications bus. At high power, the whole prop system would turn off," says Starr. Eventually, the motors and wing developed by Joby Aviation for LEAPTech

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The Starc-ABL aircraft includes a proposed electric turbofan toward the rear of the aircraft.

will be used as NASA's Hybrid Electric Integrated Systems Testbed (HEIST) and eventually the Sceptor test aircraft in 2018.

For the larger-scale aircraft, NASA is studying the Boeing 737-size hybrid turbo-electric powered airliner. Turbo-electric propulsion concepts create more efficient aircraft by combining turbine engines with generators that distribute power to electrically driven propulsors. Using the Boeing 737 aircraft size as the test platform allows NASA to introduce the advantages of a turbo-electric system while retaining the conventional tube-and-wing configuration.

The Starc-ABL (single-aisle turbo-electric aircraft with an aft boundary layer propulsor) is the new test proposal that builds upon previous N3-X team hybrid designs and Boeing's concepts for turbo-electric airliners—research done under the joint Boeing-NASA venture the Sugar Program. The turbofans provide 80% of thrust during takeoff and 55% at the top-of-climb. The rest is done via the aft-fan propulsor located at the end of the aircraft below the tail. The aft-fan is designed to operate at a constant 3,500 horsepower at high throttle settings. Even with the additional weight from the empennage and larger wing compared to a similar-sized hybrid wing bodies, initial studies show a 15% improvement in thrust-specific fuel consumption at the start of the cruise.

According to NASA Langley Aeronautic Systems Analysis branch engineer Jason Welstead, "this translates into 7% and 12% block fuel-burn savings for the economic and design missions, respectively." By ingesting the slower-moving air coming off the fuselage body, the study proves the efficiency possible by the aft fuselage boundary layer ingestion fan, which achieves its benefit by ingesting up to 45% of the boundary layer. The electrically driven aft-fan provides the added ben-

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## Electric Hybrid Planes

enefit of suffering no thrust loss or power lapses that typically affect air-breathing engines at increased altitudes. Due to the increased efficiency of the propulsor, the diameter of the turbofans can be reduced from 70 in. to 52 in., helping the aircraft achieve an overall lower weight.

### AIRBUS' HYBRID AIRCRAFT CONCEPTS

Airbus set a new world record in July 2015 by being the first manufacturer to cross the English Channel using an entirely electrically operated aircraft. The E-Fan Electric Aircraft is a twin-engine electric plane with a maximum speed of 220 km/h that can run for 45

minutes to an hour on a single charge. E-Fan's two electric motors deliver 60 kW of combined power, which drives the two aft-mounted, ducted, variable pitch fans. The lithium-ion battery system that powers the motors is comprised of 2,982 cells with a capacity of 2.8 amperes per hour each. The test aircraft that crossed the English Channel was a one-manned piloted aircraft that weighed around 600 kilograms at an altitude of 1,000 meters.

The E-Fan program is an expandable platform that leads to its Airbus larger program, the Distributed Electrical Aerospace Propulsion Project (DEAP Project). The program is part of Airbus'

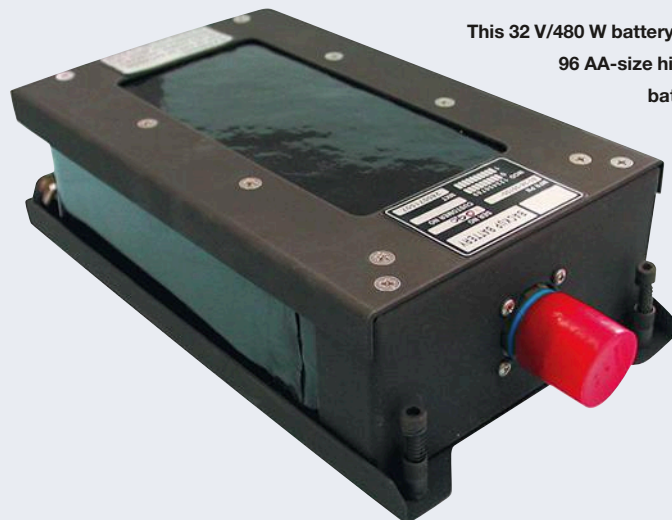
## SMALL BATTERIES DELIVER BIG POWER TO UAVS

By SOL JACOBS, Tadiran Batteries

**ADVANCEMENTS IN UAV/DRONE** technology have created a need for small lithium batteries that can pack large amounts of power into very small spaces. Design engineers are continually seeking to make UAVs smaller and lighter to benefit aerodynamics and range of flight. Large UAVs typically utilize gasoline engines, with lithium batteries being deployed to reduce size and weight when powering specific sensor or instrumentation platforms or for emergency backup power requirements.

### MILITARY-GRADE LITHIUM METAL OXIDE BATTERIES

Lithium metal oxide batteries deliver a nominal voltage of 4V, and a discharge capacity of 135 mAh to 500 mAh, capable of handling 15A pulses. They are constructed with a carbon-based anode, multi-metal oxide cathode, organic electrolyte, and shut-down separator for



This 32 V/480 W battery pack consists of 96 AA-size high-power lithium batteries capable of delivering up to 120 Watts per hour at -30 °C, and weighs approximately 2 Kg, including its metal enclosure.

E-Thrust Concept, which is being developed in conjunction with Rolls-Royce. The Airbus Group Innovations will take lead on the project, designing the electrical system and optimizing the integration of the propulsion system while Rolls-Royce develops an electrical system propulsion plant to build the new engines. The E-Thrust concept involves a distributed propulsion system that has six electrically powered fans distributed along the wing span. There will be one centered gas-powered unit providing hybrid electrical power for the six fans and for recharging purposes. To achieve optimal propulsive efficiency, the bypass ratio values need to be beyond 12, which

is the current value of today's most efficient turbofans. Current estimations state that values of over 20 are achievable that leads to significant reductions in fuel consumption and lower emissions. The benefit of having a number of smaller e-powered fans as compared to larger electrical turbofans as seen in the Starc-ABL is reduced system noise.

The three essential parts of the DEAP architecture according to Airbus are: a wake re-energizing fan; structural stator vanes that supply electrical power and cryogenic coolant; and a hub-mounted superconducting electrical machine. Just as the concept behind the Starc-ABL, by ingesting the boundary layer

enhanced safety, and should feature an extremely low self-discharge and a wide operating temperature range (-40°C to 85°C.). For example, a UAV utilized for unmanned air reconnaissance is deploying lithium metal oxide batteries to create smaller, lighter battery packs for the emergency recovery system, which enables the aircraft to glide to a safe landing in case of a catastrophic system failure.

The batteries should comply with MIL-STD 810G specs for vibration, shock, temperature shock, salt fog, altitude, acceleration (50,000 gn), and spinning (30,000 rpm), and also conform to UN 1642 and IEC 60086 standards for crush, impact, nail penetration, heat, overcharge, and short circuit, making them ideal for use in guided munitions.

Unlike reserve/thermal batteries, lithium metal oxide cells permit instantaneous activation without the need for squibs or gas generators, allowing power to be drawn intermittently so the circuitry can be periodically tested for system readiness. These cells also avoid the high internal temperatures created by reserve/ thermal batteries, thus eliminating the need for bulky layers of thermal insulation, or the squibs, gas generators, and external heating elements required by silver zinc batteries.

#### RUGGEDIZED LI-ION BATTERIES

Rechargeable lithium-polymer (LiPo) batteries, which are essentially the same as consumer-grade lithium-ion (Li-ion) rechargeable cells, have traditionally powered miniature UAVs flown by consumer hobbyists.

Consumer-grade Li-ion cells are generally not intended for long-term deployment in mission-critical applications involving extreme environmental conditions. Consumer grade Li-ion cells have a life expectancy of less than five years and 500 recharge cycles and operate within a moderate temperature range of 0°C to 40°C. However, if the miniaturized UAV is intended for use in remote, inaccessible locations or extreme temperatures, then design engineers should strongly consider the use of an industrial grade Li-ion battery, as these ruggedized cells can deliver up to 20 years of operating life with 5,000 full recharge cycles, an expanded temperature range of -40°C to 85°C, and the ability to deliver high pulses (5A for a AA-size cell). Industrial grade Li-ion cells are also constructed with a hermetic seal, which is superior to the crimped seals found on consumer-grade rechargeable batteries, which may leak. Industrial-grade rechargeable Li-ion batteries are being deployed in miniature UAVs that soldiers carry into the battlefield and deploy as needed to observe enemy positions.

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The E-Fan from Airbus is the first fully electric plane to cross the English Channel.

and accelerating it by the fans, can cause a reduction in the losses in momentum that form a wake, lower drag, and increase efficiency, the DEAP system, with its relaxed engine-out design and better weight distribution, allows for greater flexibility over aircraft design leading to a smaller vertical tail plane. The stator section of the electric fans provides stator vanes that are aerodynamic and recover thrust from the swirling air.

The stator vanes also accommodate internal routing of superconducting cables to the hub-mounted superconducting electrical machine. Superconductivity is a quantum mechanical phenomenon where you have zero electrical resistance. This occurs in materials cooled below a critical temperature and allows electrical system components to be smaller and lighter. Cryogenic fluids like liquid hydrogen or liquid helium or a cryocooler—a technology used in many space applications—are used to achieve the desired effect.

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“ Within the next two decades, energy densities will exceed 1,000 Wh/kg, according to Airbus, which will double our best-performing batteries to date. The upcoming advancement in batteries is lithium-air batteries. ”

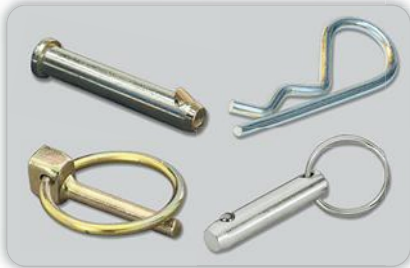
The hub-mounted superconducting electrical machine drives the wake re-energizing fans. Rolls-Royce and Airbus Group Innovations, with Magnifye Ltd and Cambridge University, are currently designing the Programmable Alternating-Current Superconducting Machine (PSAM). PSAM is a superconducting stator that will generate an electromagnetic field that rotates around the circumference at a velocity that is directly related to the frequency of the electricity supply. The electromagnetic torque is created by aligning the rotor's magnetic field with the field electromagnetic field generated within the stator. The superconducting magnets used to

generate the field are aligned in a puck form and can be programmed to deliver different controllable field strengths. This machine will eventually replace conventional copper and iron stator structures.

**WHAT TECH IMPROVEMENTS ARE STILL REQUIRED?**

Lithium-ion batteries are the best choice for electrical hybrid systems. However, higher-capacity batteries will be needed to hold and distribute the large power requirements required for these systems. Within the next two decades, energy densities will exceed 1,000 Wh/kg, according to Airbus, which will double our best-performing batteries to date. The upcoming advancement in batteries is lithium-air batteries. They will have a higher energy density due to oxygen being a lighter cathode and a freely available resource. However, these batteries are still not yet commercially available.

NASA's Sceptor design to Airbus' E-Thrust concept cover the road map of aviation for the next five to 25 years. The ICAO hopes to curtail emissions by 2040 and the European Commission's "Flightpath 2050-Europe's Vision for Aviation" outlines a plan to accomplish their goals by 2050. By then, they hope—when compared to standards from 2000—to reduce CO2 emissions by 75%, nitrous oxides by 90%, and noise levels by 65%. **md**



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# IIoT SEESAW on the ROI Fulcrum

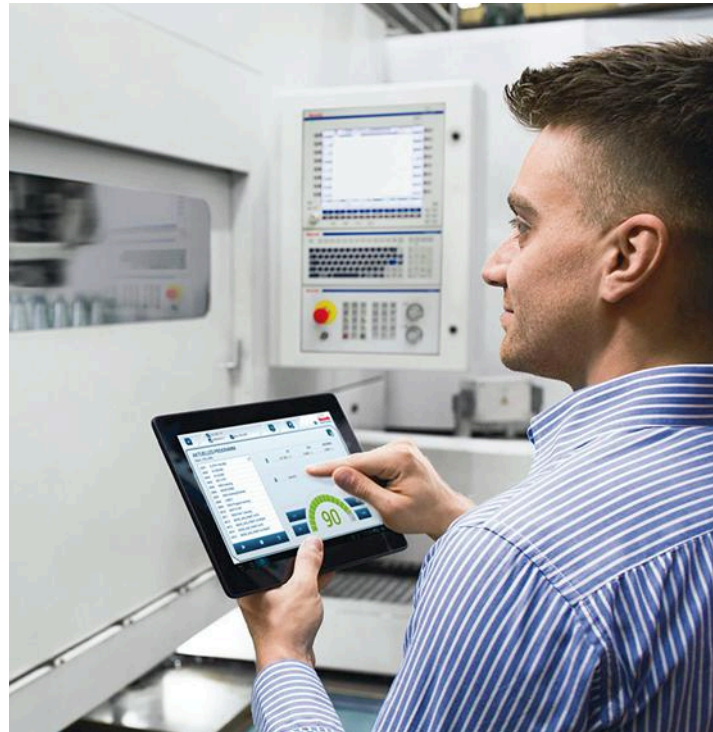
New equipment might bring more benefits, but retrofitting could work better for IIoT applications.

**W**hile the Industrial Internet of Things (IIoT) grows, many question what value it brings to industry. Some IIoT systems work with current production lines and equipment. For example, smart sensors or cameras can mount on existing equipment to provide features and data that add value to the production line and company. Other technology aims to replace equipment by offering already-integrated, value-added smart sensors and IIoT devices. *Machine Design* talks to the experts to see where the return on investment (ROI) is with replacing or retrofitting when considering IIoT.

## THE RIGHT ADOPTION RATE

Economics can help assess the adoption rate and ROI of IIoT. If the technology isn't stable enough to provide an accurate ROI, it isn't worth investing in it or you need to expand the scope of where the data could offer value. "Connected devices can augment data for managers to make more informed decisions that will improve production," says Beth Parkinson, market development director for The Connected Enterprise at Rockwell Automation. Collected data is able to improve production in multiple ways. In fact, data can keep a company competitive using two specific methods—focused and collaborative views.

Focused data—for example, that which tells how much energy a specific motor uses or if a lens is dirty—can help reduce downtime and run processes more efficiently. In a collaborative view, aggregated data can show a root-cause problem or bottleneck issues across production lines, departments, and even companies. It's more complicated to estimate an accurate ROI with a collaborative view due to the variables involved and interpretations of certainty.



Tablets act as a handheld, wireless human-to-machine interface that offers control and information, enabling technicians to stay connected and adjust a process as necessary. (Courtesy of Bosch Rexroth)

The hype surrounding IIoT seems to be traveling faster than its adoption rate. Often medium- to large-sized companies are reluctant to change due to the size of the company's operations. The bigger the operation, the bigger the investment, and the more stable a new technology or equipment needs to be for larger companies to adopt.

However, a study released in 2014 by Cisco revealed that 52% of manufacturers were willing to migrate to hybrid clouds within two years. This may be due to the foundational groundwork that's been building for the cloud and IIoT over the years.



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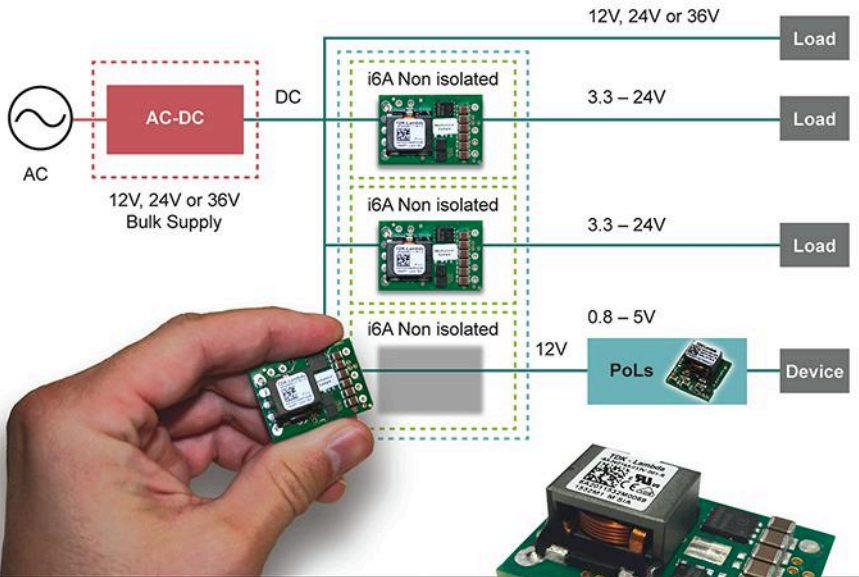


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Loram is a railroad maintenance company that was experiencing downtime with its automated rail grinders due to a lack of historical or real-time data. However, new software called FactoryTalk offered remote access and documentation that improved data collection. As a result, technicians were able to reduce grinder downtime. (Courtesy of Rockwell Automation)

“In the past, different equipment could have operated with different logic controls or languages,” says Parkinson. “Today, I could go to a food-processing plant or an automotive production line and it is possible that they have the same, or similar, controls and languages. In addition, four to five years ago, companies installed smart sensors in production lines. Now, those smart sensors provide a foundation on which to build the IIoT. With the ability for a production line to transmit and communicate data, a whole architecture is ready to be organized to take advantage of IIoT.”

New technology often provides competitive advantages. Aeris Communications, a machine-to-machine service provider conducted a survey of executives from the United States and United Kingdom (published October 2015) in which 73% of respondents indicated that IoT gave them a competitive edge in manufacturing. In December 2013, a manufacturing outlook survey from the American Society for Quality (ASQ) stated that 82% of companies using smart manufacturing have experienced an increase in efficiency.

#### EDUCATION AND TRAINING

Small- to medium-sized companies may benefit from this technology as IIoT and smart equipment could be easier to adopt on a small scale. However, the resources and training

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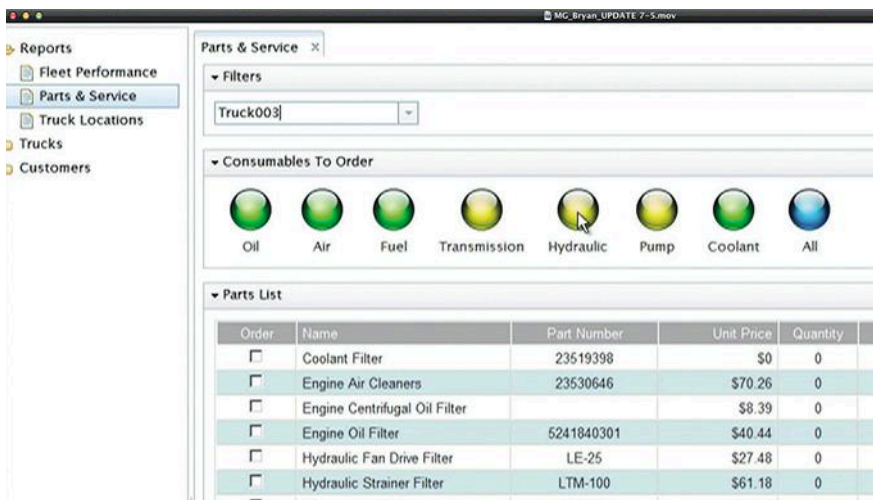


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needed to implement new technology may be problematic for small companies.

The IIoT is about information—the more you know, the smarter your decision-making. Continued education works in a similar way. Staying on top of new technology prevents uneducated decisions and becoming stagnant. Some companies suffer from a generation gap. This doesn't necessarily relate to the age of employees, but rather the comfort level of the technology. If a particular process or software has worked in the past and everyone is comfortable with it, changing it can create resistance. Continued education keeps employees up-to-date on available technologies and how to use them.

Training is important. Engineers graduating from school tend to want to push for new technology. They will be more comfortable with technology they know, which may differ from what was imbued by the last generation of engineers. If this is the case, IIoT may have a longer adoption rate, simply due to having to wait for a generation to understand and be comfortable with IIoT and smart devices.



Software can help compare data across a company, or companies, to find bottlenecks, performing root-cause analyses, and other types of issues. (Courtesy of Rockwell Automation)

#### GOING CUSTOM

IIoT is highly customizable. Installing custom equipment can provide data that enables better decision-making while maintaining flexibility. For example, in the past, automated equipment used to seal flexible bags around products for

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## Industrial Internet of Things

shipping might have sealed one size bag despite the size of the product. Without any information, or the ability to be dynamic, packaging lines (i.e., the flexible bag sealing lines) were less efficient and wasted packaging material.

Today, with the amount of products available, and the speed of delivery demands with Internet ordering, packaging lines must be dynamic and be able to handle many shapes and sizes to keep up. Smarter systems implemented in the flexible bag sealing lines, along with other processes, can scan a product and alter the size of packaging.

It's important that customized smart systems adjust for future applications. If a production line doesn't maintain flexibility, it can develop a type of manufacturing momentum in one direction, and it might become difficult and expensive to update equipment and stay competitive. Take the automobile industry, where much of the equipment and stamping processes must use steel. If a manufacturer wanted an aluminum

door, it might mean over \$100,000 for new tool and die setups, and changing the molds generally turns into a long process. While the automotive industry may have the volume to justify a change, it can still take millions (or in Ford's case, \$1 billion) and long lead times to make this happen. Manufacturing lines must limit manufacturing momentum by using IIoT and smart devices to promote flexibility.

### REPLACE OR RETROFIT

"In my experience, equipment is being augmented by the IoT, not replaced," says Jeremy King, product-marketing manager for Bimba. "Early adopters are still leading the IIoT movement, so they are still experimenting, looking for the best way to improve on their existing equipment and processes. Easy-to-install sensor networks integrated with existing machines are most popular for retrofits. When retrofitting a machine, the goal is to improve the equipment while minimizing the



M.G. Bryan, a firm that provides heavy equipment in the fracking industry, needed a scalable way to manage vehicles in the field. Taking relevant data from each truck, Rockwell used Microsoft's cloud to monitor vehicle and fleet performance. It lets M.G. Bryan offer after-market services, such as preventative maintenance alerts. (Courtesy of Rockwell Automation)

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It's not just Internet-capable devices that are saving money and providing valuable data. Pressure sensors with built-in diagnostics let technicians check whether they're working properly from the field. Traditionally, when a pressure sensor would fail, a technician would replace all of the sensors. With field-service work costing as much as \$120 per hour, it was standard practice to replace any suspect pressure transducers to get the machine back into service quickly. This led to machine manufacturers having to pay warranty claims on pressure sensors where 50% had no failures. (Courtesy of WIKA)

impact of the installation." If the downtime to install IIoT or smart devices is long and tedious, it can diminish the upgrade's ROI.

"A lot of companies focus on increasing uptime because it is one of the easiest areas to show an ROI," continues King. "For smart and IIoT products, it's important for buyers to understand exactly how they will decrease downtime. If the device just provides data, it is not that useful. The value is if the device can tell you when equipment will fail and why, so you avoid downtime. Each piece of smart equipment adds its own value—new or retrofit. Currently, I have seen retrofitting provide better ROIs."

Retrofitting adds customization and flexibility while minimizing downtime. "Due to the increased costs of replacing equipment, it may not happen for some time," says Matteo Dariol, product support engineer for Bosch Rexroth. "The difference between replacing and retrofitting is often a matter of what type of company you are. If you are a small family-owned machine shop, smart devices and IIoT might not offer enough benefits to consider either option. But an OEM might invest in new equipment to stay competitive. Other companies may find extra benefit in replacing equipment with newer IIoT or smart devices that allow the users to connect to a broader range of modern communication protocols and to access more insightful information on the equipment."

Communicating across the entire company can complicate the economics. IIoT equipment may be specially customized and offer its own economical or ROI equation. Each equation could involve multiple interpretations of certainty, risks, and other unknowns that decrease its accuracy. The ASQ manu-

facturing outlook survey said 49% of companies using smart manufacturing experienced fewer defects. However, your defects are low or not expensive, so adding expensive retrofit or new equipment will not provide much of an ROI.

Statistics often don't provide the full picture or gravity of IIoT's potential, which is why marketing and buzzwords may be circumnavigating a better ROI until more data is available. It may also suggest that IIoT is broad and contains so many

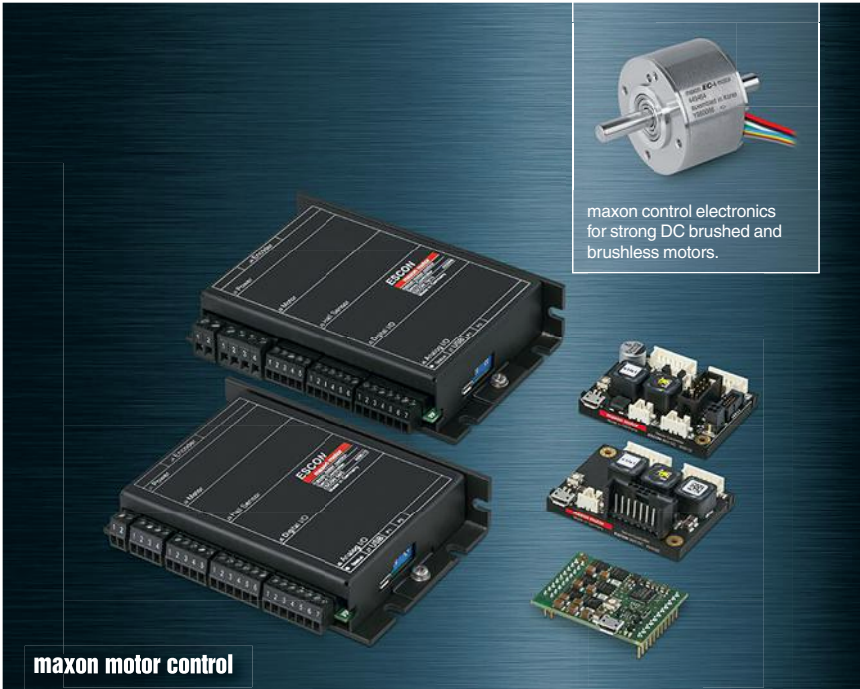
different variables that an accurate ROI isn't possible until you analyze a specific project.

Retrofitting IIoT into older equipment can add years to their lifetimes. Retrofitting can incorporate features to make the older machines competitive with new equipment. This equipment also provides data for more efficient maintenance schedules. Preventative maintenance is not just about reducing downtime, but increasing the life of the equipment.

"Eventually equipment might be replaced by IIoT devices, creating an influx for a secondary market, but it is not here yet," says Bimba's King. "Equipment users are just now experimenting with smart devices. They have not forced the requirements back to the machine builder. Machine builders are keeping an eye on smart technologies, but have not gone all in on it because of the increased costs. Once machine builders start offering smart machines and end users realize their value, those that can afford the investment will look toward replacement. That is still five to 10 years away." So if any startups or small companies are waiting for a boost in the secondhand market from IIoT, they will have to wait.

The race for IIoT has to focus on software, according to Bosch Rexroth's Dariol. The ability to interpret data is the value behind IIoT. For example, dedicated shop-floor servers will monitor the status and the execution of orders and provide useful insights on processing throughput or other overall equipment effectiveness. Meanwhile, software programs will monitor sound sensors and reveal when a possible breakdown may occur. It's how the software interprets the data, not just collecting data, which will improve a new machine's ROI.

Make sure your IIoT plan focuses on economics and knowledge. "Do not invest in buzzwords—know what data you need and why it's needed," says Rockwell Automation's Parkinson. "In addition, an IIoT device must not only perform the task assigned, but also generate useful information that leads to smarter decisions, and make sure you don't fall back into using multiple controls that don't communicate." **md**



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# Ethernet Connectors Evolve to Meet New Demands

Connector designs keep pace with new networking capabilities as more manufacturers begin using Ethernet.

**T**he industrial connectivity landscape has changed dramatically over the last five years as industrial Ethernet has rapidly become the network of choice for demanding environments. And it wouldn't have been possible without the right connectors.

Connectors form the critical link between cables carrying data and devices that record and communicate information. Here's a quick exploration of the trends influencing connector design for the industrial Ethernet, from ever-smaller applications to ever-greater data-transmission speeds.

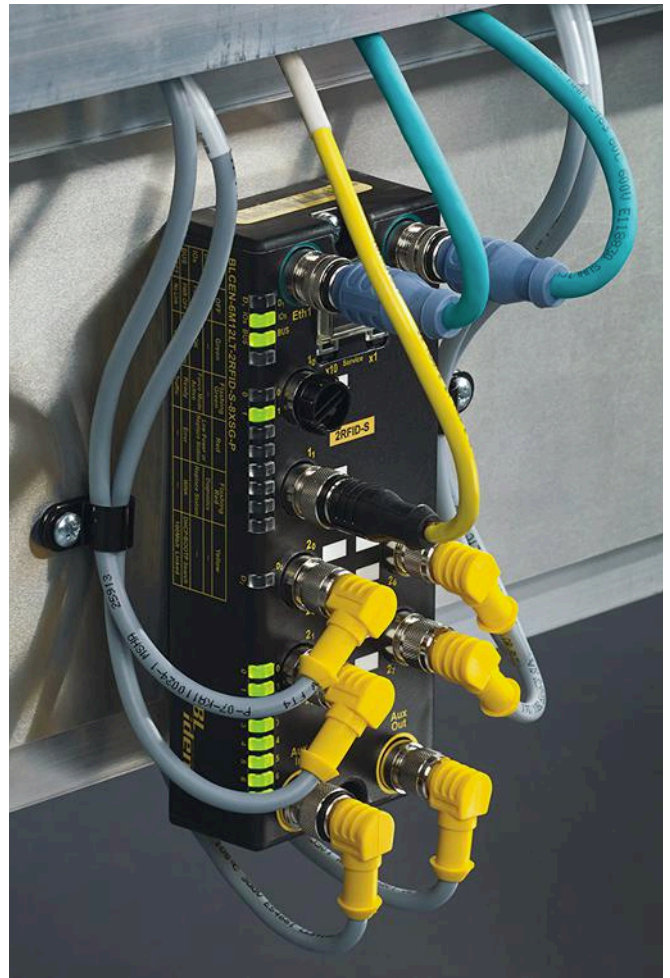
## THE RISE OF INDUSTRIAL ETHERNET

Ethernet's capabilities and benefits are convincing more and more companies to expand their utilization of it in industrial environments. They are putting Ethernet in place alongside of—or entirely replacing—industrial networks such as CANopen, DeviceNet, PROFIBUS, Foundation Fieldbus, and AS-interface.

One reason is that industrial Ethernet networks handle significantly larger amounts of data at faster speeds than other networks. Worldwide, the global industrial Ethernet market should grow at an average rate of about 9.5% through 2019, according to Technavio, a market-research firm.

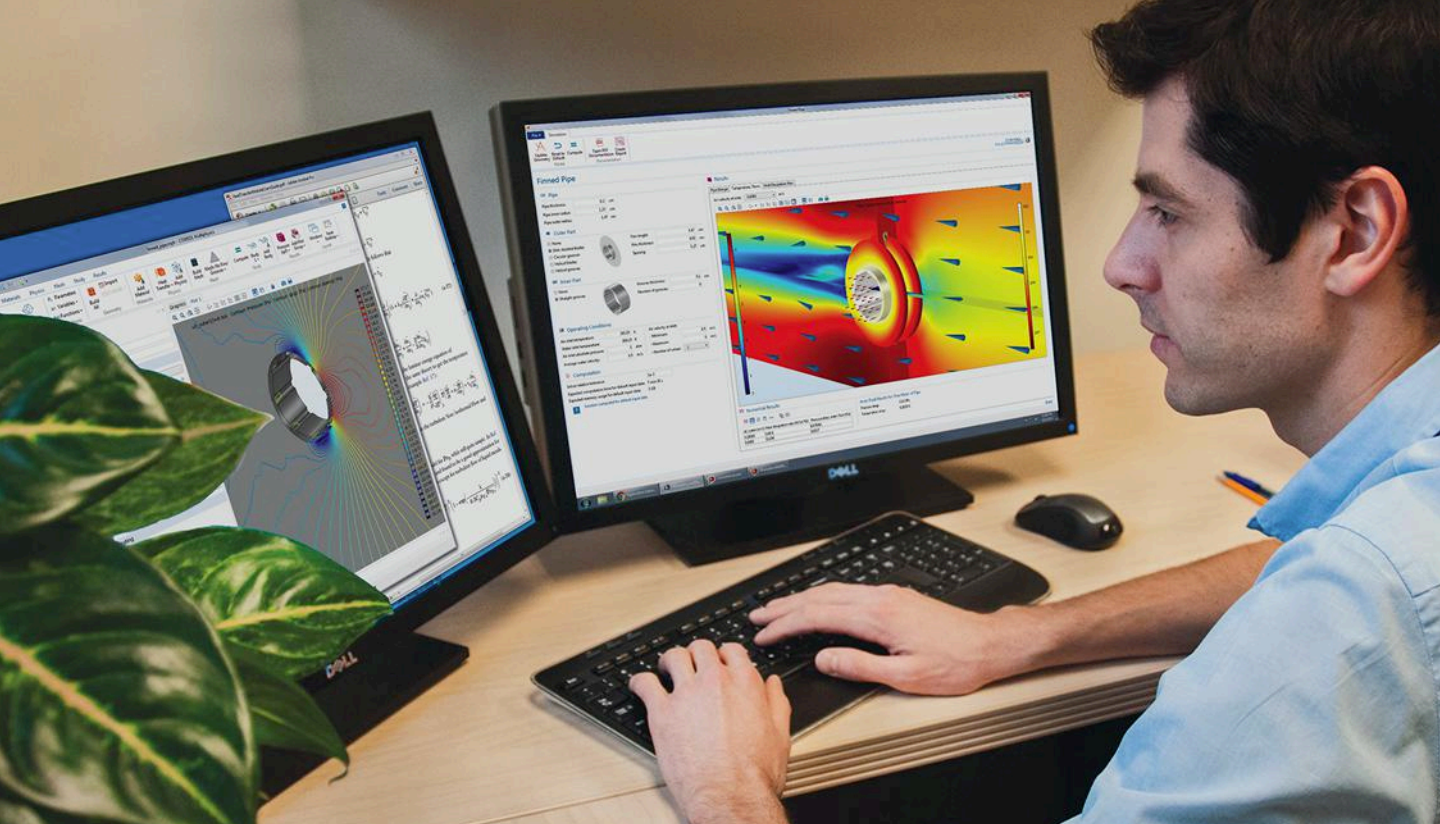
Ethernet was first used in office environments. Over time, it was adapted for industrial settings, as companies wanted its faster data-transfer speeds where they could do the most good—on the factory floor. It was quickly adopted by a range of industries and companies based on their long familiarity with it and its network design.

Moving to Ethernet is considered an easy change because most companies already have experts in it on staff. Existing IT departments operate the enterprise network, which means their technicians know how to troubleshoot traditional Eth-



M12 Ethernet connectors, such as the blue ones shown at the top of this photo, are more robust than RJ45s for connecting the plant floor and communicating data in industrial environments.

ernet. Understanding the ins and outs of traditional Ethernet is a good foundation but, in practice, the factory floor differs significantly from protected office environments. This complicates the move to industrial Ethernet.



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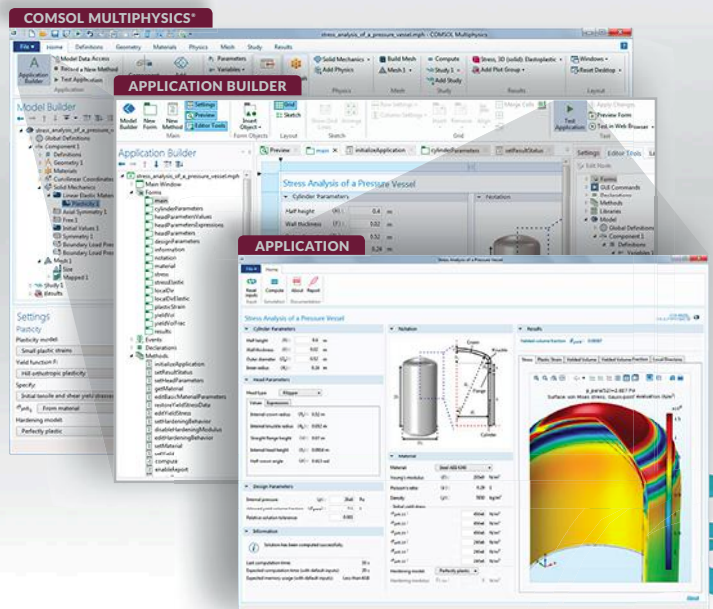
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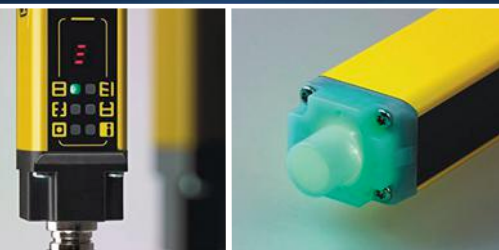


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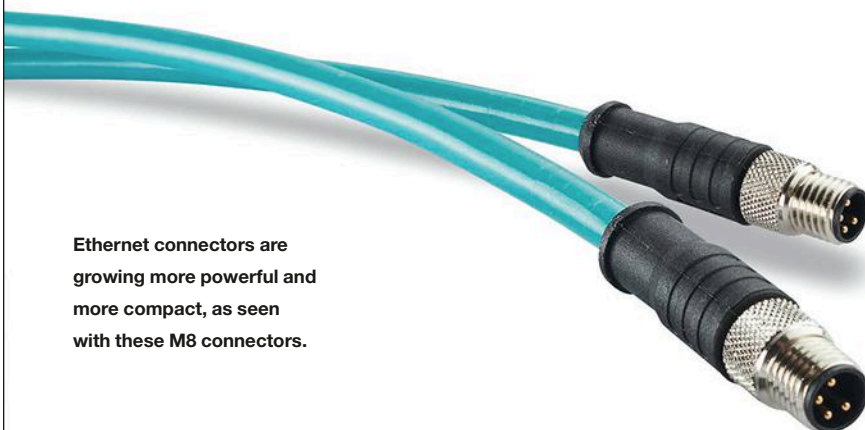


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## Ethernet Connectors



Ethernet connectors are growing more powerful and more compact, as seen with these M8 connectors.

Another factor affecting the decision to adopt industrial Ethernet is its ability to move more data at faster speeds than fieldbus networks. This makes it a top choice for high-end and data-heavy applications where bandwidth and bottlenecks can be issues, and holds true even for more compact applications.

These trends contribute to what could be the largest influence on Ethernet's adoption—organizations wading into the Industrial Internet of Things (IIoT). Across manufacturing and process industries, companies are scrambling to add sensors, connecting them with a host of other plant equipment so that managers can gather all of the data they need to get a better real-time view of what's happening on the floor. Ethernet is an ideal way to tie devices together. And, because it's also used in offices, it lets managers, engineers, floor personnel, and supervisors access and view data from inside the factory and offices.

### ADAPTING CONNECTORS FOR INDUSTRY

The most widely known Ethernet connectivity cordset is the RJ45 (8P8C connector). These connectors represent the office gold standard because of their universal connectivity, ease of use, and quick connect/disconnect performance.

The IEC 60603-7 standard defines RJ45's design and construction. There are RJ45 8-pin connectors for all current Ethernet categories, and the connectors can handle 2- and 4-pair wiring. Typical commercial RJ45s carry an IP20 rating.

Although RJ45s are the most widely used Ethernet connector, manufacturers began demanding more robust alternatives as they brought Ethernet onto the floor. Its plastic ends and overall design are not ideal for harsh factory and plant

### RJ45s IN INDUSTRY

**ALTHOUGH M12 IS** the recommended and preferred connector for industrial Ethernet, RJ45 connectors are still widely used for certain industrial applications such as:

- Inside panels and cabinets, one of the most common uses for RJ45 connectors in industry. These areas are protected from the environment, eliminating some concerns related to shock, vibration, and problems with water or oil.
- Quick access points for data, when some engineers want the flexibility to plug a laptop directly into the network on the factory floor. Because RJ45 connections are the same as a computer's Ethernet port, maintaining them on the floor lets engineers quickly get the data they need without special adaptor cables.

environments, where shock, vibration, changing temperatures, and exposure to water and oil can damage connectors.

In response, engineers turned to M12 connectors, which were commonly used with sensors, and adapted them for the Ethernet. M12 Ethernet connectors feature a rugged overmold that encapsulates the connector's components. The connectors carry a minimum of IP67-rated protection against dust and water ingress, as well as against vibrations and accidental impacts. M12 connectors are available as 4-pin D-Code, 8-pin A-Code or 8-pin X-Code. Data-transfer speeds can be as high as 10 gigabits per second (Gb/s), depending on the number of pairs and category of cable (much like RJ45 connectors).

In one case, a company that assembles conveyor segments and components into complete conveyor systems for customers had long used RJ45 connectors but continually saw them damaged during transit and assembly. Technicians had to re-terminate the RJ45s on site or, in extreme cases, replace the entire cable. Frustrated by the cost of time and resources lost to repair damaged RJ45s, the company explored their options before adopting M12 connectors. Switching to this rugged, overmolded design helped the company eliminate connector damage and cut its downtime for repairs and replacement.

#### **CONNECTORS KEEP PACE WITH ETHERNET SPEEDS**

Another set of influences on connector design are the data-transfer speeds possible with Ethernet.

Generally, connector technology follows advances in cables. For speeds up to 100 megabits per second (Mb/s), or 100BASE-T, an Ethernet cable needs only two pairs of wires. For speeds up to 1 Gb/s, or 1000BASE-T, four pairs are needed; it also takes four pairs to reach 10 Gb/s or 10GBASE-T. So Ethernet can use both four- and eight-pin connectors, but the faster connections need the higher pin counts.

Industrial Ethernet connectors have continued to be updated to accommodate these ever-faster data transmissions. For example, what started as a 4-pin M12 turned into an 8-pin design. The most recent evolution has been the 8-pin M12 X-Code design, which can handle 10-Gb/s Ethernet transmission speeds. To reach these speeds, the X-Code connector relies on advanced shielding and either CAT 6A or CAT 7 copper cables. And inside the connector, each of the four twisted pairs is shielded from one another. This prevents cross talk from hurting data quality, as well as unwanted signal coupling from one pair to another.

X-Code connector technology is experiencing an uptick in interest as more companies look for higher network speeds and more reliable, high-quality data transmissions. These demands will continue to drive advances in connector design, especially for data acquisition and vision systems and cameras.

Data bottlenecks slow operations, but inconsistent or corrupted data can halt them altogether. Beyond end-users, manufacturers are taking advantage of this technology. For example, industrial manufacturers using cameras or vision systems in their application have begun installing M12 X-Code receptacles in their systems to ensure they work at their designed speed with better performance and efficiency.

Data-acquisition equipment manufacturers are another example. These organizations need to make sure their solutions reliably transmit data at the highest speeds possible without sacrificing data quality.

One manufacturer was already using M12 connectors with CAT 5e cable for its portable industrial solutions. But a recent project needed greater data-handling capabilities. The manufacturer chose to upgrade to the most recent design advance in industrial connectivity—the M12 X-Code with CAT 6A cabling—to meet these demanding data-handling requirements for its customer.



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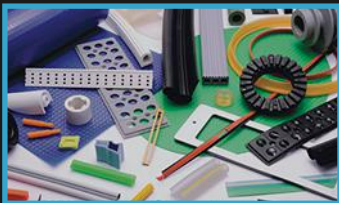




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## Ethernet Connectors

### SMALLER DEVICES, SMALLER CONNECTORS

Trends influencing automation device design are also reaching the connector level. One of these is the shrinking size of devices to accommodate ever-smaller application spaces. Advanced connectivity is required for success in these environments, which is creating demand for smaller devices that maintain advanced levels of communication. Automation component manufacturers

### ETHERNET OPTIONS

**AS ETHERNET CONTINUES** its rapid rise of adoption, manufacturers must decide which network protocol is the best for their plant and the communication needs of their applications. The first step is understanding Ethernet protocol options. Three of the most recognized are EtherNet/IP, Modbus TCP, and PROFINET.

**EtherNet/IP:** This communication protocol is supported by the Open DeviceNet Vendor Association (ODVA), and implements the Common Industrial Protocol (CIP) onto the foundation of Ethernet. It was designed for industrial-automation and process-control applications, and includes tools to deploy standard Ethernet technology for industrial applications. For data exchange, the transmitting devices produce data and receiving devices consume that data. It uses a Transmission Control Protocol (TCP) layer in industrial settings. Typically, the TCP connects plant-wide communication to a company's worldwide network through the Internet. It is also often used for data transfer, recording events and alarms, maintaining the program, supervisory control, and operator interface connectivity.

**Modbus TCP:** This variant of the Modbus family is intended for use with automation equipment. As a connection-based protocol, TCP opens and establishes a connection with a device to gather data. This data is received and combined with additional information before going to the IP layer, where it's packaged and transmitted. It is typically used for Ethernet attachment to PLCs, I/O modules, and gateways to other fieldbuses or networks. It is simple and requires minimal hardware and cost to develop and support. It is also attractive for its interoperability with devices from different vendors.

**PROFINET:** This communications protocol is PROFIBUS and PROFINET International's open industrial Ethernet standard for automation. It complements TCP/IP and IT standards with specific protocols, and works with existing fieldbus systems such as PROFIBUS, DeviceNet, and Interbus, without changing existing devices. PROFINET exchanges data via three communication channels. The TCP/IP channel works for configuration, parameterization, and acyclic read/write operations. The Real Time channel is ideal for cyclic data transfers and alarms. And the Isochronous Real Time channel handles high-speed motion-control applications. All communications take place over the same cable, eliminating the need to invest in custom cabling. PROFINET has real-time performance capabilities that are ideal for factory and process automation—specifically automotive, logistics, and food and packaging applications. It is commonly used for synchronous I/O signal transmission and data-intensive parameter assignment, as well as controlling automation devices and high-speed operations.



There are a range of Ethernet connectors available, including (from left) the M12 X-Code, 4-pin M12 (D-Code) for EtherNet/IP, shrouded RJ45, 8-pin (A-Code) M12, shielded RJ45, and 4-pin (D-Code) M12 for PROFIBUS.

are downsizing those devices, as well as the connectors used with them.

One example is seen with I/O modules and their associated connectors. OEMs are continually looking for ways to adapt their processes to new customer demands without needing to overhaul their operations, purchase new machines, or expand the size of their equipment in footprints. Breakthroughs in technology have let automation component manufacturers shrink the size of I/O modules so OEMs can add advanced on-machine communications without reconfiguring processes. The smaller inputs and outputs on these blocks call for smaller connectors. That's why some companies making automation components are moving from M12 connectors to the smaller M8 designs.

Before it was adapted for Ethernet, M8 connectors were favored for many industrial sensor applications and still remain popular today. The M8 design works well for industrial Ethernet because its pin spacing meets the performance requirements needed for the network and protocol. Performance depends on the location of twisted pairs in the connector. If they're too far apart or too unevenly spaced, the chances of signal errors and loss increase. Because the M8 meets optimal performance specifications, and carries ingress protection for industrial applications, it can transfer data at up to 100 Mb/s while fitting into smaller applications than the M12.

#### WHAT'S NEXT?

As Ethernet continues its rapid expansion into industrial settings, manufacturers will adapt existing connectors for new applications and needs. In fact, automation component suppliers have already begun customizing connectors for use with Ethernet.

One of the next influences on Ethernet connector design will involve Category 8 cable, which is anticipated to reach data speeds of 40 Gb/s. With standards now being determined by the Telecommunications Infrastructure Association (TIA), it's likely this new cable will first spread to enterprise/office environments before demand grows for its increased speeds and data-transfer capabilities in industry.

Another area of expansion will be in Ethernet for hazardous locations, where PROFIBUS, Foundation Fieldbus, and AS-I currently lead the pack. This trend is emerging as engineers and system integrators look to gain the faster speeds and advanced connectivity already enjoyed by other industries.

When something goes wrong in a hazardous location, it can be catastrophic. Ethernet's ability to connect all devices and report back can help engineers more closely monitor what's happening in real time. Then they can make adjustments or schedule maintenance as needed. Component manufacturers are starting to reengineer existing connectors to meet the specific features required in these demanding environments. **ind**

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# Patent and Business Strategies for Inventors

Have you ever had a great idea and wished you could figure out how to get it to market, but you weren't really willing to "bet the farm" on it? As someone who has been in that position on several occasions, I can share a few insights.

First, I've never been tempted to contact one of those firms that heavily markets how it can help novice inventors develop ideas and provide lots of support at every step of the way. I've generally assumed, perhaps unfairly, that they're much more interested in the fees they'll collect than in really helping me succeed.

Second, I've never sought out angel investors or venture capitalists as a way to fund the process. They provide much more mainstream approaches, but such investors will rightly expect that you will be totally focused on achieving certain agreed-upon milestones on schedule. And they will be quick to walk away if they see the opportunity fading. It's a high-risk, high-reward, time-critical approach that makes sense if you're already financially independent or young enough and without major family obligations that you can weather a spectacular failure and move on with your life. Or you really like to gamble.

My approach has always been to do my inventing on "nights and weekends" as a complement to a regular job that pays the bills, investing my own funds on a schedule I can afford and putting in a few hours a week slowly pushing the idea. Not every idea is a success, but with this strategy it's possible to eventually succeed financially if only one in 10 ideas sees some level of commercial success.

Like many in the *Machine Design* audience, I have a small basement shop and some design tools that let me tinker and pursue ideas while avoiding the expense of real-estate rental, hiring employees, and bank loans or other debt. Thus, when some of my efforts proved to be "ahead of their time," I've been able to weather the long haul until the market catches up.

During that time, I am able to keep the idea alive while maintaining full ownership of the IP, persisting in overcoming the obstacles that will intrude, learning more about the markets involved, and laying a solid foundation for success. That

old adage that success is 1% inspiration and 99% perspiration is true, and you need to give yourself the opportunity to actually invest that 99% without worrying about investor demands or running out of money.

In the process of acquiring 10 patents and writing over a dozen additional provisional and non-provisional patents, I've gained a lot of insights that you may find useful:

- If you work for a company, especially one involved in design, manufacturing, or consulting, there is a strong possibility you were required to sign an agreement that assigns the rights to any invention you conceive to your employer. Sometimes this provision extends for patent filings that occur 90 days or more from the date you leave the company. So before you do anything, talk to your boss or someone in your HR department to find out if you can carve out some type of exception to that policy. Companies are often willing to let you individually patent ideas that lie outside their competitive area of interest. If you can't do that, and you're unwilling to launch your own business, there is little reason to pursue this strategy.
- Your only protection as the inventor of a product is a patent. And the only circumstance under which most potential customers/acquirers/licensees of your idea will even talk to you is if you have at least applied for a patent. They don't want to be embroiled in any charges that they've stolen your idea. A patent application, with its definitive time stamp, sets clear boundaries on who owns what.
- Patent lawyers are really expensive. Until you're sure you have something likely to provide a return on what could be a substantial investment, figure out how to use the many tools available on U.S. Patent Office's website, [www.USPTO.gov](http://www.USPTO.gov). It's especially important that you learn how to use their advanced search tools for patents and published applications.

- Our patent system is based on the “first to file” principle. Fortunately, you can file a provisional patent application on your own, without needing any help other than reading the guidelines on the USPTO website, as soon as the idea crystallizes in your mind. The cost for a first-time inventor filing under “micro entity” status is only \$65. If you don’t qualify for that rate, the fee for a “small entity” is \$130.
- Submitting a provisional patent requires that you be able to adequately document/describe your idea in both words and figures. If you’re not a good writer, get help from friends or family. And think carefully about all of the different ways your idea’s general functional characteristics might be realized. Your provisional patent not only registers the priority date for your idea claims, it also limits what you can later claim (without losing your priority date) in a subsequent non-provisional patent application.
- After you decide your idea is worth pursuing beyond the provisional patent level, legal protection starts to become more expensive. If there is a chance your idea will have broad appeal, especially on an international level, the investment in a patent attorney is certainly warranted. If, however, you determine there is a small market, but one worth pursuing for a small business—maybe something you could do almost at a hobby level for the enjoyment and small additional income it could afford—then you might think about prosecuting the non-provisional patent yourself. The USPTO lets individual inventors file pro se. I’ve done it once under just this set of financial considerations. The process is still underway, so I have limited experience to describe the pluses and minuses.
- One strategy I’ve used on several occasions is to solicit help in the patenting process from a larger firm interested in licensing the rights to the invention. Under these terms, they typically fund the out-of-pocket expenses for all legal fees. Inventors are generally expected to contribute their time to support development of the required patent specification and drawings with no compensation other than for direct expenses.

I find the whole process of invention, design, and marketing of ideas to be fun and a great sideline to my normal work life. As hobbies go, it’s one of the few with the potential to actually supplement your income rather than be a steady economic drain. Like every hobby, it gets easier as you develop skills and more experience. It’s also a great way to keep my mind active and something I hope to do well into what would otherwise be a quiet retirement. **md**

*Douglas Hoon is founder and president of ComGraf LLC, an ongoing design and development firm focused on sporting goods and consumer products. For the full text of this edited article, go to <http://machinedesign.com/contributing-technical-experts/patent-and-business-strategies-inventors>.*

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# Despite Slowing Growth, NEW TRENDS EMERGE IN CHINA

Supply chain trends shaping the market in Asia include the growing strength of China's second-tier ODMs and the emergence of a new class of technology incubators that are making it easier to bring new electronics ideas to market.

**A** changing Chinese economy is making it easier to get products designed, developed, and built in China than ever before, creating new opportunities for designers, start-ups, and companies looking to produce smaller-scale projects. This comes despite slowing growth in the region that has some companies feeling the effects of a less robust economy.

"I track most of the electronics manufacturing companies [in China] and, year-over-year, [business is] largely flat," says Dan Panzica, a senior analyst with market research firm IHS Technology. "With [roughly] 70% of the ODM companies reporting, it looks like the electronics manufacturing, year-over-year, business will be up [about] 2% on the average."

He notes that much of that is due to weakness in the mobile market and a general slowing of the overall growth of the Chinese economy. China's economy grew 6.9% in 2015, its slowest rate in 25 years and a slowdown from the 7.3% growth the government reported in 2014.

Other changes are occurring as well, especially in the electronics supply chain. The growth of tier-two original design manufacturing (ODM) firms, many of which are able to take on smaller projects that their larger counterparts cannot accommodate, represents a major change in the region, Panzica adds.

"Much has to do with that there is so much business for the larger [ODMs] that these smaller guys are getting traction," he says, pointing to their flexibility and eagerness to take on projects with smaller production runs, start-ups, or pieces of a design. "These smaller, hungrier, equally competent companies [are out there]. It's a competent, growing industry. And it represents a major, major change in China's capabilities."

Panzica says this trend is gaining the most traction in "me-



too" technologies such as cell phones, certain wearable electronic devices, and other consumer items, giving designers and entrepreneurs a wider variety of manufacturing options in China.

The worldwide Electronics Manufacturing Services and Original Design Manufacturing market grew 3% in 2015, according to a report last year by market research firm ReportsnReports. The group's Global and China EMS/ODM Industry Report, 2014-2015 pointed to a 5% surge in the market in 2014 and predicted a slowing of growth between 2015 and 2019.

Another trend to watch is the growth of technology incubator firms that are helping companies even earlier in the design process—from inception on through to design, production, and fulfillment. Panzica points to PCH International as a case in point. The custom design manufacturing company launched a hardware incubator firm called Highway 1 in 2013, as one example. Designed to help early hardware startups get their ideas off the ground and develop into strong companies,

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the program works with innovators and entrepreneurs on everything from design and production on through to supply chain, inventory, and pitching their products. The program includes a two-week module taught in Shenzhen, China, that explores the region's electronics supply chain and manufacturing industry. Based in Ireland, PCH's operational headquarters is in Shenzhen, China.

Such organizations are creating environments so that "the

kid out of Stanford can sit down and build his new (product), even though he many not know much about manufacturing or design," Panzica explains.

"That is really the next wave," he says, "Not just out of China, but in the world too."

### DESPITE OPPORTUNITIES, GROWTH SLOWS

China's changing economic landscape is overshadowed by

reports of the country's slowing growth. Many supply chain companies point to a slowdown in China's industrial base as one concern. In its most recent quarterly earnings announcement, distributor Avnet, Inc. pointed to a softening in its business in both the Americas and Asia, noting a slowdown in its high-volume production business in Asia, in particular. Avnet EM's fiscal second-quarter sales in Asia fell roughly 9%.

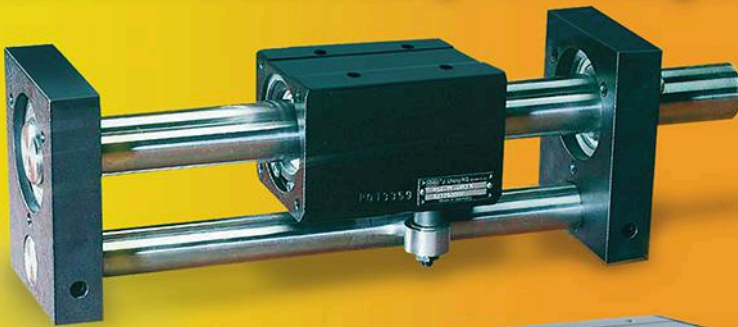
"[Over the] last 10 months, PMI has been negative in China, so there is a concern," Gerry Fay, president of Avnet Electronics Marketing global said in a February interview following the release of the company's fiscal second quarter earnings report, released January 28. "Even at [slower] growth, however, it is higher than pretty much anywhere else in the world. We've seen a slowing in the core industrial space ... but alternative energy is taking off there. It's a big growth opportunity."

Avnet rival Arrow Electronics reported better results in the region in its fourth-quarter earnings report, released February 4. The distributor reported 6% growth in its electronic components business in Asia, though sales declined nearly 4% in the region as adjusted for the impact of changes in foreign currencies and acquisitions.

Looking ahead, most economists expect growth to continue slowing in China, in particular. The country's annual GDP growth began to slide in 2010, and the country is expected to lose more economic momentum this year, as GDP growth is expected to slow from the 7.3% and 6.9% growth of the last two years, to 6.3% growth in 2016, according to reports. ■

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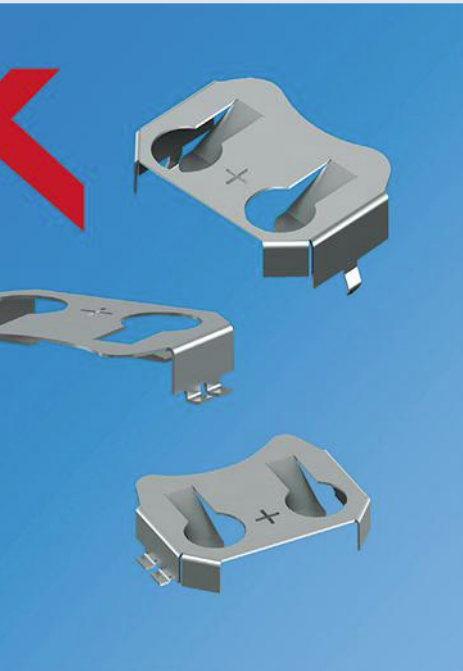
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**THE OMB** 402UNI Series of bar-graph meters feature a 30-segment tri-color LED bar graph and 6-digit numeric display. Input values can be preset with multi-function input capability. It can be easily programmed for dc voltage or current, RTD or thermocouple temperature sensors, and other applications. Mathematical functions include peak, tare, and linearization. It is backed by a five-year



warranty and has a 1/8 DIN-sized housing, with each bezel sealed to IP64 against water and dust. The meters are accurate to  $\pm 0.1\%$  of range and up to four relay outputs are available. Its time-based data storage is capable of storing up to 266,000 input and output values. It accepts power supplies between 10 and 30 V ac/dc, as well as 80 to 250 V ac/dc.

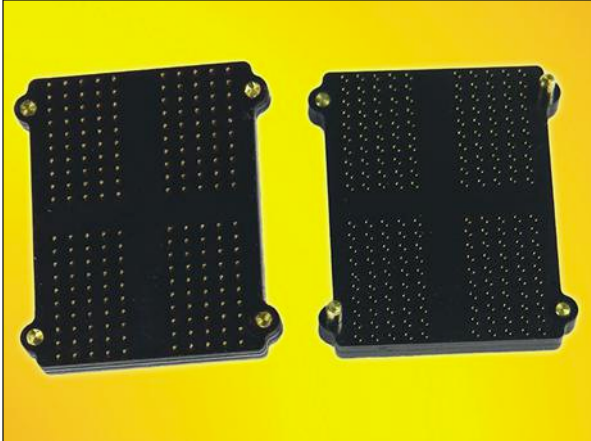
**BRISTOL INSTRUMENTS**, [www.bristolinstruments.com](http://www.bristolinstruments.com)

### Power Supplies Ensure Safety in Medical Devices

**MEDICALLY CERTIFIED** DTM65-C8 external power supplies offer Class II input, which eliminates the need for an earth-ground connection and meets Level VI DoE standards for efficiency. They are also certified to IEC 60601-1 and 60601-1-11 medical standards for use in diagnostic and monitoring equipment. Housed in a vent-free, IP21-rated enclosure, the power supplies measure a mere 106 x 60 x 31 mm and can be powered with alternating or direct current via a standard IEC60320-C8 cable and four-pin Power-DIN connector, respectively. They also offer overvoltage and over-current protection, and accept inputs between 90 to 264 V ac. Adapters with power ratings from 40 to 65 W are available with 5-, 12-, 15-, 19-, 24-, 28-, and 48-V outputs. They can operate in ambient temperatures ranging from 0° to 60°C.

**TDK LAMBDA CORP.**, [www.tdk-lambda.com](http://www.tdk-lambda.com)

**BGA Sockets, Adapters Feature High-Temp Polyimide Construction**



**THE GIGA-SNAP** pair of BGA socket adapters includes the SFS-BGA200B-52 female BGA socket and its matching male pin adapter. With unique BeCu pins, the SFS-BGA200B-52 BGA socket is RoHS-compliant and can be soldered to a PCB with little to no warping. The BGA sockets and adapters are made of high-temperature polyimide and require low insertion and extraction force to operate. Operating temperature ranges from -55° to 160°C. Current rating is 3A per pin.

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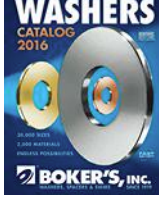


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# Triz is Now Practiced in 50 Countries

**T**riz is an innovation technique that professionals systematically apply according to a defined set of principles. Originally developed in Russia by Genrich Altshuller in the 1940s, Triz took a number of years to cross the ocean and become available in English. By the early 1990s, Triz had gained a foothold in the U.S. and slowly began spreading globally from its Russia- and U.S.-based “centers of excellence”. Triz is now practiced in at least 50 countries.

**History:** The brilliance of Triz stems from the origins of its data set. Altshuller analyzed 40,000 registered patents to determine their common inventive principles, and to hopefully observe other systematic attributes of inventions. The short version of his findings were that there were 40 basic inventive principles, 39 common parameters that engineers look to optimize, and 76 standard approaches that engineers and inventors used in their designs. Nonsense, you say? Not so. Sample sizes of up to two million patents were examined by other companies over the years, and they merely tweaked Altshuller’s discoveries.

**North American Industry Usage:** GGI has researched markets and companies where Triz was involved in analytical software since the late 1980s. Our statistically valid primary research in 2008 showed it to be the third most used tool by professionals looking to innovate. Still, it had penetrated only 21% of a cross-industry sample of North American companies: 10% used it limitedly, 10% used it occasionally, and only 1% said it was fully embedded. Adoption of innovation techniques is clearly not as mature as operational excellence techniques such as Six Sigma, lean, and other value-engineering tools. For reference, our research showed that internal knowledge wikis were number two at 38% and the free USPTO website was first at 53%.

**Global Industry Penetration:** Last year, a GGI primary research project explored the global penetration of Triz. We got reasonably good data for the period 2007 to 2015, based on the number of Triz-certified professionals we could identify in each country.

In summary, there are 50 countries with Triz-certified pro-

professionals. Between 1991 and 2007 when our data set began, 1,400 people had achieved certification. We now count over 18,000. Plus, there are about another 6,000 who chose not to publish their certification. There are now roughly 25,000 people worldwide who are certified Triz practitioners, or are likely practicing at a certified level.

South Korea dominates the global footprint with 65% of all practitioners. Germany and China each have 7%. Russia is next at 5%, followed by the U.S. and Taiwan at 3%. India and the Netherlands each have 2%.

**Potential Uses and Benefits:** Triz has wide applicability across product creation through commercialization, as well as for developing intellectual property. Right now, less strategic companies use it in late stages of design through cost reduction and value engineering. More strategic companies use it in advanced development and intellectual-property development long before detailed design and production. GGI’s research also identified a notable finding: Companies that seriously use Triz actively discourage employees from discussing it outside the company, and rarely present at conferences. Treating Triz as a confidential company subject indicates Triz creates a competitive advantage.

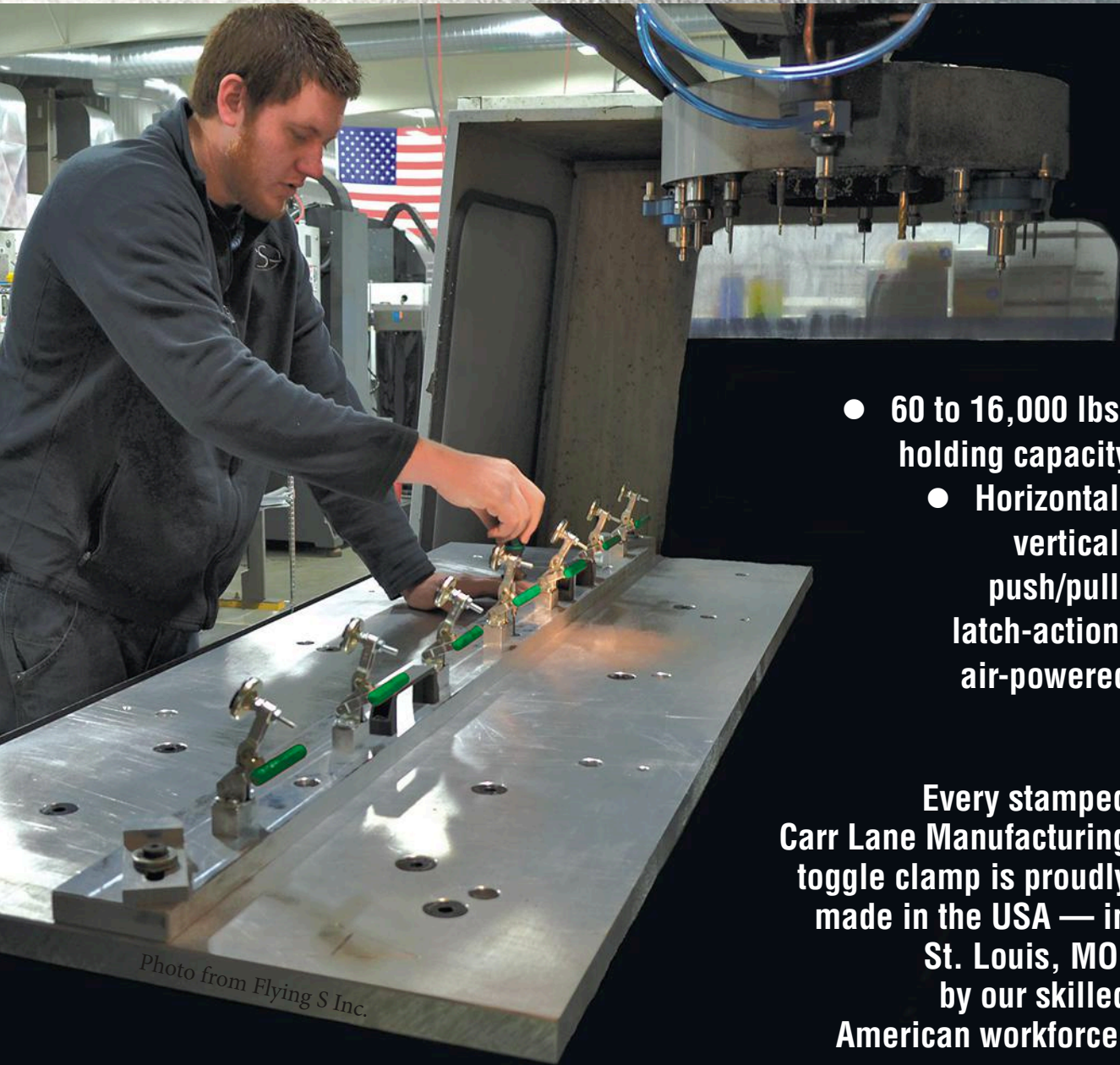
**Future Growth of Triz:** The year-over-year growth rates between 2007 and 2015 are impressive, ranging from 23 to 47% annual growth. There has also likely been a constraint on growth because there is a shortage of qualified Triz instructors. “Triz Masters” are hard to come by. There are approximately 150 in the world, with 70% in Russia; South Korea and the U.S. equally share the rest. Not all five levels of Triz must be taught by Masters. But, as others have started teaching to service a growing demand, some unevenness of skill sets in the lower two levels of certification have resulted.

When demand exceeds capacity, it is often a sign that a new industry is about to be born. **md**

---

BRADFORD L. GOLDENSE, NPDP, CMfgE, CPIM, CCP, president of **Goldense Group Inc.** (GGI) ([www.goldensgroupinc.com](http://www.goldensgroupinc.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.

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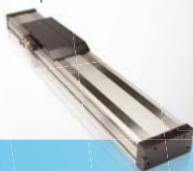
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