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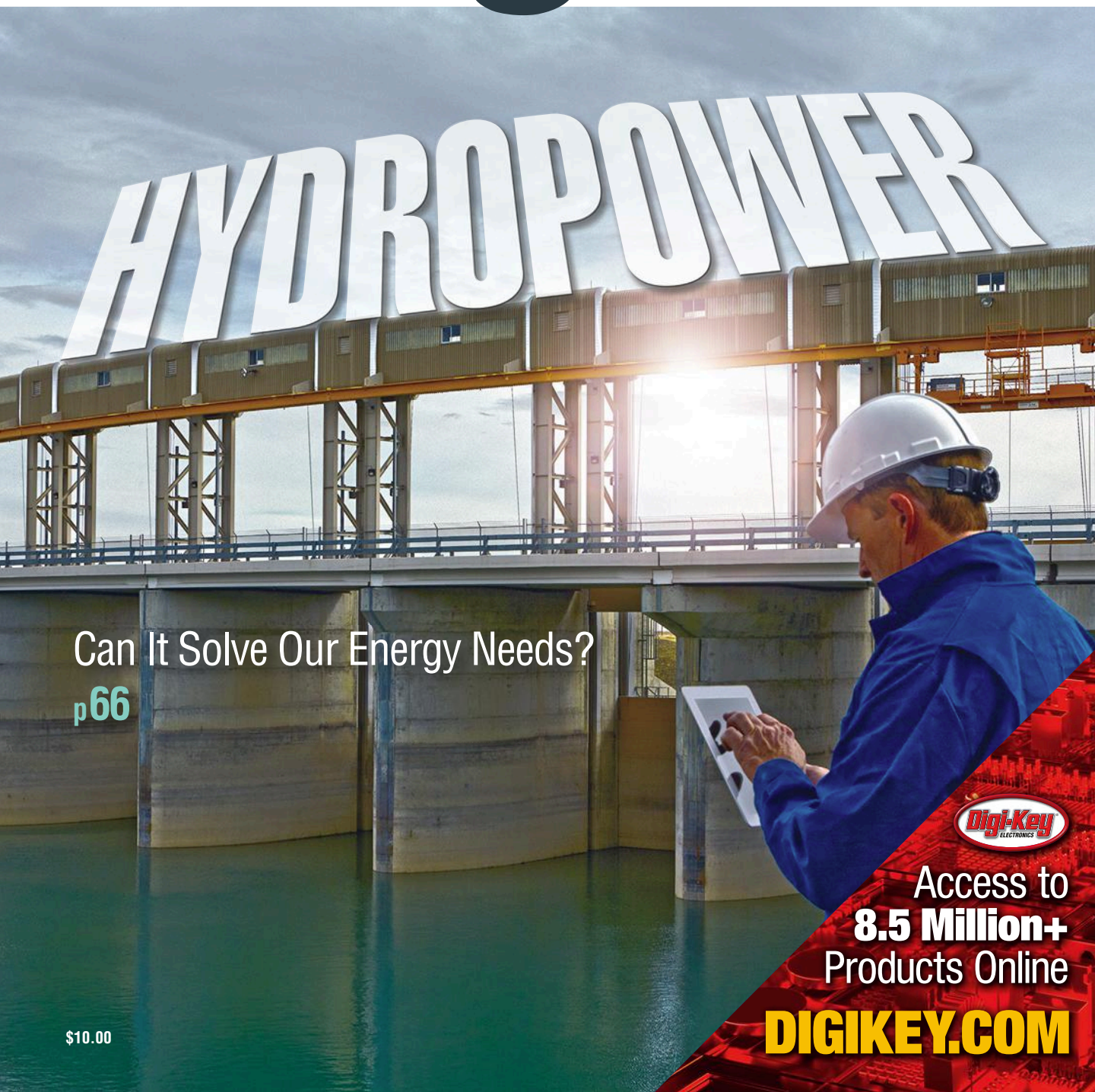

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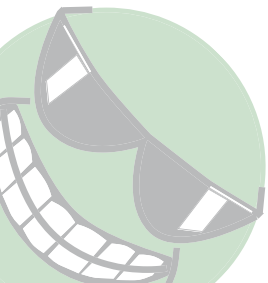

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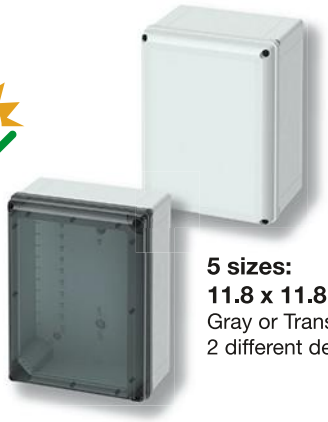

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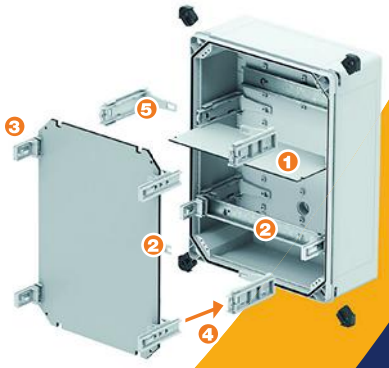

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WO 2015/063057 A1

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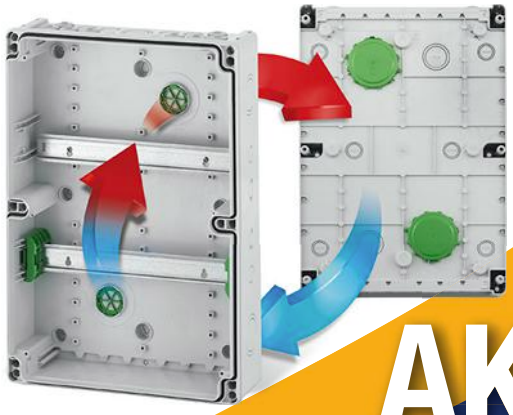

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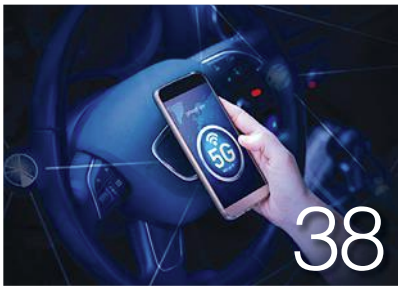

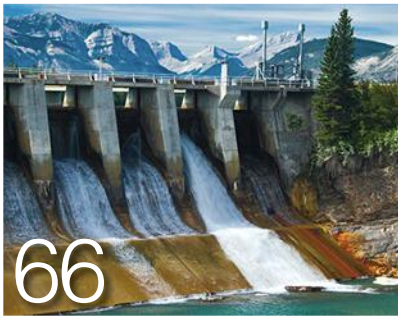

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Paid subscriptions include issues 1-12. Rates: U.S.: $139/year; $199/two years. Canada/Mexico: $159/year; $239/two years; All other countries: $199/year; $299/two years. Cost for back issues are U.S. $10.00 per copy plus tax, Canada $15.00 per issue plus tax, and Int'l $20.00 per issue. OEM Handbook and Supplier Directory, $50.00 plus tax. Prepaid subscription: Informa Media Inc. (MACHINE DESIGN), P.O. Box 2100, Skokie, IL 60076-7800. Periodicals postage paid at Kansas City, MO and additional mailing offices.
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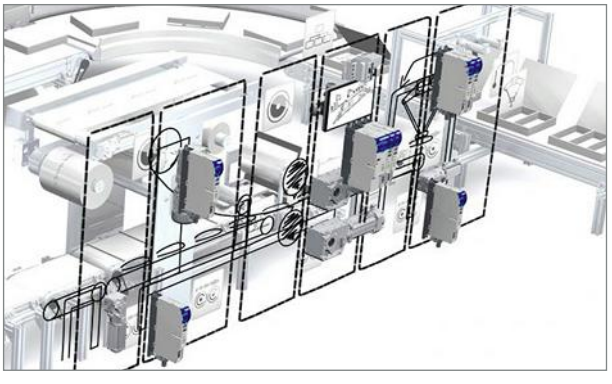

Designing with Motion Control in Mind

What OEMs and design engineers need to know about motors, drives, and controllers.

https://www.machinedesign.com/motion-control/designing-motion-control-mind

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Editorial

CARLOS M. GONZALEZ | Content Director
carlos.gonzalez@informa.com

Saying Goodbye is Never Easy

After four years at *Machine Design*, it's time to say so long for now.

Face front, true engineers! Alas, this will be my last editorial with *Machine Design*. I will be taking on a new role at the American Society of Mechanical Engineers. My departure is bittersweet, as the last four years at *MD* have been life-changing. My first job was in aviation; I worked for Sikorsky Aircraft designing helicopters in its flight control department. The work I did there helped me develop my logical thinking ability to solve problems in creative ways. Working on government contracts and having to face pilots and generals about design problems and solutions was also excellent for working out my nerves.

The problem I had working in aviation was that I wasn't growing as an engineer. I knew that there was a world outside of the field that I wasn't being exposed to; that's why I decided to take the leap and work at *Machine Design*. And the last four years have indeed changed how I view engineering. My first eye-opening experience was attending the UBM conferences in Anaheim. There was so much to learn and see from 3D printing, advanced simulation, different robots, medical devices…the list goes on. That was when I knew that this job was going to teach me so much about the wider world of engineering, and I was excited to share that world with our readers.

With technology changing on an exponential curve, engineers need to grow and adapt. In the last four years alone, I have seen significant changes in the Internet of Things, cloud computing, and artificial intelligence, just to name a few. Society will turn to engineers to explain these technologies, and engineers need to be the masters of these technologies to teach others. My main goal has been to help our readers understand what is on the horizon and how to prepare for it. I'm confident that *Machine Design* will continue to lead our readers to explore new and exciting directions.

I want to personally thank Karen Field for her guidance this past year as the new content director. Our editors Steve and Jeff are true professionals, great writers, and passionate about their work; thank you for your support. The creative content team of Jeremy, Roger, and Tony are wonderful teammates, and I appreciate all your work and help. For the other writers within our group, thank you for your hard work. To the management and sales force of *Machine Design* and the Design Engineering & Sourcing Group, thank you for your leadership and helping us to raise awareness of our engineering brands. Your hard work on the front lines and knowledge of our work help make us a leader in this industry. Many thanks to past employees who helped me over my time here, and a special thank-you to Nancy Friedrich for introducing me to this world of engineering journalism. md

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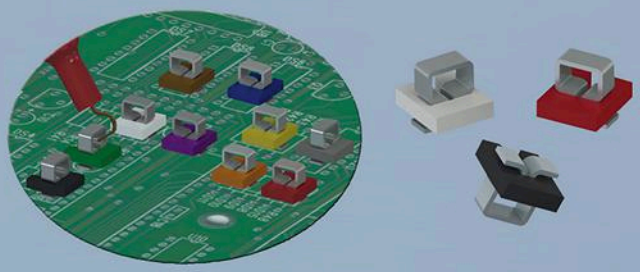

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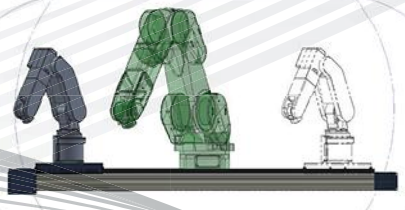


Seventh Axis

News

THE STETHOSCOPE
Gets a "Smart" IoT Upgrade

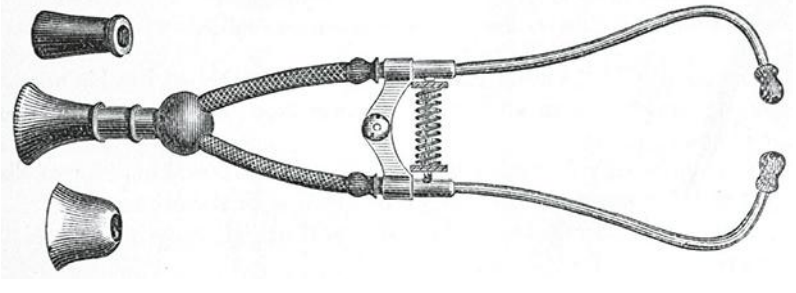
Engineers at John Hopkins University integrate AI, acoustics, and noise-canceling technology to modernize this humble medical device.

The Internet of Things and advances in technology—among them higher-resolution imaging, device connectivity, miniaturized motion components, and 3D printing—are forcing several medical devices to upgrade. No device is free from the upgrade cycle, including the stethoscope.

The stethoscope was designed and built by French physician René Laennec in 1816. When examining a patient, he decided to roll sheets of paper into a tube to amplify the chest sounds instead of placing his ear directly on the patient's body. Laennec's initial prototype led him to devise the stethoscope, cementing his status as the father of auscultation. Since then, however, the stethoscope has not undergone significant changes or improvements.

In short, the stethoscope is the abandoned child of medical devices. Part of the problem is that doctors are no longer well-trained in their use. Several years ago, the *Hartford Courant* reported on *(https://www.courant.com/consumer/hc-ls-health-tech-stethoscopes-0117-20160115-story.html)* spotlighted a 1997 research study which showed that out of 453 physicians and 88 medical students, many of them misdiagnosed 12 important common cardiac events that should have been detectable via stethoscopes.

Researchers simulated an extremely noisy environment in the lab (the sound meter shows levels of around 70 decibels). They compared the audio heard through a top-notch commercial stethoscope, in which the breathing sounds are mixed with ambient noise, to that heard through the Johns Hopkins smart stethoscope, which uses active acoustic filtering to isolate the breathing sounds. *(Credit: John Hopkins University)*



The stethoscope was designed and built by French physician René Laennec in 1816 and has remained unchanged since its inception. In the modern digital age, it is no longer a reliable medical tool.

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The *Courant* article described how the pressures facing medical physicians today contributed to the disuse of stethoscopes: "Medicine's familiar list of woes is at least partly to blame for auscultation's decline. Doctors, especially the overworked medical residents who staff hospitals, have much less time to spend with patients. That means less time for physical examinations, including listening with stethoscopes. The demands of electronic medical records have further eaten into time with patients, many doctors complain."

Doctors today are more inclined to use x-rays and MRIs to diagnose common cardiac, lung, or bowel events. This is partly because advanced imaging devices are faster, have higher accuracy, and help satisfy medical electronic records.

Nevertheless, engineers at John Hopkins University decided that the stethoscope was worthy of reinvention. Mounya Elhilali and James E. West invented a device that uses digital sensing technology to capture sound, enables active acoustics for noise cancellation, and implements artificial intelligence (AI) to help health workers make more accurate diagnoses.

Their effort sprang from the multitude of diseases being misdiagnosed in underdeveloped countries. Worldwide, several children die from pneumonia and lung ailments, infecting almost one million children a year. Underdeveloped areas do not have access to modern diagnosing equipment and rely on stethoscopes to diagnose these common lung ailments.(*https://youtu.be/hJ57NtlFxq4)*

There are modern electronic stethoscopes on the market. They work by converting acoustic waves into electric signals that are then processed in a device to amplify sounds. The device from John Hopkins mitigates noise by improving the coupling between the patient's body and the best piece. It swaps the rubber hose for an electric cable and employs digital noise-control techniques to capture a stronger signal.

The device has an external microphone in the chest piece to collect ambient sounds to help reduce noise through adaptive signal analysis. An onboard microprocessor serves as the operating system which lets the user adapt the tool to different applications.

The engineers, Elhilali and West, are on working apps to let health professionals customize the device to their specific needs. "As our smart stethoscope has a programmable platform, we're now working to develop additional apps that would make it a multipurpose tool, useful for many diseases and scenarios," the developers explain. "We think it could be useful in diagnosing heart failure and various gut disorders, and we're collaborating with cardiologists and gastroenterologists to collect training data and design algorithms."

One example is the use of the devices machine learning capability to filter out noise resulting in clearer results of the patient's lungs.

The stethoscope is undergoing extensive field testing in Peru, Bangladesh, and Malawi as well as in the John Hopkins pediatric emergency room. The tests are to determine how accurate the device is in noisy settings and the accuracy of its pneumonia diagnoses. The first products are set to launch early in 2019. md

A health worker in Bangladesh listens to sounds from a boy's lungs with the help of the Johns Hopkins smart stethoscope, which cancels out extraneous noise and identifies telltale signs of pneumonia. *(Credit: Dr. Eric D. McCollum)*

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ONE SMALL STEP FOR APPLE, One Giant Step for Medical Wearable Devices

THE INTERNET OF THINGS will change how doctors and hospitals monitor a patient's vitals in and out of the hospital. Wearable devices connected to the internet will provide electronic medical records with data to keep a patient's medical history up-to-date, monitor ongoing health concerns, and alert medical personnel in times of emergency.

Apple took a huge step toward this potential future when it announced its joint Heart Study *(https://med.stanford.edu/appleheartstudy.html)* research with Stanford University's School of Medicine. The virtual study enrolled more than 400,000 participants to collect data from their Apple Watch's heart rate monitoring feature. The study was launched in November 2017 and has been monitoring the participant's heart rate, alerting medical professionals of any irregular heart rhythms.

The heart-rate pulse sensor found in the Apple Watch (in model versions 1 through 4) can identify atrial fibrillation, a condition that often remains hidden because people tend to not experience daily symptoms. Atrial fibrillation results in 130,000 deaths and 750,000 hospitalizations each year according to the CDC. They estimate that the condition affects between 2.7 to 6.1 million people, plus 700,000 more people most likely have undiagnosed atrial fibrillation.

The heart rate app would intermittently check the participant's pulse and, when an irregular beat was detected, the participant would receive a notification to schedule a telemedicine consultation with one of the doctors from the study. Participants were then sent ambulatory electrocardiography (ECG) patches through BioTelemetry, which recorded the electrical rhythm of their hearts up to a week.

The preliminary results from the study have proven the accuracy of these types of wearables. Comparing the irregular pulse detection on the Apple Watch to ECG patch recordings showed the pulse detection algorithm had a 71% positive predictive value. 84% of the time, the participants who received notifications were found to be in atrial fibrillation at the time. 57% of those who received irregular pulse notifications sought medical attention.

One of the most important key findings was that out of 419,093 participants, only 0.5% of participants (2,116) received irregular pulse notifications. One of the many concerns among health professionals with wearable health devices is potential over-notification. Patients receiving several notifications can create a burden on the medical industry, having doctors chase down health concerns which are non-life threatening or erroneous.

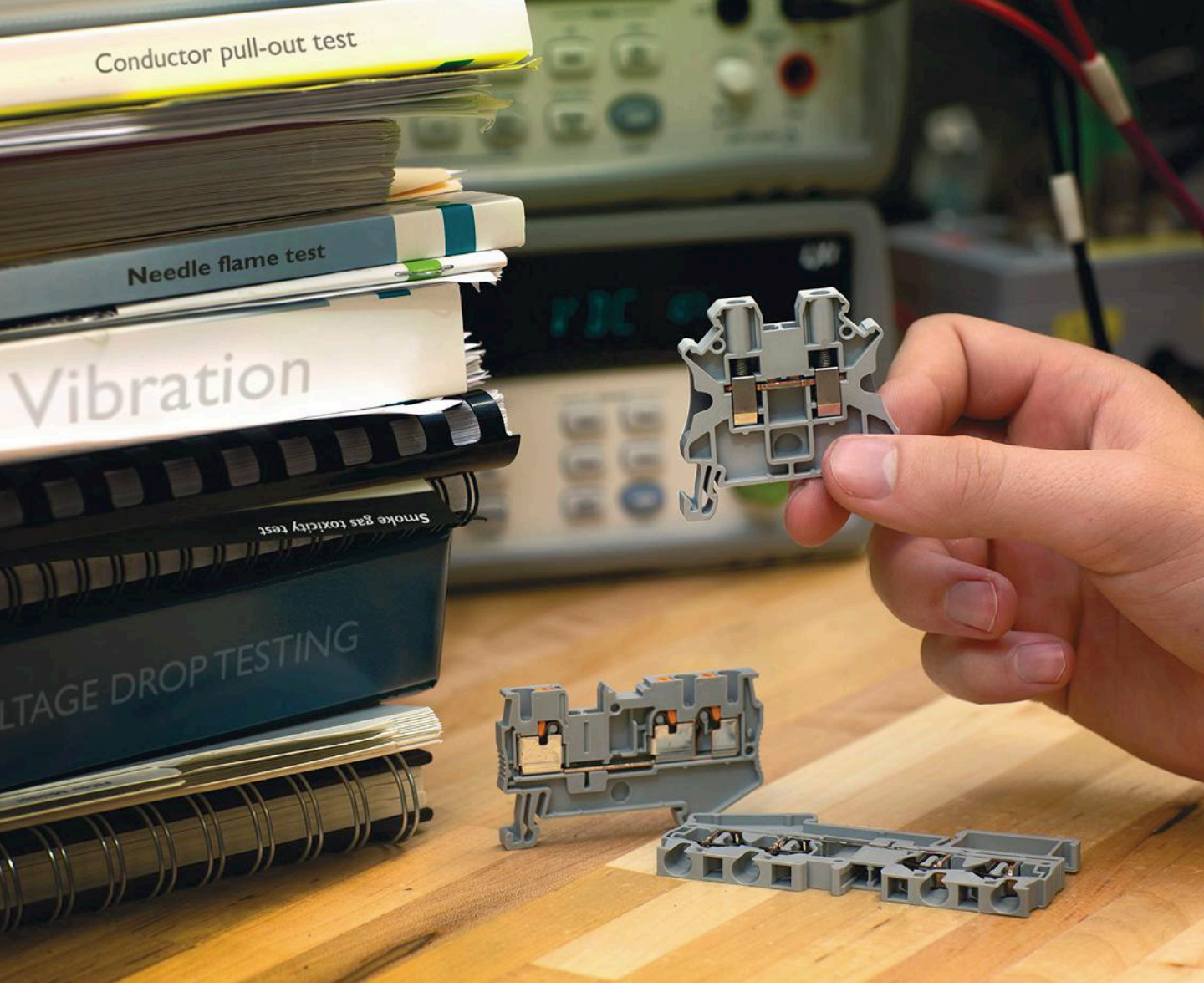
"The results of the Apple Heart Study highlight the potential role that innovative digital technology can play in creating more predictive and preventive health care," said Lloyd Minor, M.D., dean of the Stanford School of Medicine. "Atrial fibrillation is just the beginning, as this study opens the door to further research into wearable technologies and how they might be used to prevent disease before it strikes—a key goal of Precision Health."

The new Apple Watch Series 4 is a great example of what a future medical

The Apple Watch can monitor a wearer's heart rate and keep track of irregular rhythms.

The Apple Watch can notify wearers of possible atrial fibrillation, which results in 130,000 deaths and 750,000 hospitalizations each year, according to the CDC.

The Heart Study is a joint Apple and Stanford University medical research study to observe how wearable medical devices can operate outside of a hospital for patient monitoring.



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device wearable can offer. It already can detect when someone falls hard enough to cause injury and can notify emergency services to help. Another new feature of note is the ECG tool. By touching the crown on the watch, the wearer completes the necessary conductivity circuit to measure one's ECG. Apple, for now, has been clear in claiming that the ECG is not a medical diagnostic tool, and merely an indicator for the wearer. However, as the watch increases its accuracy, we can potentially see the watch being used to monitor ECG readings outside of a hospital setting.

"The performance and accuracy we observed in this study provide important information as we seek to understand the potential impact of wearable technology on the health system," says Marco Perez, M.D., associate professor of cardiovascular medicine at Stanford. "Further research will help people make more informed health decisions." ■

One of the most important key findings was that out of 419,093 participants, only 0.5% of participants (2,116) received irregular pulse notifications.

The latest Apple Watch can measure a wearer's electrocardiogram. These types of features can become lifesaving tools as they increase in accuracy.

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AI DIAGNOSES DISEASES with Less Data

Source: Getty Images

AS ARTIFICIAL INTELLIGENCE SYSTEMS learn to better recognize and classify images, they are becoming highly reliable at scanning medical images and diagnosing diseases, such as skin cancers. But as good as they are at detecting patterns, AI won't be replacing your doctor any time soon.

Even when used as a tool, image recognition systems still require an expert to label the data, and a lot of data at that: It needs images of both healthy and sick patients. The algorithm finds patterns in the training data and uses it when it tries to identify new images. But it is time-consuming and costly for experts to obtain and label each image.

To address this issue, an research team at Carnegie Mellon University's College of Engineering developed an active learning technique that uses limited data to achieve a high degree of accuracy in diagnosing diseases such as diabetic retinopathy or skin cancer.

The researchers' model begins working with a set of unlabeled images. The model decides how many images to label to have an accurate set of training data. It labels an initial set of random data and then plots it over a distribution, as images will vary by age, gender, physical property, and other parameters. To make good decisions based on this data, samples must cover a large distribution space. The algorithm then decides what data should be added to the dataset, considering the current data distribution.

To the left is a retina containing a lesion, known as an exudate (inside the box), associated with diabetic retinopathy. To the right is a retina containing a lesion known as a hemorrhage, which is also associated with diabetic retinopathy.

The algorithm measures how good the distribution is after a set of new data is added to it, then selects a new dataset that improves the overall dataset.

The process is repeated until the dataset's distribution is good enough to be used as the training set. This method, called MedAL (for medical active learning), was 80% accurate at detecting diabetic retinopathy using only 425 labeled images—a 32% reduction in the number of required labeled examples compared to the standard uncertainty sampling technique, and a 40% percent reduction compared to random sampling.

The researchers also tested the model on other diseases, including skin cancer and breast cancer images, to show it would work on a variety of different medical images. The method is generalizable, since its focus is on how to use data strategically rather than trying to find a specific pattern or feature for a disease. It could also be applied to other problems that use deep learning but have data constraints.

CMU's active learning approach combines predictive entropy-based uncer-

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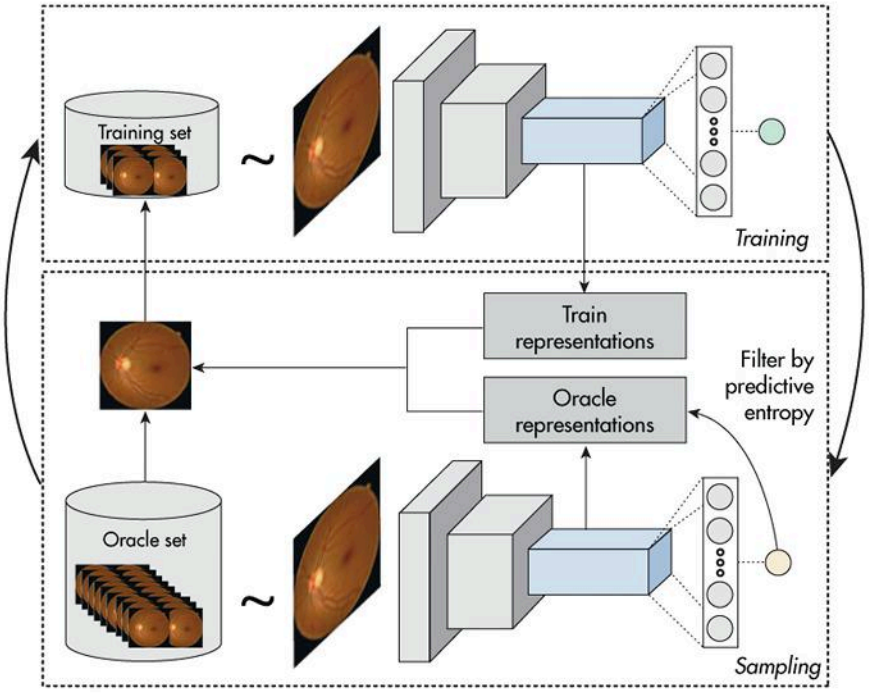
tainty sampling and a distance function on a learned-feature space to improve the selection of unlabeled samples. The method also overcomes the limits of traditional approaches by efficiently selecting only images that provide the most information about the overall data distribution, thus reducing computation cost and increasing speed and accuracy. ■



The process starts by training a model and using it to query examples from an unlabeled data set that are then added to the training set. A new query function is proposed that is better suited for Deep Learning models. The model is used to extract features from both the oracle and training set examples, and the algorithm filters out oracle examples that have low predictive entropy. Finally, the oracle example is selected that is on average the most distant in feature space to all training examples.

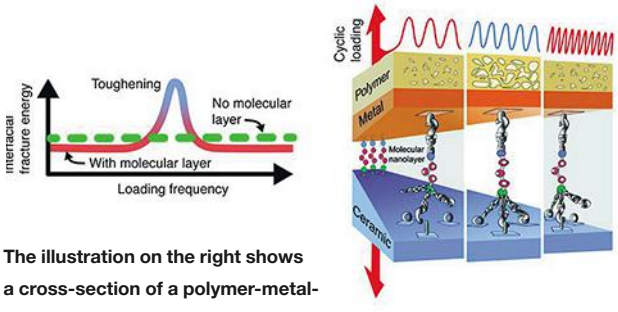
NANOGLUE Gets Stronger Under Dynamic Loading

A TEAM LED BY engineers from Rensselaer Polytechnic Institute has unlocked the behavior of new material that could open the door to new possibilities in materials engineering. The team discovered that oscillating loads at certain frequencies can increase the strength of composites several-fold, so long as the composites have a molecular layer of a secret ingredient it calls "nanoglue."

"Unearthing, understanding, and manipulating nanoscale phenomena at interfaces during dynamic loading is a key to designing new materials with novel responses for applications," says Ganpati Ramanath, the John Tod Horton Professor of Materials Science and Engineering at Rensselaer. "Our work demonstrates that introducing a nanoglue layer at an interface of a layered composite can mechanically and significantly toughen that composite at certain loading frequencies."

Ramanath and his team of collaborators found that, at certain loading frequencies, the energy required to fracture a nanoglue-modified polymer-metal-ceramic composite tripled and exceeded the static loading fracture energy. This behavior was unexpected and is significant, because fracture energy is typically lower during cyclic loading than during static loading. Such frequency-dependent toughening was observed only when a nanoglue layer was used to bond the metal and ceramic.

The results also show that although the nanolayer is necessary for toughening, the frequency range and extent of toughening depend primarily on the mechanical properties of the polymer in the composite. Specifically, the nanoglue facilitates load transfer



The illustration on the right shows a cross-section of a polymer-metal-nanoglue-ceramic composite. The graph shows the frequency-dependent toughening phenomenon.

across the metal-ceramic interface and dissipates energy in the polymer through plastic deformation, leading to an increase in fracture energy.

"Our discovery opens up an entirely new set of possibilities to design composites with novel responses using different combinations of polymers and interfacial nanolayers. For example, we could build a completely new class of smart composites that significantly toughen, or perhaps even self-destruct, at certain frequencies," Ramanath says.

"Manipulating the coupling can make composites stronger under loading conditions we have traditionally tried to avoid and, hence, vastly expand the scope and improve the performance of composites in applications," says Michael Lane, a chemistry professor at Emory & Henry College. ■

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ROBOT WITH AR Could Help People with Disabilities

CONTROLS THAT USE augmented reality could help individuals with profound motor impairments operate humanoid robots to feed themselves and perform routine care tasks such as scratching an itch and applying skin lotion, according to researchers at Georgia Institute of Technology. The web-based interface displays a "robot's-eye view" of surroundings to help users interact with the world through the machine and help make sophisticated robots more useful to people without experience operating complex robots.

The researchers looked into how "robotic body surrogates" that perform tasks similar to those of humans could improve the quality of life for people with disabilities. "Our results suggest that people with profound motor deficits can improve their quality of life using robotic body surrogates," says Phillip Grice, a recent Georgia Institute of Technology Ph.D. graduate. "We have taken the first step toward making it possible for someone to purchase an appropriate robot, have it in their home, and benefit from it."

The researchers used a PR2 mobile manipulator made by Willow Garage, a robot manufacturer for the studies. The wheeled robot has 20 deg. of freedom, with two arms and a "head," and can manipulate objects such as water bottles, washcloths, hairbrushes, and even an electric shaver.

In their first study, a group of 15 participants with severe motor impairments were each given a PR2 to use. Participants learned to control the robot remotely, using their own assistive equipment to operate a mouse cursor to perform a personal care task. Eighty percent of the participants could get the robot to pick up a water bottle and bring it to the mouth of a mannequin.

Compared to able-bodied persons, the robots are limited. But participants could perform tasks effectively and showed improvement on a clinical evaluation that measured their ability to manipulate objects compared to what they were able to do without the robot.

In the second study, researchers provided the PR2 and the new controls to Henry Evans, a California man who has been helping Georgia Tech researchers explore assistive robots since 2011. Evans, a stroke survivor who has very limited control of his body, tested the robot in his home for seven days and not only completed tasks, but also devised novel uses combining the operation of both robot arms at the same time such as using one arm to control a washcloth and the other to use a brush.

"The system was very liberating to me, in that it let me independently manipulate my environment for the first time since my stroke," says Evans. The researchers were pleased Evans developed new uses for the robot, combining motion of the two arms in ways they had not expected.

"When we gave Henry free access to the robot for a week, he found new opportunities for using it that we had not anticipated," says Grice. "This is important because a lot of the assistive technology available today is designed for very specific purposes. What Henry has shown is that this system is powerful in providing assistance and empowering users. The opportunities for this are potentially very broad."

The interface allowed Evans to care for himself in bed over an extended period of time. "The most helpful aspect of the interface

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system was that I could operate the robot completely independently, with only small head movements using an extremely intuitive graphical user interface," Evans said.

The web-based interface shows users what the world looks like from cameras in the robot's head. Clickable controls overlaid on the view lets users move the robot in a home or other environment and control the robot's hands and arms. When users move the robot's head, for instance, the screen displays the mouse cursor as a pair of eyeballs to show where the robot will look when the user clicks. Clicking on a disc surrounding the robotic hands lets users select a motion. While "driving" the robot around a room, lines following the cursor on the interface indicate the direction it will travel.

Building the interface around the actions of a single-button mouse lets people with a range of disabilities use the interface without lengthy training.

"Having an interface that individuals with a wide range of physical impairments can operate means we can provide access to a broad range of people, a form of universal design," Grice says. "Because of its capability, this is a complex system, so the challenge was to make it accessible to individuals with limited control of their own bodies."

Although the results of the study demonstrated what the researchers had set out to do, they agree improvements can be made. The existing controls are slow, and mistakes made by users can create significant setbacks.

The cost and size of the PR2 would need also to be significantly reduced for it to be commercially viable, Evans suggests. Kemp says these studies point the way to a new type of assistive technology. ■

Showing its capabilities as a body surrogate, a PR2 controlled remotely by an individual with profound motor deficits picks up a cup in a research laboratory at the Georgia Institute of Technology. *(Credit: Phillip Grice, Georgia Tech)*

COMBAT DRONE PROTOTYPE Makes First Test Flight

THE XQ-58A VALKYRIE, a prototype for a long-range unmanned drone, completed its first flight on March 5 at the Yuma Proving Grounds in Arizona. It was designed and built by the Air Force Research Laboratory in conjunction with Kratos Unmanned Aerial Systems, a company that has earned a reputation for building reliable drones. The two organizations took just 2.5 years to bring the program to its first flight test.

The multi-mission XQ-58A was designed to handle surveillance, strike, electronic warfare, and fly missions independently as part of an autonomous and cooperative swarm of drones, or as a "loyal wingman." Loyal wingman is a new concept, defined as having a piloted combat aircraft (most likely an F-22 or F-35) fly and control a drone during a mission.

The drone is said to have a range of over 2,000 miles, a mission ceiling of about 45,000 ft, and a top speed of 652 mph (Mach 0.85). It can carry up to 500 lb of bombs, most likely two Small Diameter Bombs (GBU-39/B) in ,an internal bay or under each wing.

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The single-engine jet was also designed with stealth in mind. It is relatively small—almost 29-ft long with a 22-ft wingspan. It also has a trapezoidal fuselage with a chined edge, V-tails, and an S-shaped air intake, all of which should reduce its radar and IR signature. The XQ-58A was built rugged enough to take off and land from rough airfields, which are common forward combat areas. It can also be launched using rocket boosters instead of a runway.

The XQ-58A is part of the Air Force Research Laboratory's Low Cost Attritable Aircraft Technology (LCAAT) portfolio. Its goal is to stop and possible reverse the escalating cost trajectory of tactical aircraft. LCAAT's objectives include designing and building drones faster by developing better design tools and maturing and leveraging commercial manufacturing processes to reduce build time and cost. LCASD aims to eventually field optionally reusable, highly adaptable, low-end unmanned combat air vehicles for $3 million apiece for batches of up to 99 aircraft per year, or $2 million each for yearly orders of 100 or more. In essence, the LCAAT concept is "high-volume" both in in terms of the strategy behind it and of procuring it affordably. ■

The GBU-39/B Small Diameter Bomb (SDB) from Boeing is a 250-lb precision-guided glide bomb. It was designed to let combat aircraft carry several more bombs than what was one standard. For example, most U.S. Air Force aircraft can carry four SDBs in place of a single 2,000-pounder. The bomb is highly accurate and can guide its descent using inertial navigation or GPS, and home in on targets using radar, infrared, and semi-active laser guidance.

Company to Market 3D-PRINTED PROSTHETIC LEG SOCKET

UNYQ, A COMPANY BASED in San Francisco, will begin selling its 3D-printed prosthetic leg socket—the component that supports and helps holds the person's residual leg to the prosthetic—in the UK and Germany. The company plans on expanding sales into the U.S. in July 2019 and in Japan in October. It will be available for order immediately, with the finished product shipping within three weeks. The company aims to have several clinics on board by the end of the year and anticipates the product will be covered by insurance in most targeted countries.

The UNYQ Socket offers several benefits both to the user and clinician. Users benefit from an aesthetically appealing, lightweight socket that eliminates much of the metal found in a traditional prosthetics. The design also combines several parts in one, a hallmark of 3D-printed parts. This lowers costs and reduces complexity. The socket also contains sensors that record the individuals' activity, including the number of steps taken and calories burnt. It has also been ISO 10328-tested for cyclic and static strength in lower-limb prosthetics. Clinicians benefit from improved patient satisfaction due to the custom fit and comfort, access to data, and the ability to easily replace broken or lost prosthetics. This is key, as it saves time for the clinician and the end user. Many amputees have more than one prosthetic leg, so replication of the socket at the press of a button saves several visits.

People wearing the UNYQ prosthetic socket and leg covers.

The UNYQ Socket is one of various additional products the company plans to add to its Prosthetics Wear line, with the aim of eventually providing a complete, "aesthetically unified" prosthetic leg product by the end of 2021.

The Socket is designed to be used with the company's line of personalized 3D-printed prosthetic leg covers. These are cosmetic, protective covers for prosthetic, giving the user more opportunity for "showing off [their] personality as they see fit." Both the 3D-printed prosthetic leg cover and socket are part of the "total leg solution" UNYQ plans to provide. ■

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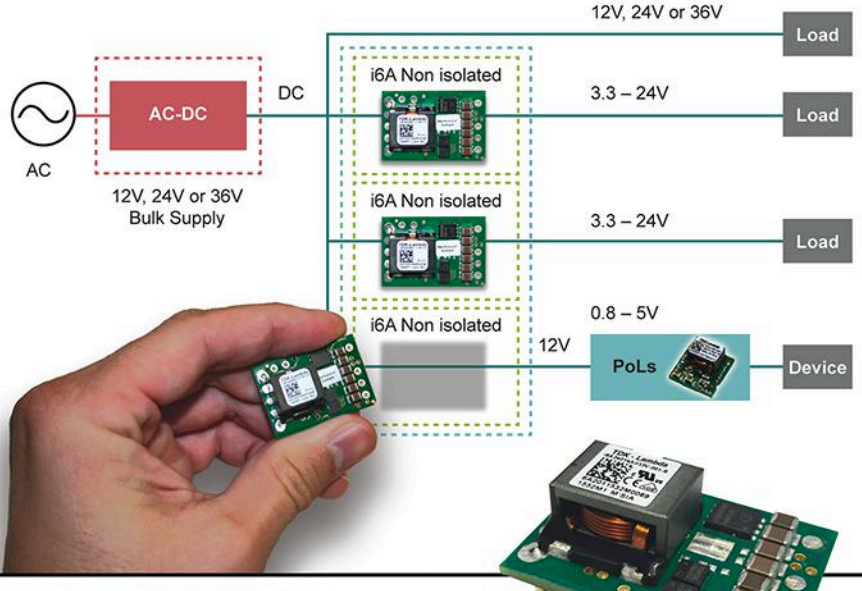

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RESEARCHERS MAY HAVE REVERSED TIME on a Quantum Computer

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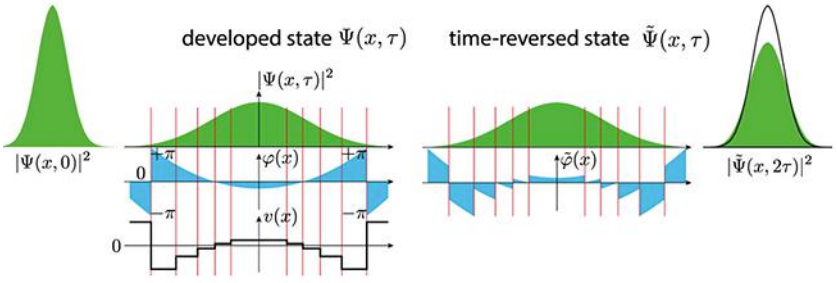


This image shows a time-reversal procedure for a spreading wave packet that represents a quantum particle. The reversed state freely evolves into the original squeezed state, which is recovered with some precision—in this case, 85%. *(Image: Argonne National Laboratory)*

AN INTERNATIONAL TEAM of scientists led by Argonne National Laboratory explored the concept of reversing time in a first-of-its-kind experiment, managing to return a computer briefly to the past. The results present new possibilities for quantum computer program testing and error correction and suggest new paths for exploring the backward flow of time in quantum systems. They also open new possibilities for quantum computer programming. A quantum computer that can effectively jump back and clean up errors as it works also could operate far more efficiently.

To achieve the time reversal, the research team developed an algorithm for IBM's public quantum computer that simulates a particle's scattering of a particle. In classical physics, this might appear as a billiard ball struck by a cue, traveling in a line. But in the quantum world, a scattered particle takes on a fractured quality, spreading in several directions. To reverse its quantum evolution is like reversing the ripples created when a pebble is thrown into a pond.

In nature, restoring this particle back to its original state—in essence, putting Humpty Dumpty back together—is impossible.

The main problem is that you would need a "supersystem," or external force, to manipulate the particle's quantum waves at every point. But, as researchers note, the timeline required for this supersystem to spontaneously appear and properly manipulate the quantum waves would extend longer than that of the universe itself.

Undeterred, the team set out to determine how this complexity might be overcome, at least in principle. Their algorithm simulated an electron scattering by a two-level quantum system, "impersonated" by a quantum computer qubit (the basic unit of quantum information) and its related changes through time. The electron goes from a localized (or "seen") state, to a scattered one. Then the algorithm throws the process in reverse, and the particle returns to its initial state. In other words, it moves back in time, if only by a tiny fraction of a second.

Given that quantum mechanics is governed by probability rather than certainty, the odds for achieving this time-travel feat were pretty good given that algorithm delivered the same result 85% of the time in a two-qubit quantum computer.

The result deepens our understanding of how the second law of thermodynamics (a system will always move from order to entropy, and not the other way around) acts in the quantum world. The researchers demonstrated in previous work that, by teleporting information, a local violation of the second law was possible in a quantum system separated into remote parts that could balance each other out.

"The results also give a nod to the idea that irreversibility stems from measurement, highlighting the role the concept of 'measurement' plays in the foundation of quantum physics," says researcher Gordey Lesovik of the Moscow Institute of Physics and Technology.

This is the same notion Austrian physicist Erwin Schrödinger captured with his famous thought experiment, in which a cat sealed in a box might remain both dead and alive until its status is monitored somehow. Researchers suspended their particle in this superposition, or form of quantum limbo, by limiting their measurements.

"This was the essential part of our algorithm," says Argonne scientist Valerii Vinokur. "We measured the state of the system in the beginning and the end, but did not interfere in the middle."

The finding may eventually lead to better methods of error correction on quantum computers, where accumulated glitches generate heat and beget new ones. A quantum computer able to effectively jump back and clean up errors as it works could operate far more efficiently.

"At this moment, it's very hard to imagine all the implications this will have," Vinokur said. The study also begs the question: Can researchers now figure out a way to make older folks young again? "Maybe," Vinokur jokes, "with the proper funding." ■

(News continues on page 86)

CARLOS M. GONZALEZ | Content Director

GE Current

Marries LED Light Fixtures and IIoT Sensors to Provide an Efficient IIoT Network Solution

The light fixtures from GE Current introduce efficient LED lighting and IIoT sensor and data collection capabilities.

GE Current is in the business of installing LED lights into current manufacturing sites. The bonus of these light fixtures is that they provide the building blocks to deploy a connected network of IIoT sensors and data collection.

Implementing an Industrial Internet of Things (IIoT) network can be daunting, especially if one does not have the existing infrastructure in place. GE Current has addressed those concerns by introducing a new way to set up an IIoT infrastructure via the use of LED light fixtures. Several businesses are beginning the transition to LED lighting in commercial and industrial buildings. While the primary goal is energy efficiency, connected lighting has the potential to modernize productivity and revenue outcomes via the benefits of IIoT networks, as well as to prepare manufacturing organizations for the future of smart systems technology. We sat down with Rudy Calderon, general manager for Industrial Accounts

at GE Current, to discuss how the company is transforming the industrial manufacturing workspace—one light fixture at a time.

What is GE Current, and what does it offer manufacturing sites?

GE Current is a business that I would say has helped transition our customers from using old technologies to ones that are cutting-edge. Our LED light fixtures help increase energy efficiency by 70% over traditional technologies and allow for the introduction of IIoT networks.

Rudy Calderon is the general manager for Industrial Accounts at GE Current.

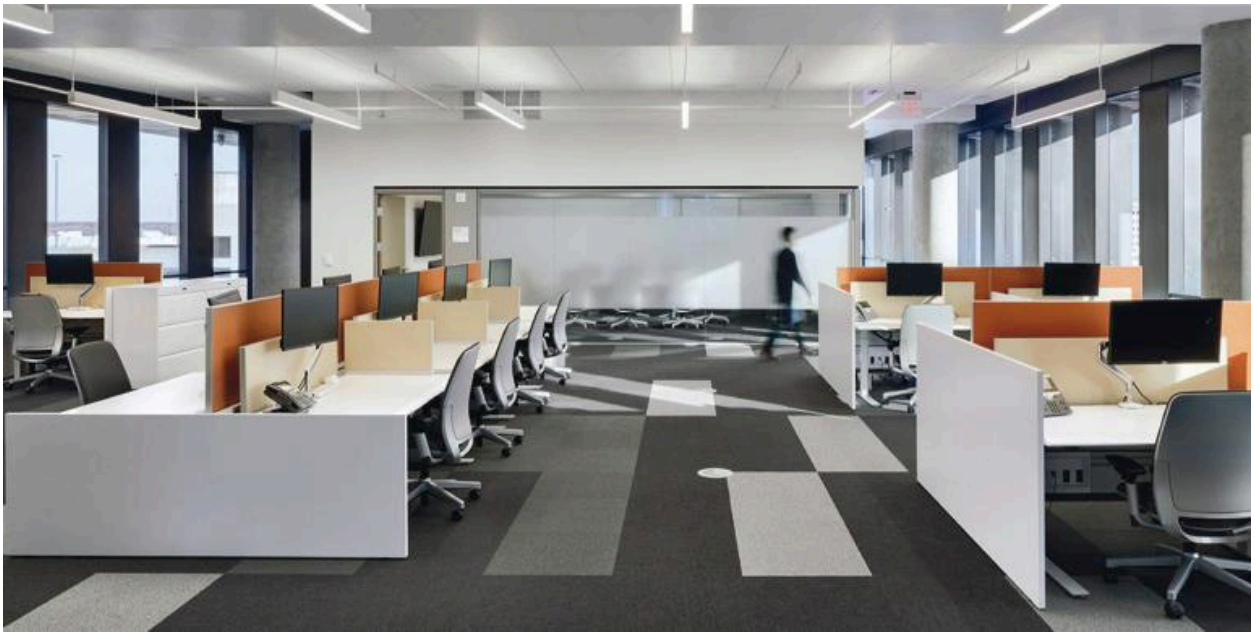
When LEDs are employed with sensor technologies, users can save another 10 to 20%. The real big opportunity we see is around business productivity, especially on the manufacturing side. We ensure that the plant is optimizing throughput; the more you can produce and ship, the better it is for the company.

When we join our sensors and fixtures, we are trying to tackle a customer's larger issues. For example, for a manufacturing company, it is very easy to lose assets. Our architecture allows us to provide better tracking and control of the product as it goes through the plant. Our control system, Daintree, is unique because it is completely open from the top to bottom. Several of our competitors have a propriety closed system or [one that is] only open in certain aspects. This limits the growths of customers because they only grow at the pace of the system. An open system on the bottom allows our customers to procure sensors and other system products based on what they need or want to add from any supplier, not just GE.

Our methodology is that the more competitiveness there is in the marketplace, the more customers will adopt IIoT networks. The top of an open system is along the data sheets and how they control their data. They can try to manipulate the data and make their own decisions, or they can go and find independent software vendors to help them make those changes and create productivity tools. Having access to data allows our customers to figure out how the data applies and can compare it to data from other plant sites, providing unique solutions based on the manufacturing site. The data is not propriety and belongs to the customer, giving them full control to scale and make their own decisions.

IIoT implementation is happening at different levels. How do advanced LED light fixtures introduce IIoT to a plant?

Our LED fixtures allow for easy implementation of sensors across a manufacturing site, as well as introduc-



The light fixtures can be installed in any existing lighting infrastructure and the sensors used can be from any outside vendor, as the GE Current architecture is completely open.

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> “We are looking to expand our IIoT LED light fixture technology to smart cities. Being able to monitor traffic and outside environments and collecting the data will help a city determine the best way to regulate the flow of a city.”

ing massive energy savings. In general, the manufacturing industrial segment LED adoption rate ranges today around 10 to 20%. There is a larger opportunity to introduce a cost-effective and easy way to introduce IIoT networks to manufacturing plants.

Each of our LED fixtures has the ability to carry a verity of sensors. Additional work does not need to be done to install sensing equipment. Fixtures don’t move. From a tracking standpoint, for example, you know that fixture 1A is not going to move from its installation location, giving customers a good bird’s-eye view of their entire manufacturing plant. A manufacturing site can install a sensor to track any assets that pass by fixture 1A and help prevent the loss of assets. Also, by using an established infrastructure of light fixtures, you don’t need to install another electrical connection network for the sensors. They can use the electricity already there. An added benefit of using LEDs is that the estimated savings of 70% will end up covering the cost of a sensor infrastructure.

What are some typical sensors that can be attached to the LED light fixtures?

There are a variety of sensors that can be attached today. This includes motion, temperature, air quality, asset tracking, noise and vibration, Bluetooth low energy, and predictive maintenance sensors. The benefit of our architecture is that with an open system, customers can use other vendors’ sensors, and that is market which grows exponentially. Just a few a years ago we probably only had half of the sensors we have today, and we expect to see more new sensors enter the market in the upcoming years.

Wireless Area Controllers (WACs) collect the data from the light fixtures and upload them to the cloud.

What are the steps necessary to update the manufacturing site’s lighting system?

Upgrading the control system is quite easy. First, you need to understand from the outside looking in what type of environment is currently being used in your plant. Whether it is—for example, metal-halide or fluorescent light fixture—you need to know what kind of light output you currently have. The second step is implementing a design that meets the lighting requirements of your space, either by OSHA or the customers’ needs. This is also where you consider the location of your light fixtures for sensor deployment, ensuring that their fixtures in key locations for either environment or asset tracking.

The third step is to agree on the price of installation once the design is complete, and then lastly is the execution of installation. In the installation phase, for every 150 fixtures, you will have a wireless area controller (WAC). The WAC collects the data from the sensors and sends it to the cloud. The contractor works with us to determine the best locations for the WACs to optimize network connectivity.

What are the future plans for GE Current and how do you plan to expand?

We are looking to expand our IIoT LED light fixture technology to smart cities. Being able to monitor traffic and outside environments and collecting the data will help a city determine the best way to regulate the flow of a city. These are across the board from car traffic flow to helping people finding parking spots on the street…even monitoring the air quality in a neighborhood. For smart cities, the key to its future development is in the data.

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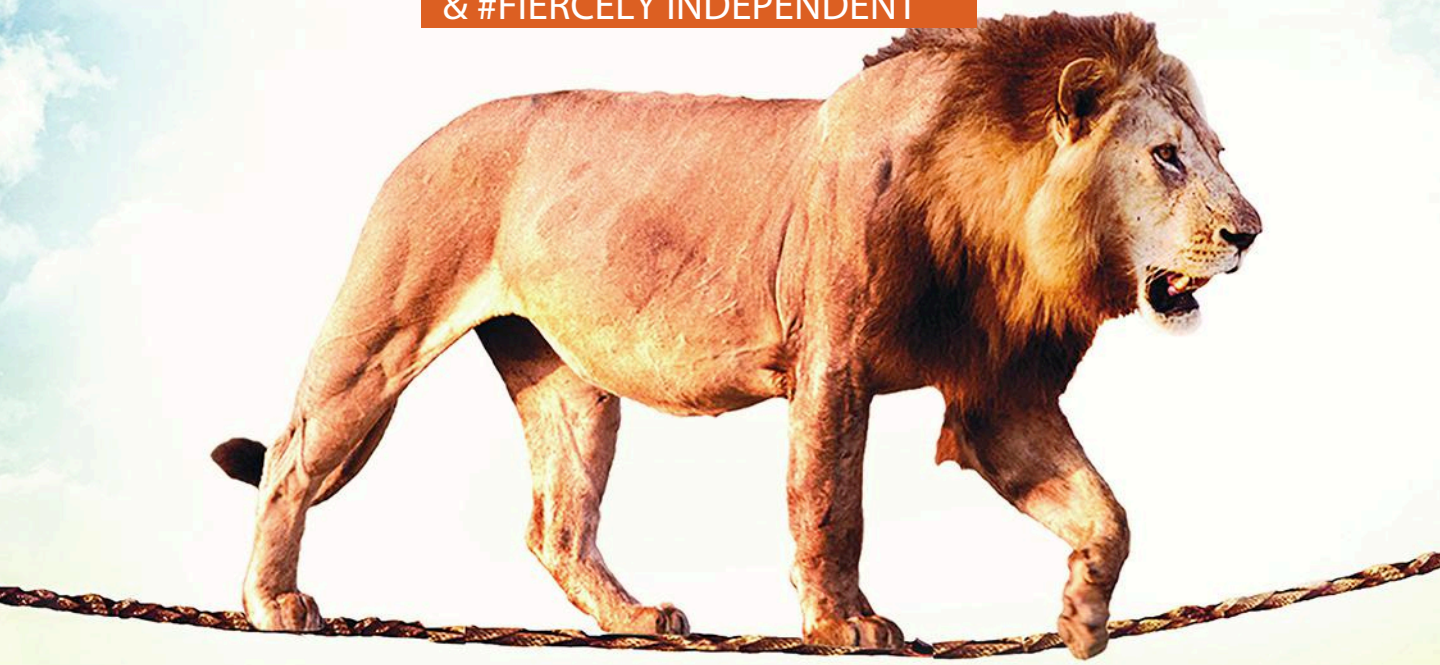

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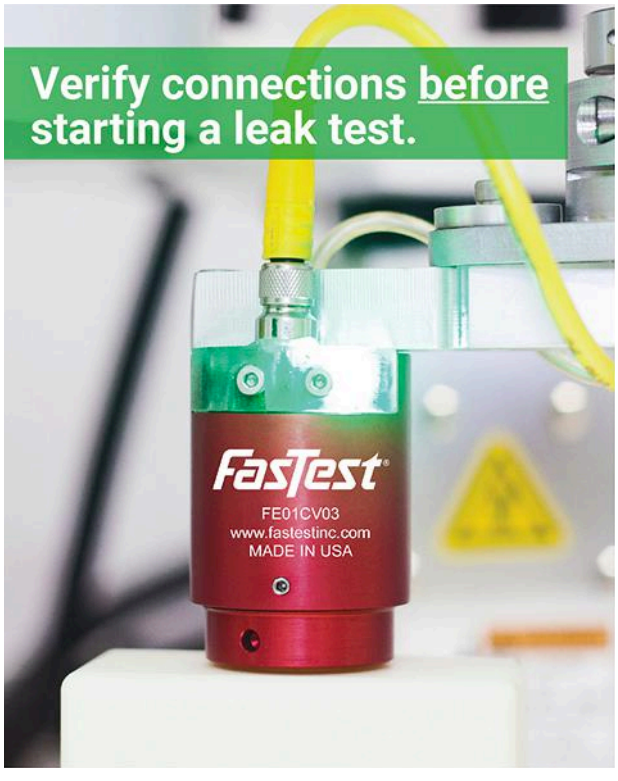

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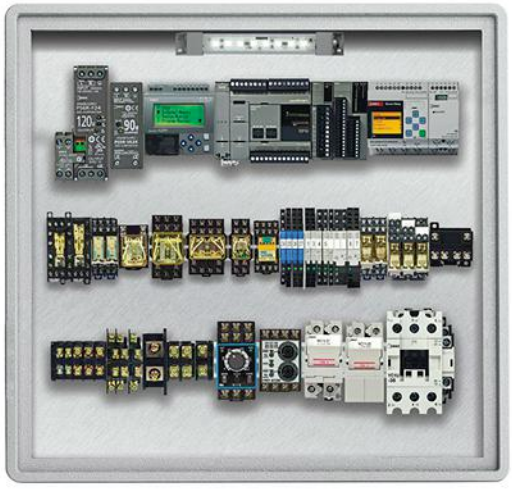

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RALF LLANASAS | Contributor

5G's Importance for Self Driving Cars

The automobile industry is experiencing exponential growth of self-driving features, and this trend is expected to continue. 5G network connections will have a major influence on the development of self-driving cars, making them faster, smarter, and safer.

The momentum for the realization of autonomous vehicles in mainstream use is reaching critical mass. Companies such as Tesla and Toyota are now testing self-driving vehicles on the roads in places like Pittsburgh, Boston, and Phoenix. But while many Americans already had grave concerns surrounding driverless cars, a recent fatal accident by an autonomous Uber vehicle has many questioning if autonomous cars will ever be safe enough to feel confident with them sharing our roads.

Still, with self-driving features already in widespread use, it does appear that fully autonomous cars will be appearing on our roads, and perhaps sooner than people realize. Even more surprising, they will also be considered much safer than human-controlled vehicles.

For autonomous car technology to be unlocked, many experts agree that large-scale adoption of 5G—the next-generation wireless technology—is required. The current 4G network is fast enough to online stream full HD

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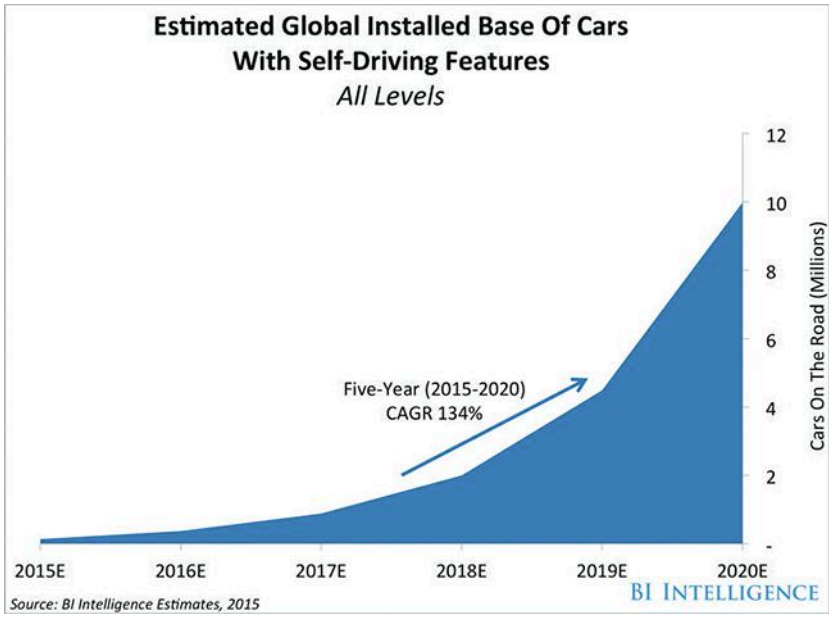
Driverless cars are just one of the many incredible technologies that are likely to be ushered in with 5G. Virtual reality and artificial intelligence are two more examples of the breakthroughs that we can expect once the data network catches up with technological advancement.

content and play online games, but it can't support safer and smarter autonomous cars.

Said Nokia's Jane Rygaard in a recent interview *(https://www.bbc.com/news/business-45048264)* with the BBC: "We need to look at how long it takes for the message to be transmitted between sensors and then get to the computer in each car, and then how long it takes for the computer to make a decision, and all of this has to be in less time than a human would take to make a decision—2 milliseconds. We need a network supporting this, and 5G is that network."

The current 4G network is simply not fast enough to provide the capability to give autonomous vehicles human-like reflexes that may have prevented the Uber vehicle fatality.

Driverless cars are just one of the many incredible technologies that are likely to be ushered in with 5G. Virtual reality and artificial intelligence are two more examples of the breakthroughs that we can expect once the data network catches up with technological advancement.



Self-driving car features are already becoming popular with car makers. *(Credit: Business Insider)*

EVOLUTION OF THE NETWORKS

The wireless data network has advanced steadily over the past 30 years, and some life-changing technologies have been hot on its heels. The modern evolution began in the early '80s with the introduction of the first-generation analog cellular system. Though cell phones were still relatively rare, people could finally talk to each other on the go.

By the early '90s, second-generation and 2.5G mobile systems enabled people to send text, but it wasn't until the start of the new millennium that people had access to broadband-speed internet through 3G. Phones evolved from devices for making calls to a tool for multifaceted communication, entertainment, shopping, and much more.

4G is the latest evolution, and it offers enough bandwidth and speed to allow real-time information- and location-sharing. This evolvement enabled the sharing economy and helped give birth to companies like Uber and Lyft. However, it's still not fast enough to support technologies that require the speed of human reflexes. That's where 5G comes in.

WHY 5G IS CRUCIAL FOR AUTONOMOUS CARS

The fifth-generation wireless technology is expected to connect almost everything around us with an ultrafast, highly reliable, and fully responsive network. 5G will allow us to leverage the full potential of advanced technologies such as artificial intelligence, virtual reality, and the Internet of Things (IoT).

Self-driving cars use hundreds of sensors to make vehicles faster and smarter. These sensors generate unprecedented amounts of data, much more than any other IoT adoption would. Handling, processing, and analyzing this amount of data requires a much faster network than the existing 4G technology. Autonomous cars, systems require incredible data processing capabilities and speeds needed to mimic the timing of human reflexes.

According to Dr. Joy Laskar, CTO of Maja Systems, future autonomous cars will generate nearly 2 petabits of data, which is equivalent of 2 million gigabits. "With an advanced Wi-Fi connection, it will take 230 days to transfer a

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Communication technology like V2V and V2X will provide car connection to 5G networks. *(Credit: Qualcomm)*

week-worth of data from a self-driving car, and that is why we need much faster ASIC processing technology and products," Laskar said.

The world's leading semiconductor companies, such as Intel and Qualcomm, are advancing toward an ASICs revolution, combining large available bandwidth at 5G frequencies with new innovative digital radio and antenna architectures. Simply put, these companies are creating chips to turn autonomous vehicles into mobile data centers, allowing driverless cars to make real-time, complex decisions.

Market watchers say that 5G, when adopted at the full scale, will offer internet speeds up to 100 times faster than 4G. It will present exciting possibilities for the automobile industry used for vehicle-to-vehicle (V2V) and vehicle-to-everything (V2X) connectivity. Furthermore, the technology's low latency will make these vehicles extraordinarily safe and reliable on the roads—safer than vehicles today that are operated by people.

EDGE COMPUTING POWERED BY 5G

Offering a range of advantages, edge computing is recognized by many experts as one of the latest significant enterprise trends. Edge computing refers to infrastructure that allows data processing as close to the source as possible, enabling faster processing of data, reduced latency, and overall better outcomes. When it comes to edge computing, there are many challenges in terms of network reliability.

With autonomous cars comes the responsibility of managing the infrastructure which processes massive amounts of unstructured data and privacy protection when collecting sensitive data at the edge. Edge computing will allow lightning-fast response time because of 5G's promise of lower latency and ability to offload computing tasks and better location awareness.

REMOTE PILOTS

Another key reason why 5G is crucial for autonomous cars is the inclusion of specific safety measures in the vehicle. For example, suppose a self-driving car fails to navigate due to a traffic jam caused by a road accident.

The autopilot feature might hand the reins over to the driver. However, it would not be possible in case of an elderly or a disabled rider. For this reason, many tech companies have been testing remote pilots, who are trained drivers sitting miles away in a simulator that can take over instantly. However, to achieve it, a stable and fast connection offered by 5G would be crucial.

Additionally, 5G will provide passengers in self-driving cars with high-quality infotainment services. It will make the communications service provider an important partner for autonomous cars, whether for data analytics, safety, or entertainment reasons.

Further opportunities for 5G technology to enhance self-driving car technology exist. These opportunities are yet to be explored by regular examination of the safety performance of autonomous vehicles.

If you are concerned about driverless cars on the road, think about the evolution of smartphone devices over the past few decades. At one point, you probably couldn't even imagine being able to make a call to someone on the other side of the world from a pocket-sized device. Today, you can't imagine a day without the ability to connect to friends, family, and colleagues around the world using your mobile phone.

Technology and network evolution bring incredible and useful advancements to society. 5G's promises to bring safer and smarter self-driving cars would be one of the most remarkable developments of our time. md

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CARLOS M. GONZALEZ | Content Director

Should VR Headsets Be Considered Medical Devices?

Virtual reality is changing the digital industry by creating immersive and interactive environments. As VR makes headway into the medical space, the question becomes: Are VR headsets a medical device or just an entertainment hardware?

Virtual reality, or VR, is about to be everywhere. It's the kind of invention science-fiction fans and technologists have been clamoring about for decades.

VR undoubtedly provides a wide variety of opportunities for escaping from boring old reality—but can it improve lives in a meaningful way? Could that impact ever become meaningful enough to qualify VR headsets as medical devices?

Makers of virtual reality hardware and software want to make their mark on medical innovation. Let's take a look at the present definition of a medical device, and whether current or future VR technology might qualify.

WHAT IS A MEDICAL DEVICE, LEGALLY SPEAKING?

Before we dive into the crux of this debate, it's useful to define the key

terms. The United States Food and Drug Administration (FDA) already provides a definition for the phrase "medical device":

A wide variety of products qualify as medical devices in the eyes of the FDA:

- Tongue depressors
- Bedpans
- Test kits and reagents
- Some radiation-emitting equipment
- Programmable pacemakers
- Surgical devices and lasers
- Ultrasound equipment
- Other medical devices containing microchips
- Diagnostic equipment for use in laboratories

What all these products have in common is that they are labeled and marketed for medical purposes. Under FDA regulations, these are products that may be used to prevent, detect, mitigate, or cure a known medical condition in humans or animals.

It also includes any device intended to influence the function or structure of a living body by any means other than chemical action. The European Union provides very similar directives and regulations for recognizing medical devices, as does the World Health Organization.

The intention here is to draw a solid boundary between devices and drugs. Most important to today's discussion is the fact that, under section 520(o) of these FDA regulations, software applications do not qualify as medical devices.

VR can benefit people suffering from some medical conditions. But should they be considered medical devices? *(Source: https://www.pexels.com/photo/man-wearing-black-vr-goggles-373905/)*

THE CASE FOR VR HEADSETS AS MEDICAL DEVICES

VR headsets are, of course, more than just software—and that makes their current place in the medical device landscape a little uncertain.

Nevertheless, VR technology has already demonstrated a considerable amount of potential in patient treatment, diagnoses, and physician training. There's clearly big money in this game already, too: an estimated $5 billion per year by 2023, according to research from Goldman Sachs. By 2025, the study says, electronic entertainment and healthcare will be the two most popular and valuable applications of VR, in that order.

What does the current landscape look like for VR in healthcare? So far, adoption among healthcare companies has been sluggish, and "killer apps" have been slow to materialize. Some of the companies singled out already as major players in this emerging markets are those with the billions required to research and develop the technology: names like Google, Oculus—owned by Facebook—and Microsoft.

With the above legal definitions of medical device in mind, what are the most compelling current applications for VR in healthcare? Here are several:

Physician training. Johns Hopkins, the University of Chicago and the University of Calgary are all early adopters of VR-based surgical training programs. In addition to providing safe and detailed environments in which to observe and take part in surgeries, the technology also provides the capability to fully immerse oneself in patient scans for a level of pre-surgery planning that wasn't possible before.

Improving patient vision. Generations of conventional wisdom said television ruins our eyes—but VR headsets might just be able to help patients improve their vision. A company called Vivid Vision, which already has partnerships with 88 clinics, offers VR-based treatments for lazy eye, crossed eyes, and other sight disorders. Patients sim-

VR is still a relatively new technology, which could make classifying it tricky. *(Source: https://www.pexels.com/photo/man-wearing-white-turtle-neck-t-shirt-1036645/)*

ply don their headset and play immersive games under supervision to correct the movement of their eyes.

Treatment for anxiety disorders. Mental health professionals see a lot of potential in VR programs from Psious and similar companies. The idea involves creating relaxing virtual spaces and deliberate, meditative, relaxation-focused exercises for patients to learn mindfulness and achieve better control over intrusive thoughts.

Physical therapy and patient rehab. VRHealth is a worldwide VR company with a presence in Boston and Israel. Its mission is to improve the effectiveness of current treatment models in physical therapy, pain management, problems with coordination, and even cognitive rehabilitation. The company has a presence in 30 healthcare locations in the United States. One of the advantages is that doctors can evaluate patients remotely, from the comfort of home.

Anxiety, panic disorders, and elder care. A VR program called jDome BikeAround seeks to help elderly individuals recover their motivation and confidence while navigating the outside world. While riding a virtual bike along virtual streets—lovingly rendered by Google Maps—elderly patients can rediscover places they used to visit and practice other forms of mindfulness and cardiac training.

Each of these is a real-world demonstration of the power of virtual reality in healthcare. The signs seem to point decisively to VR having real staying power and relevance in the lives of patients of all ages and conditions.

Do these products qualify as medical devices, though? Is there anything holding VR back from staking a lasting claim in the healthcare landscape?

THE CASE FOR CAUTIOUS OPTIMISM

The first reason to advise caution—at least for now—is a two-pronged problem: a lack of quality content and a hesitation among healthcare system decision-makers to invest in the required hardware. In a survey, more than half of the respondents cited a lack of compelling, high-quality experiences as their reason for not bringing virtual reality into their healthcare systems.

Those are the first two hang-ups. The third is the high price tag and the poor ergonomics of VR headsets. Products like HTC Vive, Oculus Rift, and Samsung Gear VR hold promise, but they need additional product iterations to achieve the immersive environment patients expect, and the comfort and ease-of-use ailing patients deserve.

Let's return to the original question: *Should VR headsets be considered medical devices?*

Having explored how several companies are already using this technology, or are planning to in the future, it's clear that the highest-profile VR projects in medicine today seem to qualify as medical devices under FDA and EU regulations and directives. These VR software applications, coupled with wearable hardware, provide fairly convincing tools for:

- Correcting muscular problems resulting in poor eyesight using VR-based games
- Evaluating a patient's cognitive and physical abilities
- Providing relief for a variety of mental health disorders
- Helping patients approach soundness of mind and body through rehabilitation

It's clear enough that if hardware makers continue finding ways to lower the price and raise the comfort of their headsets, and software makers keep furnishing evidence that their VR treatments deliver noticeable results in patients, VR in healthcare is here to stay.

There's just one last question: How do regulatory bodies like the FDA handle the approval process for cutting-edge treatment modalities like these? Will they, as is the mission of many prominent voices in healthcare, help bring down the cost of treatment in both developed and developing nations?

Products from VRHealth boast both FDA approval and certification under ISO standard 13485. Early VR applications in surgical training found

themselves subject to another ISO standard—ISO 13407—which covers human-centered design for interactive systems.

It was with the intention of facilitating safer innovation that the FDA recently outlined plans to modernize its approval process for new medical devices as well as iterations on existing ones.

The response from device makers has been mostly positive, with many expressing support for the longer approval and documentation process, as well as guidelines for more actively monitoring device performance in the real world vs. relying on complaints from patients.

VR technology in healthcare is fairly novel, but most of the pieces seem to be coming into place—including cautiously optimistic physician and patient interest as well as relevant and modernized guidelines from the FDA, ISO, and other consumer protection agencies. md

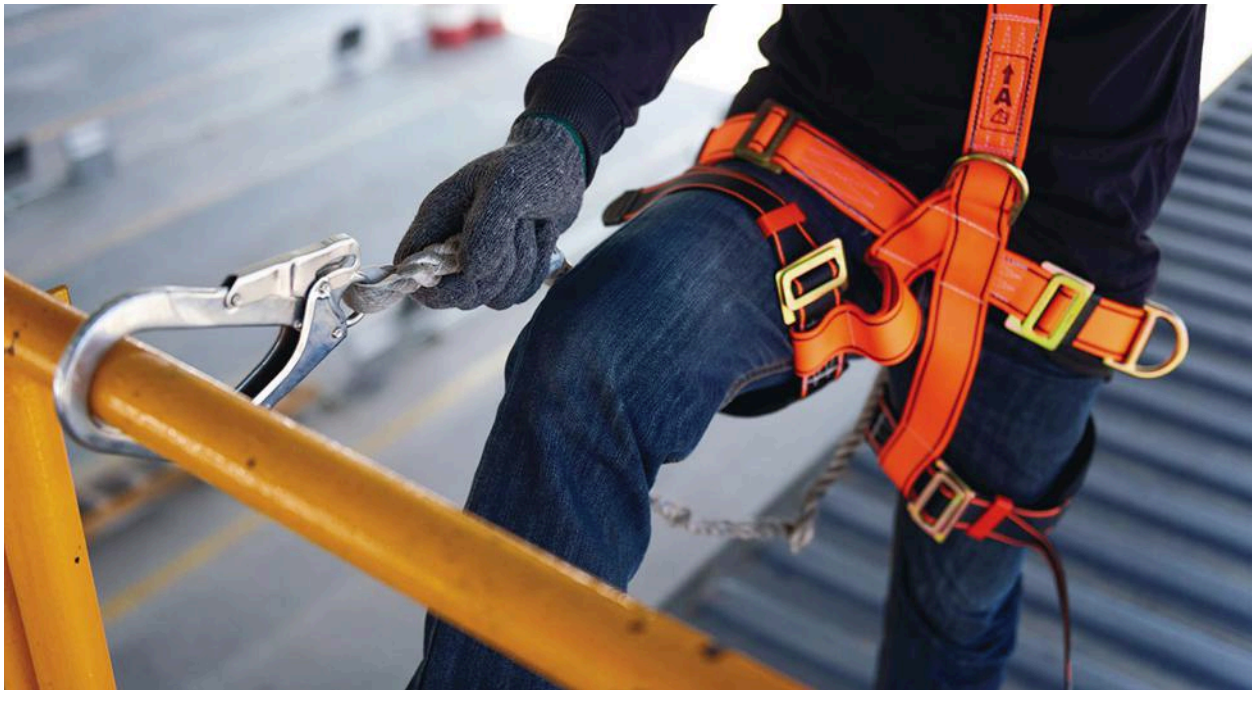
Treating anxiety, use in physical therapy, and elder care are just a few ways VR can apply to medicine. *(Source: https://www.pexels.com/photo/woman-using-black-vr-headset-1893417/)*

shirt-1036645/)

FREDRIC YUTZY | Senior Project Engineer, JLG Industries, Inc.

How to Keep WORKERS SAFE ON AWPs

Advanced detection systems can slow or even stop lifts and machines before endangering workers.



Refining how workers maneuver aerial work platforms (AWPs) around structures is something the access industry continuously works at. These innovations have resulted in more precise, proportional controls and the adoption of familiar and mature operator awareness systems.

Previously, the access industry saw the development of soft touch detection systems from several aerial work platform manufacturers that aid operators in reducing costly damages to structures on the jobsite. These systems use mechanical limit switches to stop machine functions once it has contacted a structure. The switches are activated by an oversized padded frame that is suspended underneath the work platform or poles above the work area with limit switch whiskers.

Following the advancement of sensors in the automotive industry, aerial work platform manufacturers are continuing to evolve an even better solution for contractors that will enhance the operator's awareness of their surroundings.

When mounted on an aerial work platform, advancing enhanced detection systems use progressive ultrasonic technology to detect the presence

of a nearby object. The system alerts operators to the object's presence with audible and visual warnings while simultaneously slowing, then stopping, the machine before it comes in contact with an object.

Many aerial work platforms work near sensitive structures that must not be damaged by contact with the platform. If damage were to occur, it would likely cause substantial and costly project delays. An enhanced detection system is perfect for use in specialized industrial applications where the maintenance of structures requires extra care, and sensitive materials must not contact any type of machine that could make even a slight dent or abrasion on them.

SELECTING THE BEST SENSOR

We have seen and experienced the rapid increased use of sensor technology across the automotive industry. While there are multiple sensor technologies available today, each comes with certain limitations. When developing an EDS for aerial work platforms, it is crucial to use sensor technology that will provide the best coverage of the desired area. There are several types of sensors that can be considered for enhanced detections systems, including:

- Ultrasonic sensors
- Radar
- Light-based radar sensors

Ultrasonic sensors function by producing a burst of sound waves in very rapid succession. When these sound waves then hit a target, the sound wave is reflected to the sensor. Because the sound wave travels at a known speed (the speed of sound), the travel time of the signal can be measured, and an operating system can calculate the distance between the sensor and the target.

Radar, by contrast, works not with sound waves but with electromagnetic waves; this is the main difference between the two sensors. Processing similarly to ultrasonic sensors, the waves emitted bounce off an object traveling at a known speed.

Based on the current state of sensor technology, ultrasonic sensors are the most ideal for aerial work platforms and have been widely adopted within the automotive industry for similar applications. In addition, the durability and familiarity of these systems also lend themselves to intuitive adoption on the jobsites. Light-based radar sensors provide a more 2D fan style

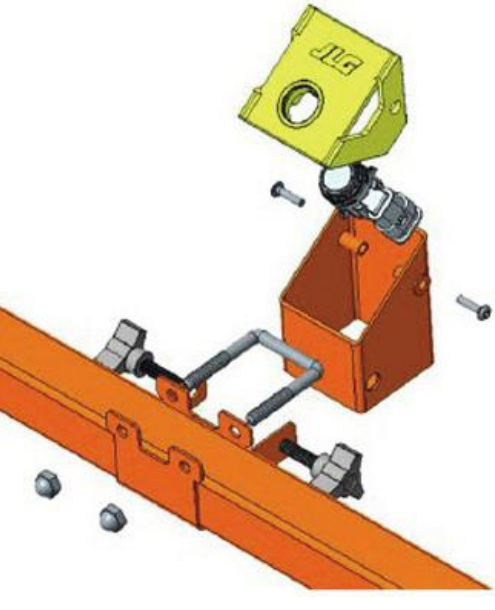
The JLG Enhanced Detection System (EDS) expands upon the JLG Soft Touch System, notifying of approaching obstructions and stopping functions before the machine makes contact.

sensing area where ultrasonic sensors offer a cone-shaped coverage area, creating a greater range of detection for a work platform, especially behind the operator.

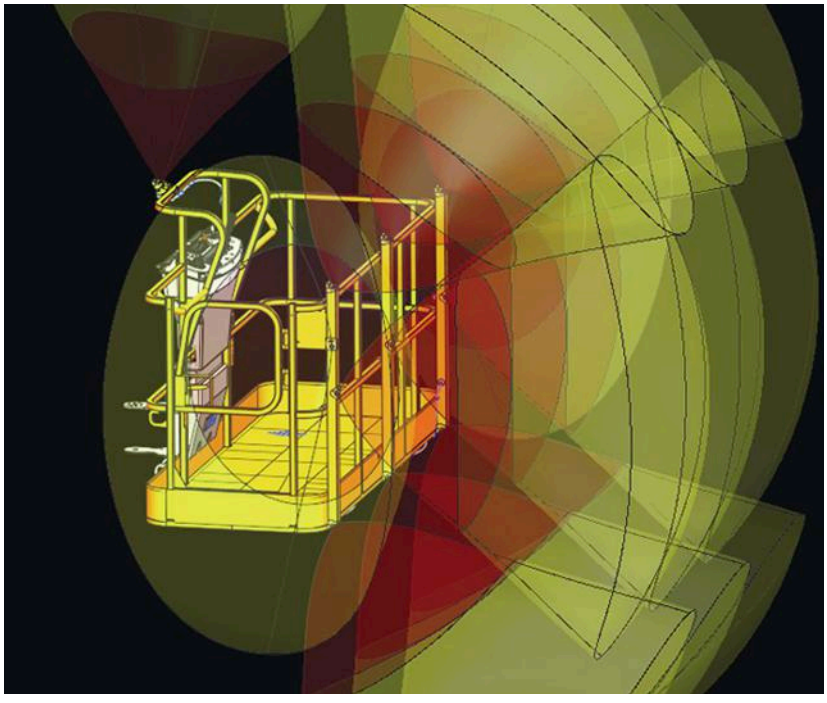
SENSOR PLACEMENT ON THE PLATFORM

Determining the best placement of sensors on the work platform is crucial to creating an effective enhanced detection system. Sensors need to provide coverage across the work platform without detecting the operator's movements and falsely slowing down and or stopping the machine functions. The work platform structure itself is another obstacle that needs to be kept out of the line of the sensors without taking away from the coverage. Effective placement and orientation of the sensors becomes extremely challenging. Accommodating existing fleets as well as new equipment only exacerbates this challenge of getting the technology integrated into today's jobsites.

The packaging of the sensors also plays a significant role in the placement of the sensors on the work platform. Sensors and retainers are affixed to structures with sometimes multiple sensors each depending on the level of coverage desired. Boom lifts offer a level one enhanced detection system which has eight sensors, or a higher-coverage level two system that has 12 sensors across the work platform. Scissor lifts also come with the option of two levels of coverage—level one with four sensors or level two with eight sensors. Designed with the need for multiple operators in mind, certain sensors can be adjusted based on each operator, creating the most efficient and effective coverage possible.



Sensors and retainers are affixed to the tubes, and knobs allow for sensor angle adjustment.



The yellow cone sections represent the warning zones while the red cone sections begin the stop zone.

ESTABLISHING WARNING ZONES

Some systems have a sensor detection area with warning and stop zones established. A system with this capability can give the operator visual and audible notifications of an approaching object and slow the machine's operation. Additional features may include the ability to minimize unwanted detections. Adaptive warning zones can change the size based on the machine's speed. For example, traveling at full speed the warning zone increases, whereas at only 50% speed, the warning zone is decreased.

The aerial work platform is automatically placed in creep mode as the operator enters the warning zone. This function helps the operator to recognize and avoid possible hazards before coming close to them. Once enacted, the warning zone is not latched, meaning that the control system allows for return to normal boom function speed

Some systems have a sensor detection area, warning, and stop zones established. A system with this capability can give the operator visual and audible notifications of an approaching object and slow the machine's operation. Additional features may include the ability to minimize unwanted detections.

without operator intervention as soon as sensors report the aerial work platform is safely out of the warning zone. Once the object enters the stop zone, operation is stopped. The operator is free to move away from the object after cycling the footswitch. However, if the operator intends to move closer to the object, they must activate the override function.

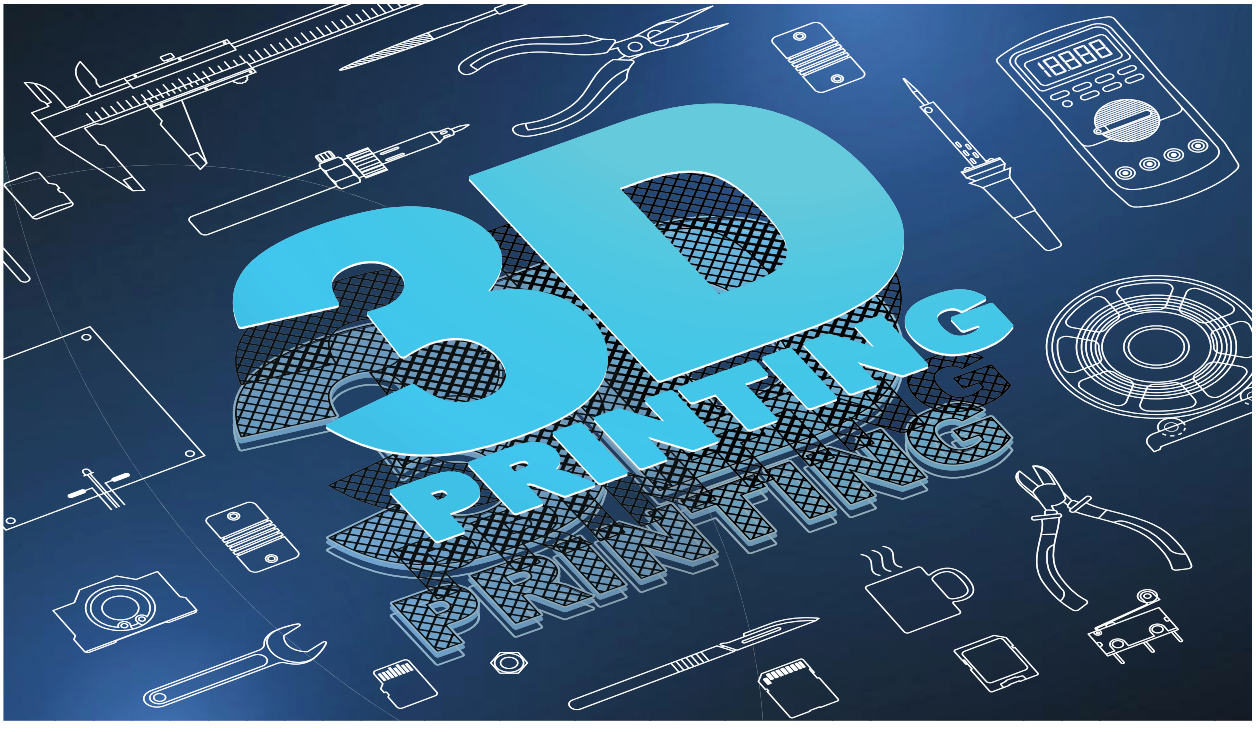
ENHANCED DETECTION SYSTEM

Following the automotive industry's expanding adoption of sensor-based systems for operator awareness, machine control, and autonomy, the demand for similar enhanced detection systems on aerial work platforms is growing. With the introduction of enhanced detection systems in the access industry, operators will have increased confidence maneuvering boom and scissor lifts on the job.

This technology will advance. For example, there will be an optional JLG Enhanced Detection System expected to be available for purchase with two levels of coverage on select model boom and scissor lifts by mid-2019. Thereafter this technology will be phased into production on booms and scissors. md

FREDRIC YUTZY is a senior project engineer with JLG Industries. In this role, he is responsible for leading a team focused on delivering innovative solutions for use on existing JLG product lines. His team focuses on developing new options and accessories to enhance the operator's experience and confidence while working or handling material at height. Fredric has been with JLG Industries for over 4 years and has over 14 years of new product design experience.

JEFF KERNS | Technology Editor



3D Printing

Trends in Manufacturing, Part 1

A third of the way through 2019, we take a look at what advances are still to come for the process.

I talked a lot about 3D printing in 2018, and this year the process will continue to grow. Some companies say the technology is at a tipping point of mass adoption, while other continue to take incremental steps towards disruption. This article will look at some of what we can expect moving forward.

THE 3D PRINTING MARKET

It's hard to compare predictions. Many predictions have different timeframes, focus on a specific part of 3D printing, or break up the technology into industries. These differences can make it hard to compare trends. Below are only a few comments on the 3D printing market that are available.

- According to SmarTech Publishing's 3D printing market outlook and summary report, the 3D printing industry grew 24% in 2018 for a total market of $9.3 billion. In addition, in 2018 the polymer 3D printing segment was growing to an estimated $5.5 billion.

- As reported by Forbes, "The eponymous "Wohlers Report 2018"… reveals significant increases in metal additive manufacturing (AM) this year. Investors will appreciate the solid 21% growth as the AM industry exceeds $7.3 billion."
- MarketsandMarkets.com says the overall 3D printing market is expected to reach $34.8 billion by 2024, from $9.9 billion in 2018, and will grow at a CAGR of 23.25% from 2018 to 2024.
- The market for 3D printing technology and materials in aerospace is expected to increase to $531.1 million by 2024, according to Frost & Sullivan.

These statements do not cover everything. There are still many opportunities companies are not taking advantage, or full advantage of in 3D printing. For example, "The opportunity for additive manufacturing in repair applications is often overlooked, but when you consider that corrosion and wear cost the U.S. economy $300 billion per year, and that the global commercial aviation industry spends almost $100 billion annually on repair, you can get a better sense of the magnitude of these markets," said David Ramahi, president and CEO of Optomec.

These are obviously a lot of numbers, and the potential to disrupt traditional processes is large with 3D printing. Currently, aerospace and the automotive industries are helping to drive these numbers, but medical is also finding new ways to use 3D printing. Moving forward it will be not only new technology and materials that drive the 3D printing market, but also standardization and the digital thread.

STANDARDS AND INSPECTION

Aerospace, automotive, and medical are highly regulated industries. For 3D printing to really take off in these areas, in addition to others, engineers need a way to verify quality. A complete digital thread of everything from feedstock materials, equipment, and process parameters per parts to delivery might be necessary to ensure parts meet standards and regulations.

Obtaining repeatable results can be difficult. An entire industry will have various powder providers and building parts with different machines, all which can yield different results. In fact, even if you have the same powder and machine you could still see different results. For example, selective laser sintering (SLM) has shown even with the same batch of powder and the same machine, it is possible to tune Al-12Si yield strength between 235 and 290 MPa, ultimate strength between 220 and 460 MPa, and ductility between 2.8% and 9.5% in tension.

Ford and Carbon have teamed up to use 3D printing to produce finished parts. This is an exciting step forward and will help to digitize Ford's production line.

To advance 3D printing it would be difficult to inspect and verify everything. For scalability in-line or automated processes will have to be used. This will lead to more inspection equipment in the 3D printing industry. 3D scanners, reverse-engineering software, CT scans, and a full digital thread will carry a lot of value to standardize the process while not slowing it down.

CT scans are proving to be a good way to inspect plastic parts, and it could potentially be worked into the production line. Partner CT technology with vision inspection software, and it could be automated. Unfortunately, metals can present difficulty.

Sigma Labs is working on this and now offers a vision process that works to do more than just complete a digital thread for part certification. PrintRite3D INSPECT in-line process quality monitoring and control is able to determine if any parameters have skewed too far from the standard and stop production.

Stopping the process when errors have been detected is important. Speed is one of 3D printing's limitations, and metal powder isn't cheap. If a part fails

Ford and Carbon have teamed up to use 3D printing to produce finished parts. This is an exciting step forward and will help to digitize Ford's production line.

Speeding up the process while reducing cost is grabbing headlines and will continue to do so as we move further into 2019. While plastic printing can offer multiple cost-effective options, Metal 3D printing has taken more time to find a way to reduce the barrier to entry.

early into the print, you might not know until much later in production. Image if a part has a failure on the second layer but is hundreds or thousands of layers until completion. Monitoring the process and stopping it could save days of wasted machine time in addition to material.

MATERIALS

Speeding up the process while reducing cost is grabbing headlines and will continue to do so as we move further into 2019. While plastic printing can offer multiple cost-effective options, Metal 3D printing has taken more time to find a way to reduce the barrier to entry. Printers like HP Metal Jet and Desktop Metal look like they might change the way we think about metal printing, but there are limitations. Binder jet-made parts are not be as strong as parts made in other processes. But there are many low and non-load-bearing parts to be optimized, and so the binder jet process has gotten attention in the industry. As engineers become more comfortable with 3D printing, we might continue to find more solutions with this process.

Not all disruption is in metal. I'm excited to see what happens with 3D printing and carbon fiber this year. Markforged claim to be the first and only carbon fiber process in town, but last year Stratasys released a carbon fiber focused printer. As complex, lightweight, strong parts are able to be printed faster and stronger, the intensive manual labor process might be finding a way to automate.

Stratasys launched the Fortus 380, carbon fiber edition. With aerospace and automation leading much of the 3D printing market expansion, weight and strength are important, and being able to reduce the cost of carbon fiber parts would be a great step toward disrupting traditional carbon fiber industry.

Arevo, a carbon fiber 3D printer, is focusing on software to optimize the carbon fiber printing process. By looking at the process from the software point of view, the fiber is laid in the best direction to increase a parts strength based on how the part is used. This new printer has a continuous carbon fiber wetted into the filament, which needs to be cut between layers, but the software also reduces the cutting of the fiber to only when it is necessary. According to Avero, random fiber can improve strength, but controlling fiber orientation could make a part five times the strength of titanium at one third the weight.

New materials are providing OEMs with stronger or more flexible polymers, and companies are experimenting. As I toured and talked with many companies in 2018, I noticed many of them have purchased some type of plastic printer. While this can provide value, some large companies have invested heavily into 3D printing processes.

TECHNOLOGIES

Materials are helping to progress 3D printing, but there are some new technologies that I think will provide more than just an incremental jump forward for the process. While the continuous

Longer fibers means stronger material. The fibers help spread a load over an area. A continuous fiber orientated in the direction a load is expected can help increase the final part's strength.

liquid interface production (CLIP) was developed years ago, it is seeing success in the automotive industry. I will cover this more in part 2, but this type of technology is going to move 3D printing forward, and it looks like the liquid polymer vat curing processes might be adding more innovation to its arsenal.

Many years ago, I saw my first 3D picture made in a clear polymer that looked like crystal. This novelty was made in minutes on location—which was a small kiosk that couldn't have had many resources other than maybe a 110 V outlet. A single laser would pass through the polymer, but when intersected with a second layer the energy at the intersection would create a small bubble. After the process repeated many times, a 3D image would emerge in the polymer.

When I first heard of 3D printing, specifically stereolithography (SLA), I wondered if it would be possible to use the same technology in 3D pictures to speed up the 3D printing process and eliminate post-processing. 3D printing is a three-dimensional process, yet we are still building stacks of two-dimension layers. Two technologies might change how we view this in 2019.

The multi laser volume stereolithography (MLVS) and computed axial

lithography (CAL) methods represent a true 3D building process. MLVS could be simply described the same way the 3D picture is, but instead of a hard polymer forming a bubble, it is a liquid polymer being solidified. CAL is also a liquid vat polymer process, but might be considered more of an evolution of digital light projection (DLP).

DLP project the entire cross-section into the polymer at once. Often the light source isn't strong enough to use higher strength polymers, but by projecting the entire cross-section at once rather than tracking it with a laser, it can operate faster. The CAL process uses two-dimensional images like DLP but from different angles. This means it is possible to solidify large sections, or the entire part at once in a few seconds where the light/energy sources overlap. Using superposition exposures from multiple angles the material is exposed to enough energy to solidify into the desired geometry. The CAL technique also lets parts be overmolded. Faster production with the ability to overmold inserts, threads, etc. into parts are why I think this process will receive more attention in 2019. The core concept was inspired by Computed Tomography.

Both MLVS and CAL are said to increase speeds and eliminate problems with stepping and support structures that increase post-processing times and waste material. These processes might not be adopted in 2019, but at the speed technology moves today, it might not be long until they are causing more disruption.

In our next installment, I'll cover how Stratasys is pushing for carbon fiber tooling, Ford and Carbon's work on the F-150 Raptor Auxiliary Plugs, how Ultimaker's is moving farther into industrial printing, and how Optomec acquiring Huffman will accel the company into the repair and aftermarket markets. md

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KAYLA MATTHEWS | Contributor

4 Things Hospitals Look for When Adopting New Medical Devices

When adopting new medical devices into a health facility, its important to remember how that device will integrate with your current medical setup. Ease of use, security, and overall cost are important factors to remember when assessing new medical devices and equipment.

Hospitals are full of devices that assist with making diagnoses, easing symptoms, tracking patient characteristics, and more, and outsiders may think there's a straightforward process for bringing those products into the facilities.

The truth is that hospitals want the items to have certain characteristics before they agree that the devices are worthwhile enough to adopt. Here are four of those qualities.

EASE OF USE

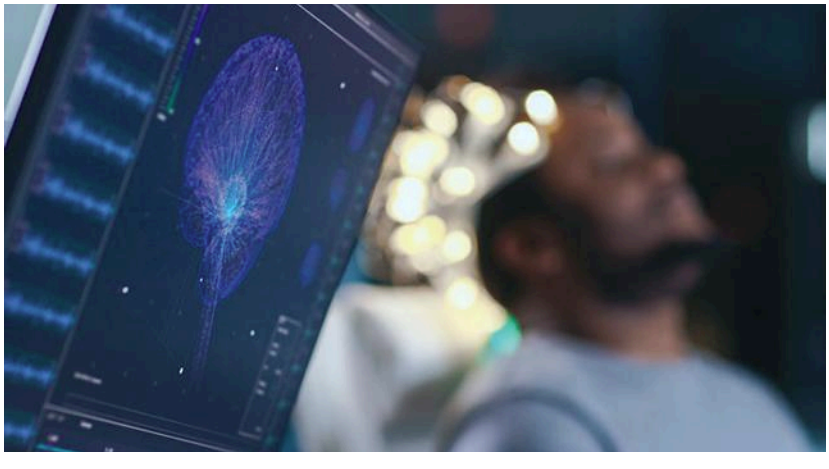
Technology should ideally make things easier for patients and providers. As such, hospitals want new medical devices that are user-friendly. One study found that electronic health records (EHR) and computerized physician order entry (CPOE) applications put physicians at a higher risk for professional burnout than those who didn't use them.

So why are doctors feeling fed up by uses of technology in the workplace? In the case of medical devices, they'll either need to use the devices themselves or teach patients how to do it. Obviously, when providers see for themselves that the devices can be used without hassle, it paves a smoother path toward their adoption.

PROTECTION AGAINST CYBERATTACKS

The Food and Drug Administration (FDA) is the body responsible for approving medical devices in the United States. A medical device receives one of several classifications. For example, a device manufacturer submits a particular application if there are other devices already on the market that are substantially similar to the new gadget.

Numerous reports warn that health care is among the industries most vulnerable to cyberattacks. If a medical device has characteristics that could make cyberattacks especially likely to happen, the chances go up that hospitals will pass on adopting it. Hacking can prove fatal to individual patients, especially when devices such as those that administer medication or regulate the heartbeat are tampered with.



Patient hooked up to a brain scanning device. *(Source: Paid for via iStock)*

It's not surprising that the FDA may soon require device manufacturers to submit a "Software Bill of Materials" with their device applications. That document would show potential or known vulnerabilities associated with the device components, helping hospitals and patients get more informed before deciding on a particular device.

One survey found that 83% of doctors experienced cyberattacks in their practices. Moreover, nearly three-quarters of the respondents dealt with disruptions from those incidents. Physicians are becoming increasingly familiar with the damage cyberattacks cause, and they'd likely want to avoid more issues when adopting new devices at hospitals.

ABILITY TO SOLVE KNOWN PROBLEMS OR IMPROVE PATIENT CARE

Selecting a new medical device requires time, money, and other resources. That's why medical device salespeople have difficulty convincing hospitals to adopt their products if those customers don't believe the device solves a problem. Some sales pitches focus too much on a device's flashy features but don't emphasize that it can do things to help a hospital overcome obstacles.

A medical device could also become exceptionally attractive to a hospital if it performs a function in a way that's superior to the current method. In one example, an Israeli startup made a wound treatment device called SpinCare. It applies a temporary and transparent layer of ultra-thin fibers that mimic skin. Device users can cover skin without touching the affected area, which can reduce pain. Also, it's possible for doctors to monitor wound healing without continually re-dressing the injured area. After the wound heals, the layer peels off.

If hospitals receive real-world examples of how a medical device helps patients or providers, they should be more interested in it. Otherwise, they could quickly assume that even a high-tech gadget isn't worth the required investment for adoption.

SUITABILITY FOR THE HOSPITAL'S BUDGET

Hospitals invariably make decisions about adopting new medical devices after figuring out whether the cost aligns with the facility's budget. Hospitals may be more willing to pay a premium for devices that deliver value concerning efficacy, efficiency, or usability. But providers don't typically have the authority to make purchasing decisions without appealing to administrative superiors.

Research shows that although the majority of hospital executives understand the importance of digital inno-

vation, three budgetary barriers can stop or slow innovation in hospitals. Overcoming them requires convincing decision-makers that a device fits into the budget—and better yet, that the hospital cannot afford to go without it.

The implementation phase that comes before adoption often sets the tone for how the financial authorities feel about a device. If a short-term trial proved exceptionally costly and caused frustrations for patients and providers, a hospital probably wouldn't move into the adoption phase because of the lack of evidence supporting that choice as a smart decision.

UNDERSTANDING VARIOUS PRIORITIES COULD INCREASE ADOPTION RATES

As medical device manufacturers and their marketing teams assess how to appeal to clients, they must remember that each group at a hospital has different priorities, although there are some consistent ones between them.

From the business side of things, hospitals want devices that keep costs down and increase patient satisfaction. Providers, on the other hand, would probably be more interested in devices that improve their workflow or boost patient outcomes.

If device manufacturers take time to understand the differences between hospital groups and tailor their pitches accordingly, they may have higher-than-average rates of adoption at targeted facilities. mc

Medical professional taking care of a person with a broken leg. *(Source: Rawpixel)*

ANDREW GILLINGS | Taylor Studwelding Ltd.

Stud Welding: The Basics and Benefits

Why this fastening technique should be your welding method of choice.

Whether you are a qualified engineer or a manufacturer, you most likely use welding on a regular basis when carrying out metalwork. Just to clarify, welding is a heating process that uses an electric arc to join two metal parts together. A common process, yes—but by no means a simple one. There is a wide range of methods, materials, and tools that can be used. With regard to the methods, the ones used should be firmly rooted in the type of application at hand, your specific requirements and abilities, the equipment available, and the budget.

And that brings us to stud welding, one of the more popular welding methods based on its speed, accuracy, reliability, and visually appealing aesthetics.

Here's everything design engineers need to know about stud welding, including the three different processes,

the benefits of each, and the tools and equipment involved in the process.

WHAT IS STUD WELDING?

Essentially, stud welding is a single-side fastening method that joins a metal part to another metal component, usually a metal sheet known as the parent material. Parts are fused together using a strong arc of electricity created by a positive electric current. The arc generates enough heat for both metals to reach their melting points. Once a molten pool forms, the part and parent material are pressed together to form a secure joining and become one.

Stud welding is popular partly because of how quickly it can be carried out. With the right equipment, workers can turn out a stud weld in milliseconds. The speed, however, does not affect the strength and reliability of resulting joints. They are actually stronger than the parent material itself once formed and will last a lifetime.

Here are some of stud welding's benefits:

Appearance. Stud welding is favored for the largely "invisible" effect it creates due to the fastening process only being carried out on one side of the parent material. It leaves minimal marks on the reverse side. Therefore, it is the recommended welding method if the goals are fastening that is easy on the eye but still highly secure.

Adaptable. Stud welding can be used with a variety of metals and stud sizes. Stainless steel, mild steel, aluminum, copper, and brass can be effectively stud welded if the proper equipment is used. The studs can be threaded, unthreaded, or internally threaded, and range in diameter from 1 to 25 mm, if you have the correct attachments and equipment to go with them.

Accessible. With stud welding, workers do not have to contort themselves to make an effective weld. They only need access to a single side. And there is also equipment to make maneuvering even easier. For example, thinner welding tools let welders work in hard-to-reach areas.

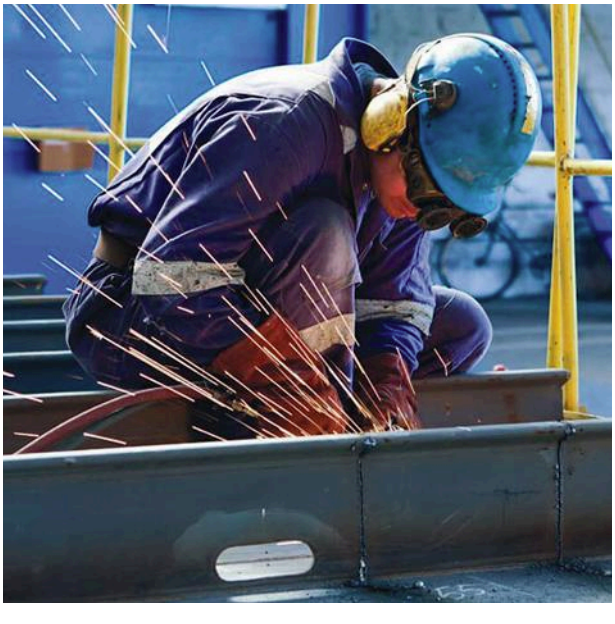
No holes. No holes are made in the metal sheet when the stud is fused to it, so there is no need to clean or finish the metal sheet after the process. The risk of there being any leaking or weakening of the sheet is therefore eliminated. No leaking also prevents the weld from corroding, so it remains clean and durable.

Speed. Stud welding is an extremely quick fastening technique. To use stud welding on a large scale, users can speed up the process by investing in heavier-duty equipment. There are stud welding machines, for example, that can create up to eight stud welds per minute. The process can also be completely or partially automated to create up to 60 stud welds per minute.

Automation can be applied to the entire process or just portions of it. You may require the whole process be automated or only a certain stage depending on requirements for accuracy, speed, and appearance. Companies can produce similar results using smaller-scale equipment and hand tools, so don't be put off by assuming you need a significant budget.

TYPES OF STUD WELDING

There are three major types of stud welding which are equally as effective. Deciding which to use depends on weld requirements and materials.



Stud welding only requires worker access to one side of the joint, making the job a simple one-person task.

To increase throughput, plants can invest in automated stud welders that make up to 60 welds per minute.

Capacitor Discharge (CD) welding is a common stud welding process recommended for instances where weld joints must be practically flawless and reverse marking needs to be kept to an absolute minimum for appearance's sake. It is highly effective on clean and flat parent materials such as mild steel, stainless steel, and aluminum.

CD welding works with materials at least 0.7 mm thick, so it the best option for thin parent materials. CD is more restrictive than the other processes in terms of the diameter of the stud that can be welded. Smaller-diameter studs (≥ 1 mm) are required for effective and reliable welds.

CD is not as versatile as the other types of stud welding. Therefore, if your parent material is dirty, coated, or bent, the better choice might be Drawn Arc (DA) welding.

Despite CD welding not being as tolerant to imperfections on parent material as other welding types, it is inexpensive and fast (hence its popularity).

CD welding involves capacitors set to certain pre-set voltages depending on the stud diameter and parent thickness. The stud is placed so that the weld pip, a small bit of metal on the bottom of CD studs, touches the parent materials. That way, an electrical current discharged through the metal sheet and stud heats both to their melting points and forms a molten pool. A spring in the welding gun then pushes the stud into the melted surface area of the parent material to fuse the two parts together.

COMPARING STUD WELDING METHODS

Stud Welding Type	Stud diameter	Material thickness	Power source
Capacitor Discharge (CD)	1 mm /M10	≥ 7mm	Single phase, 240/110 V
Drawn Arc (DA)	3 to 30 mm	≥ 2 mm	3-phase, 415 V
Short Cycle (SC)	M3 to M8	≥ 1.5m	3-phase / 415 V

To make long-lasting stud welds, the CD equipment needed is lightweight, easy-to-use, and will not take up much space.

There are several factors to keep in mind when choosing CD gear, including how light the welder is, how hard is it to use, the recharge time for the equipment, the welding speed, and its flexibility. Different factors may be more of a priority when choosing CD equipment depending on the anticipated tasks.

Drawn Arc (DA) welding is far more versatile and adaptable in terms of the materials and diameters that can be welded. For example, if you are working with a thicker parent material (> 2 mm) and it is rusted or coated, DA is the stud welding method that works effectively and accurately with thicker or less-pristine metals.

Similarly, if requirements involve a stud weld of a larger diameter, this is most likely the one that should be used.

For DA welding, the current and weld times are pre-set according to the diameters being welded. Placing the stud onto a plate or metal sheet triggers a pilot arc of electricity. The stud is lifted to a pre-set height to create the main arc which causes the stud's pointed weld end to melt into a molten pool. Return pressure on the weld gun pushes the stud into the pool to fuse the stud and metal sheet together. A ferrule holds the stud in place and shapes the weld, but is chipped away once the weld is complete.

There is a range of welding machines and products to choose from for DA welding, including some that handle studs larger than 25 mm in diameter or larger. The proper equipment for any application depends on how accessible and maneuverable the welder must be, the current needed, the base stud diameter, and the required welding rate.

Short cycle welding (SC) is practically the same as DA but even faster. Studs can be welded to a parent material in 10 to 100 milliseconds.

SC welding uses a combination of the CD and DA processes, so it can be used with thicker and more imperfect materials than CD, but not as thick materials and studs as DA can tolerate. SC welding may be suitable for those with smaller budgets, as the equipment and tools are less expensive than those used for DA.

The SC process, like DA, requires a weld time and current to be pre-set according to the stud diameter. Similar to CD, the studs have a weld pip, which is placed on the parent material, causing a pilot arc of electricity. Once the stud is lifted to the pre-set height, a main arc melts the surface of the metal sheet and weld pip to create a molten pool.

As with the other processes, return pressure pushes the stud and sheet together to form the secure fastening.

STUD WELDING IN ACTION

Stud welding as a metalwork technique is suitable across a range of different industries and for a variety of different tasks. Outlining some of these uses will highlight stud welding's versatility and effectiveness.

Bridges. Stud welds are used to fuse expansion joints between bridges and roads based on their reliability and operational life. They help ensure the bridge does not buckle due to changes in weather or temperature.

Nameplates. Those official-looking brass plaques used on and inside buildings to state the company or individual with offices inside are often fastened to the walls using stud welds. They are used because the weld and fasteners are not visible from the front (single-side fasteners), resulting in a clean and professional appearance.

Catering. Stud welding is commonly used in catering and food-preparation settings because it does not require holes be made in the parent material, so leaks are virtually eliminated. It also makes for a clean weld and easily cleaned surfaces.

Vehicles. Stud welds are used to assemble many vehicles—everything from planes to trains to automobiles. Again, it is a single-side fastener and strong, so the joint is extremely secure and practically invisible to the eye.

Stud welding clearly has a range of benefits and functions. However, it is important to use high-quality equipment from a reputable source to ensure stud welding is efficient and the results are reliable. md

ANDREW GILLINGS is director of Taylor Studwelding Systems Ltd. in the UK, a leading designer, manufacturer, and supplier of stud welding equipment. If you have questions regarding stud welding, contact the company at +44 (0) 1924 452 123 or via its website (www.taylor-studwelding.com).

There are several factors to keep in mind when choosing CD gear, including how light the welder is, how hard is it to use, the recharge time for the equipment, the welding speed, and its flexibility.

Hydropower 2019 Update

CARLOS M. GONZALEZ | Content Director

Can HYDROPOWER Deliver Enough Energy to Turn On the World?

Hydropower is one of the main sources of renewable energy worldwide. Countries are installing hydropower plants at an increasing rate not only to provide power to their people, but also to reduce their reliance on fossil fuels.

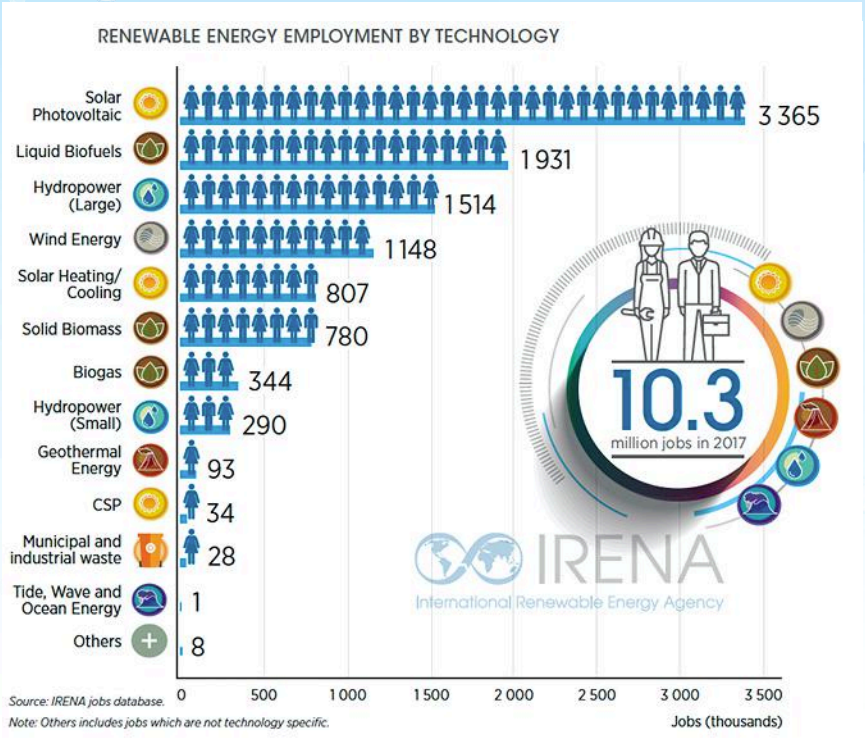
Hydropower is a renewable energy source derived from flowing water. Its history can be traced as far back as ancient Greece, where 2,000 years ago waterpower was used to operate wheels for grinding grain. Today, hydropower is one of the most cost-effective means of generating electricity. For example, in Norway, 99% of the country's electricity is generated from hydropower. The Gorges Dam in China is the world's largest hydropower plant at 22.5 gigawatts (GW), producing 80 to 100 terawatt-hours per year—enough energy to supply between 70 to 80 million households.

The basic principle of hydropower is using water to drive turbines. Hydropower plants are designed in two basic configurations: with or without dams and reservoirs. Hydropower dams with a large reservoir store water over short or long periods to ensure they can meet peak demand. Hydropower plants without dams and reservoirs produce at a smaller scale and typically operate in constant flow body of water such as a river.

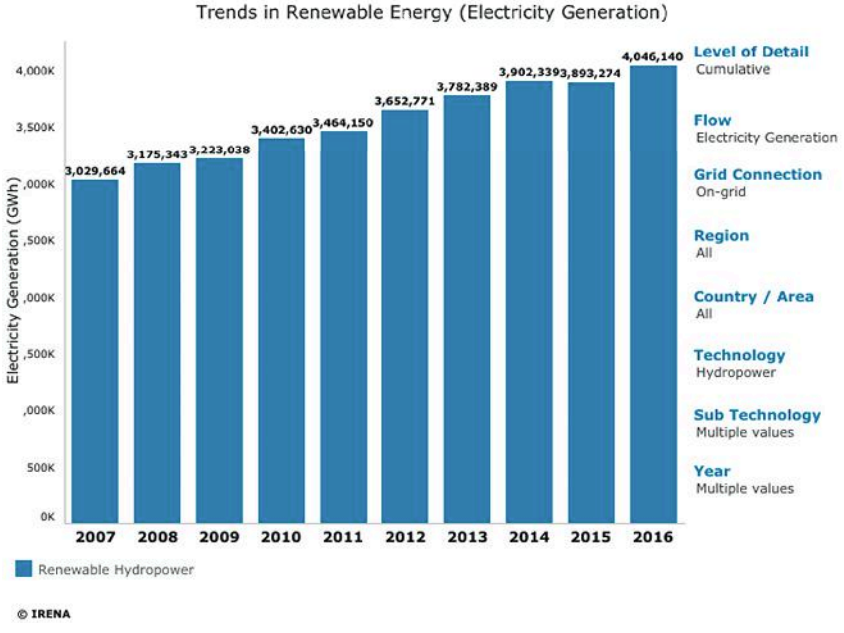
And hydropower, whether on a large or small scale, can make a big difference in the race to find suitable energy sources to replace fossil fuels.

THE ECONOMICS OF HYDROPOWER

Hydropower has the largest electricity generation capacity compared to other renewable energy sources. The International Renewable Energy Agency (IRENA) has collected extensive data on how different renewable energy sources have performed worldwide, the energy they output, the cost it takes to implement these technologies, and the employment opportunities per renewable energy source. According to IRENA, renewable hydropower is the largest contributor to electricity generation at almost 70%.



IRENA reports that 1.5 million people worked in the hydropower sector and another 290,000 in the small hydropower sector in 2017. *(Courtesy: IRENA)*



In 2016, IRENA reports the 4,000K GWh of electricity was generated by hydropower plants. *(Courtesy: IRENA)*

For on-grid hydropower plants, the generation of electricity exceeds 4,000K GWh. That number has been growing year after year, with more plants being developed across the globe. Asia has the largest capacity for hydropower according to IRENA's "Renewable Capacity Statistics 2017" at 515,666 megawatts (MW). Europe is second at 215,717 MW and North America is third at 196,075 MW.

IRENA's "Measurement and Estimation of Off-Grid Solar, Hydro, and Biogas Energy" report collected off-grid capacity and generation data for 2017. Off-grid is defined as plants that are not connected in any way to the main electricity grid of a country. In this report, hydropower dams like the Gorges Dam were not included. These are smaller sources of renewable energy that feed directly to the end-user.

According to the IRENA report, there are 38,664 hydropower plants across the world, totaling an installed capacity of 813 MW. 70% of the power is directed towards non-specified end-use, while the rest is divided among residential end-uses, agricultural use, and public or commercial use. Since 2010, 400 off-grid hydropower plants have been commissioned each year.

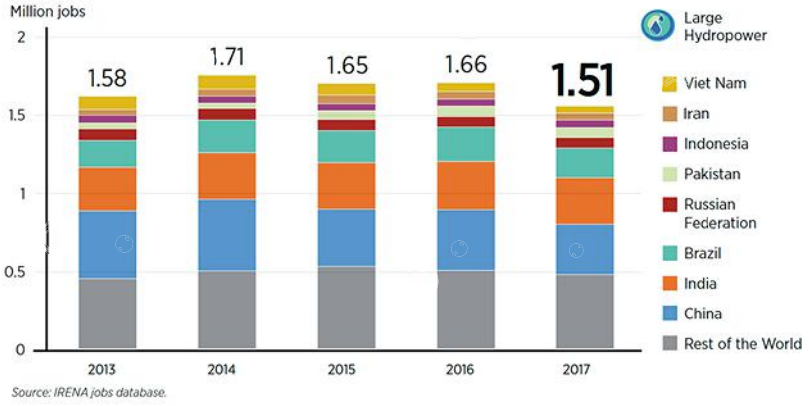
The job market for hydropower has also remained steady. Large hydropower employs 1.5 million people directly, a number which has been consistent since 2013. 63% work in either operation or maintenance across the large key markets of China, India, and Brazil. In small hydropower plants, 290,000 jobs were reported in 2017.

Investments into hydropower have started to rise. In 2010, the 2016 U.S. dollar investment averaged $1,171 per kilowatt (kW). As project sites started to develop in challenging areas, especially in untapped areas like Asia and South America, civil engineering, infrastructure, and logistics costs started to rise. By 2017, costs rose to $1,535 per kW. Some of the cost was offset by an increase in the weighted average project capacity factor, which decreased from 51% in 2016 to 48% in 2017.

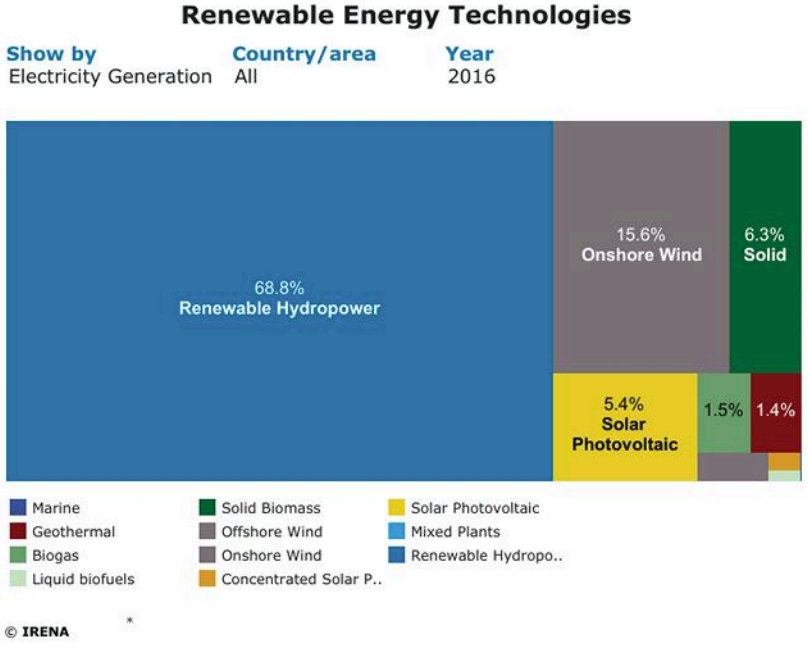
Hydropower remains one of the strongest and most competitive renewable energy sources. The global weighted average levelized cost of electricity increased from an average of $.04 per kWh to $.05 per kWh. In comparison, offshore wind costs $.14 per kWh and geothermal cost $.07 per kWh. Only solar photovoltaic energy had a better rate at $.1 per kWh.

TURBINE BASICS OF HYDROPOWER

In the world of hydropower plants, there are two main types of hydro turbines: impulse and reaction. The factors that go into deciding which turbine is chosen are the head—the height of standing water—and the flow or volume of water at the site. Other factors like how deep turbine must be set, efficiency, and cost determine which type of turbine is selected.



IRENA breaks down employment in hydropower worldwide with China, India, and Brazil leading the rest of the world. *(Courtesy: IRENA)*



In 2016, hydropower lead electricity generation at almost 70% compared to solar photovoltaic at 5.4% and onshore wind at 15.6%. *(Courtesy: IRENA)*

In the world of hydropower plants, there are two main types of hydro turbines: impulse and reaction. The factors that go into deciding which turbine is chosen are the head—the height of standing water—and the flow or volume of water at the site. Other factors like how deep turbine must be set, efficiency, and cost determine which type of turbine is selected.

Impulse Turbines

Impulse turbines use the velocity of the water to move the runner and discharge to atmospheric pressure. The water stream impacts each individual bucket on the runner, and there is no suction on the down side of the turbine as water flows out of the bottom of housing once it has it the runner. Impulse turbines are generally suited for high-head and low-flow applications. They can be broken up into two categories: Pelton and cross-flow turbines.

Pelton turbines. A Pelton turbine consists of a wheel that has one or more free jets of discharging water into an aerated space, impinging on buckets of a runner. Draft tubes are not needed for impulse turbines since the runner must be placed above the maximum tailwater to permit operation at atmospheric pressure. According to Renewables First, Pelton turbines are used for high heads of 25 meters or greater, and low flows of 0.01 m^3/s – 0.5 m^3/s.

Cross-flow turbines. A cross-flow turbine is drum-shaped with an elongated rectangular-section nozzle directed against curved vanes on a cylindrical shaped runner. It allows flow through the blades twice. The first pass is when water enters from the outside to the inside, and the second pass is from the inside to exit. A guide vane at the entrance directs the flow to a specific limited portion of the runner. The main application of cross-flow turbines is when you have a larger water flow and lower head requirements than the Pelton. Renewables First lists that for

Reaction turbines draw power by combining pressure and moving water. The runner is placed in the water stream, allowing it to flow over the blades rather than striking each individually. Reaction turbines are typically used in lower head and higher flow conditions. They can be categorized as follows: propeller, Francis, and Kinetic.

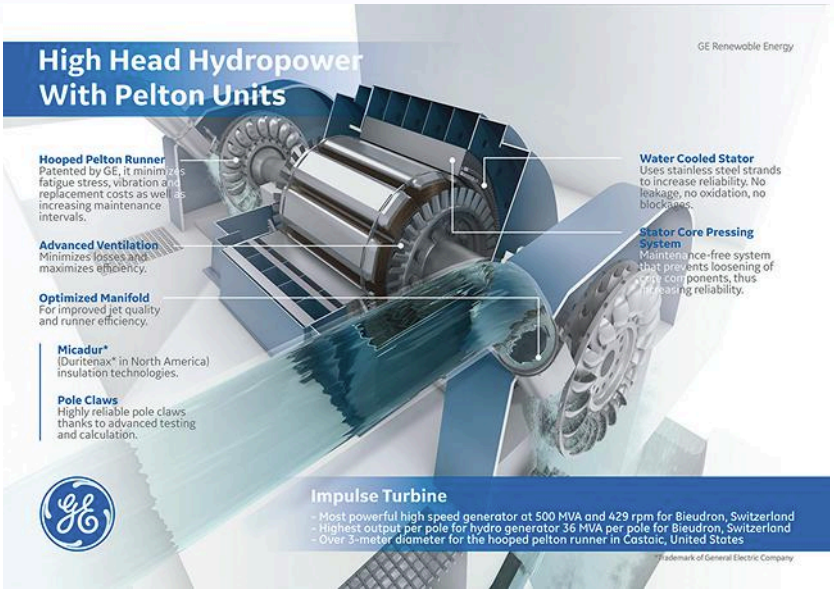
cross-flow turbines, the head should be low to medium from 2 to 40 meters, with low to medium flows of 0.1 to 5 m^3/s.

Reaction Turbines

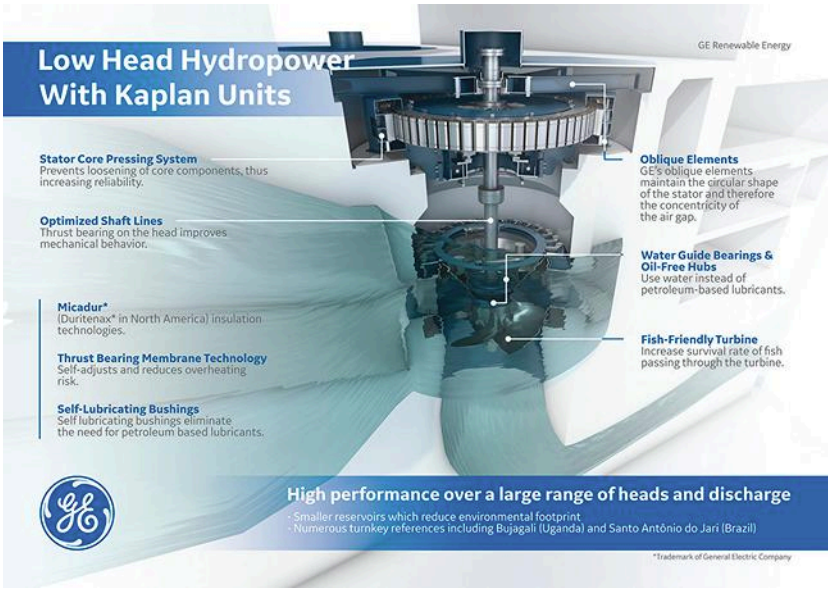
Reaction turbines draw power by combining pressure and moving water. The runner is placed in the water stream, allowing it to flow over the blades rather than striking each individually. Reaction turbines are typically used in lower head and higher flow conditions. They can be categorized as follows: propeller, Francis, and Kinetic.

Propeller. A propeller turbine generally has a runner with three to six blades. Water makes contact with each blade constantly. The pitch of the blade may be fixed or adjustable. The turbine's other components are a scroll case, wicket gates, and a draft tube. There are several types of propeller turbines.

- Bulb turbine: Turbine and generator are a sealed single unit placed in the water steam
- Straflo: Generator is attached directly to the perimeter of the turbine
- Tube turbine: The turbine's penstock bends prior to and after the runner, allowing for a straight-line connection to the generator
- Kaplan: The blades and the wicket gates are adjustable, which allow for a wider range of operation. According to Renewables First, Kaplan turbines are used for low to medium heads of 1.5 to 20 meters, and medium to high flows of 3 m^3/s to 30 m^3/s.



Pelton turbines are impulse turbines used for high heads of 25 meters or greater, and low flows of 0.01 m^3/s – 0.5 m^3/s. *(Courtesy: GE)*



Kaplan turbines are reaction turbines used for low to medium heads of 1.5 to 20 meters, and medium to high flows of 3 m^3/s to 30 m^3/s. *(Courtesy: GE)*

Francis. A Francis turbine has a runner with fixed vanes of nine or more. Water enters the turbine just above the runner and all around it and then falls through, causing the turbine to rotate. They no longer commonly used except in very large storage hydropower systems. For older turbines, Renewables First lists low to medium heads of 1.5 to 20 meters and medium flow rate of 0.5 to 4 m^3/s.

Kinetic. Free-flow turbines or kinetic turbines generate electricity from kinetic energy which is present in flowing water. This is different from other turbines that capitalize on the potential energy from the head. Kinetic turbines are found in rivers, man-made channels, tidal waters, or ocean currents. They do not facilitate the diversion of water through man-made channels, riverbeds, or pipes, but rather are located in such conduits. They also can be installed in existing structures such as bridges, tailraces, and channels.

HYDROPOWER PROJECTS WORLDWIDE

Several different agencies around the world are increasing their hydropower projects. In New Delhi, India, only hydropower projects up to a 25 MW capacity were considered renewable energy projects and were eligible for various incentives such as financial assistance and lines of credit. To boost hydropower generation, the Indian government expanded those benefits to projects above the 25 MW limit. This decision has added hydro capacities of about 45 GW to already 74 GW existing renewable energy sector of solar, wind, and small hydropower. India is aiming to reach 175 GW of renewable energy by 2022. The country is currently on track to reach 225 GW by 2022.

In Maine, the Maine Land Use Planning Commission held public hearings on hydropower company's proposal to rebuild the Middle Dam. Brookfield White Pine Hydro proposed

Free-flow turbines or kinetic turbines generate electricity from kinetic energy which is present in flowing water. This is different from other turbines that capitalize on the potential energy from the head.

Hydropower will continue to grow and drive the renewable energy sector. In comparison to other renewable energy sources, which are still developing their technologies to be more efficient like solar photovoltaics, hydropower technology is already fully developed and ready to deploy.

to rebuild and upgrade the dam which was constructed in the 1850s on Richardson Lake in Western Maine. The dam does not currently meet Federal Energy Regulatory Commission requirements, and rebuild efforts will take up to five years.

Maine is also holding public hearings on a proposed $1 billion hydropower transmission line to deliver Canadian hydropower to consumers in Massachusetts. Maine's Department of Environmental Protection will hold hearings in April to hear the public's concerns. Central Maine Power has proposed $258 million in incentives, including money for low-income consumers. Governor Janet Mills said the project will reduce Maine residents' reliance on fossil fuels.

According to *Hydroworld.com*, the growth of hydropower in Latin America will peak in the next decade. BNAmericas reported that average annual hydropower output growth in South and Central America will be almost 18 TWh between 2017 to 2030. BP Energy Outlook reports that only China will experience a faster energy generation growth from hydroelectric dams at 21.9 TWh annually. By 2030 the figure will drop to 7.3 TWh, but overall global hydropower output is projected to reach 1.3% by 2040.

Hydropower will continue to grow and drive the renewable energy sector. In comparison to other renewable energy sources, which are still developing their technologies to be more efficient like solar photovoltaics, hydropower technology is already fully developed and ready to deploy. Governments and organizations simply need to invest more into the allocation and installation of hydropower plants to power the world via water. md

Francis turbines are reaction turbines that are only commonly used in large storage hydropower plants. They are ideal for low to medium heads of 1.5 to 20 meters and medium flow rate of 0.5 to 4 m^3/s. *(Courtesy: GE)*

Kinetic turbines use the kinetic energy from a water flow to generate power. The hydropower variable speed pump shown above can operate at different water flows and install into existing structures. *(Courtesy: GE)*

CARLOS M. GONZALEZ | Content Director

11 Best STEM Toys from the 2019 International Toy Fair

Coding, robotics, and physics, oh my! The STEM toys on display at the 116th International Toy Fair are helping children to prepare for an engineering future with robots and the digital environment.

The 116th Toy Fair in New York City continued the theme from previous years of blending engineering and toys. This year, there was a visible uptick in the number of coding toys. The future of the digital world is focused on the Internet of Things, the cloud, and robotics. Teaching coding to future scientists and engineers is now more important than ever. The fundamentals of engineering are also being repackaged into fun activities. With that in mind, here are some of the best sights from the 2019 Toy Fair.

ROBOTIX STEM EDUCATION KITS AND ROBOTS

Robotix is a line of STEM education toys to help the next generation of inventors and creators to learn coding, robotic programming, and critical thinking. The red handheld device, Phiro, is a robotics platform for children ages 4 to 18. Phiro is built with a progression system so that as kids develop and hone their skills, the device grows with them. It can wirelessly code Scratch 2.0, Snap!, or Phiro Code. The device is also Lego- and Arduino-compatible; kids can add Lego pieces to the side of the device to perform actions such as wheels for motorized movement. Taco Playbits is the puzzle piece kit seen above next to Phiro. It is an interactive screen

free STEM for kids 3 and over to help teach coding by simply tapping on the chips with the Taco smart wand. It helps teach young children how to code through logic games, learning the alphabet, music, and math.

Phiros device and Taco Playbits from Robotix.

PAI BOTZ BLEND ROBOTS WITH AUGMENTED REALITY

Pai Botz is a toy company engaging young children in augmented reality (AR) STREAM experiences. Children can create their own robot or one of the six offered by Pai Botz. Once created, they can use a tablet to scan the robot into an AR environment. By using the tablet as the visual interface, the child can program the robot and guide the robot around AR mazes and obstacles.

DO-IT-YOURSELF SCIENCE KITS FROM THE YOUNG SCIENTISTS CLUB

The Young Scientists Club offers different science and engineering kits filled with fun facts, interactive toys like a human skeleton or a night vision flashlight, and notebooks to record observations. It released a line of Magic School Bus kits in 2011 to celebrates Ms. Frizzle's 25th anniversary.

Robots offered by Pai Botz.

Do-It-Yourself Science Kits from The Young Scientists Club

Wearable technology is poised to become the next disruptive technology wave. With devices like the Apple Watch expanding into the healthcare arena, it's only a matter of time before everyone has a computer on their wrist.

KURIO WATCH: NEW WEARABLE FOR KIDS

Wearable technology is poised to become the next disruptive technology wave. With devices like the Apple Watch expanding into the healthcare arena, it's only a matter of time before everyone has a computer on their wrist. KD Group introduced at the Toy Fair a new wearable watch for kids. The Kurio Watch as 20+ games and includes communication

Kurio Watch from KD Group.

Smart Lab's Archi-Tech Kit.

over Bluetooth to other Kurio watches and devices. It also includes a self-facing camera for AR interactive features.

SMART LAB'S ARCHI-TECH KIT INSPIRES HIGH-RISE DESIGNS

The Archi-Tech kit from Smart Lab combines its creative and interactive design kits with the fun of constructing your own building. The Electronic Smart House lets children snap together baseboards and posts to construct their own high-rise, and it includes the wires, switches, lights, and motors to automate the house. Children can install active lights, elevator pulley systems, fireplaces, burglar alarms, and even trap doors. The companion activity book teaches fundamentals in circuitry with 20 construction projects.

Smart Lab's Tiny Science and Tiny Robots kits.

TINY SCIENCE KITS FOR SCIENCE ON THE GO

If you have ever found yourself on the go but you don't have any science activities to occupy yourself with, Smart Lab has you covered with its Tiny Science and Tiny Robots kits. These are special small case snap-shut cases with all the tools you need to conduct science experiments on the road. The kits include mini-versions of science tools such as vials, test tubes, motors, gears, and installation hardware.

Mindware's Science Academy Robot Lab.

CUSTOMIZE YOUR ROBOT WITH MINDWARE'S SCIENCE ACADEMY ROBOT LAB

Mindware's Robot Lab is part of its Science Academy kit line. It teaches a kid how to code via push-button programming. The kit includes missions like teaching the robot to draw, bulldozing objects in a given pattern, and the pick and place of metal objects. Children can customize the robot to their liking with googly eyes and feathers. The companion

4M's Engineering Kits.

4M also offers eco-engineering kits in its Green Science line.

book is also filled with robot programming principles, including the appropriate way to measure the robot's turns.

4M'S ENGINEERING KITS OFFER EVERYTHING FROM ROBOTS TO MAGLEV

The design kits from 4M offer a wealth of educational resources that cover a large scope of topics. Its KidzLabs line covers robotics, space exploration kits, maglev engineering, and hydraulics. The Hydraulic Robot Arm kit is new this year and features a fluid-powered gripper that can lift and move a variety of objects.

THE FUTURE OF CLIMATE CHANGE WILL BE DRIVEN BY FUTURE ENGINEERS

4M also offers eco-engineering kits in its Green Science line. These kits teach children how to use renewable energy tools such as solar panels, wind turbines, and solar-powered robots. The Solar Rover kit, for example, mimics the same robotic principles found in NASA's Mars Rover. The robot runs on solar power only—no batteries needed—converting sunlight into electricity.

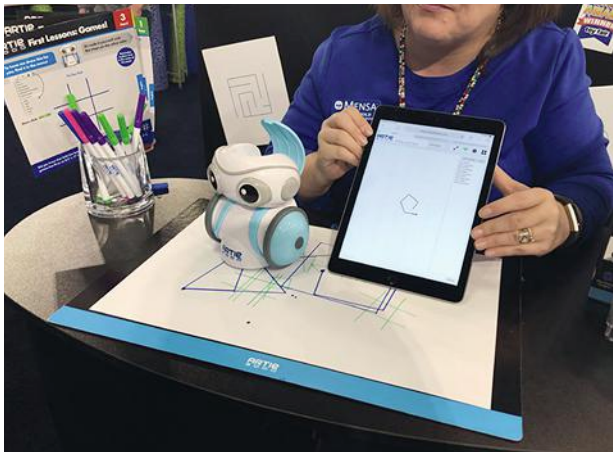
INSIDE LEGO'S AUGMENTED REALITY WORLD

The Lego booth at the Toy Fair is always one of mystery. Its walls cover many of the company's new products to protect its ideas. This year I was able to see the new line AR toy line "Hidden Side" meant to help children interact with Legos on a brand-new scale. The kit above is one of haunted mad scientist lab. By using AR, kids can explore a haunted world, catch ghosts, and solve puzzles. Using AR in this fashion mirrors how companies like PTC are using AR to provide instructions to maintenance engineers.

ARTIE 3000 IS MENSA-APPROVED TO TEACH CODING TO KIDS

Educational Insights had the Best Toy

Lego's AR toy line "Hidden Side."



Educational Insights' Artie 3000.

of the Year in the form of Artie 3000, a drawing robot to help kids learn to code. They can draw simple and complex drawings by writing code via a tablet or computer. The coding starts basic with drag-and-drop functions and scales up to line coding. Kids can code in collaboration with other kids and compete against each other in games like tic-tac-toe. Artie is the only third toy and the first robot to receive an honorary Mensa card. md

Educational Insights had the Best Toy of the Year in the form of Artie 3000, a drawing robot to help kids learn to code. They can draw simple and complex drawings by writing code via a tablet or computer.

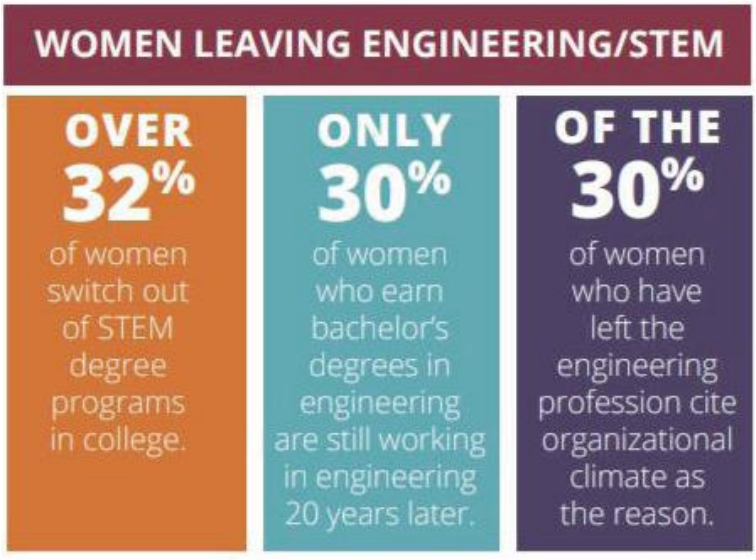
Education

PAMELA KAN | President, Bishop-Wisecarver

5 Ways to Increase the Number of Women in the Manufacturing Industry

For Engineers Week, we focus on women in engineering and manufacturing, the struggles they face, and how small manufacturers can help raise the number of women employed in manufacturing above 27%.

Pamela Kan



The main reasons women end up leaving STEM education paths and professions are due to the organizational climate and lack of mentorship. *(Credit: Society of Women Engineers)*

This is an exciting time to be in U.S. manufacturing as the industry is experiencing incredible growth, supports 17.6 million jobs, is considered the world's 9th largest economy, and provides above-average salaries for employees. Yet, any of you reading this article are well aware of the skills gap problem we are facing in this industry—with more than 2 million jobs expected to go unfilled in the next decade.

And, while women were introduced into the manufacturing workforce with World War I, the U.S. Bureau of Labor Statistics (2014) notes that while women represent nearly half of the total U.S. labor force (47%), they comprise less than a third (27%) of the manufacturing jobs. In nearly 100 years, there has been a meager 8% increase in the number of female employees in the manufacturing industry. Not the kind of stellar advancement anyone would like to see.

Why are there so few women in manufacturing? If the jobs are there, and the pay is great, why aren't women taking advantage of them? A 2014 Women in Manufacturing report showed that young women, like most people considering future careers, want interesting and challenging work and a high earning potential.

However, the WIM survey found that only 7% of respondents listed manufacturing as a field that offers opportunities for young women. Even worse, 59% said they could not recall a manufacturing company they would consider a leader in attracting and advancing women. Therefore, it is not surprising that 68% of the respondents stated they were not likely to consider manufacturing as a career path.

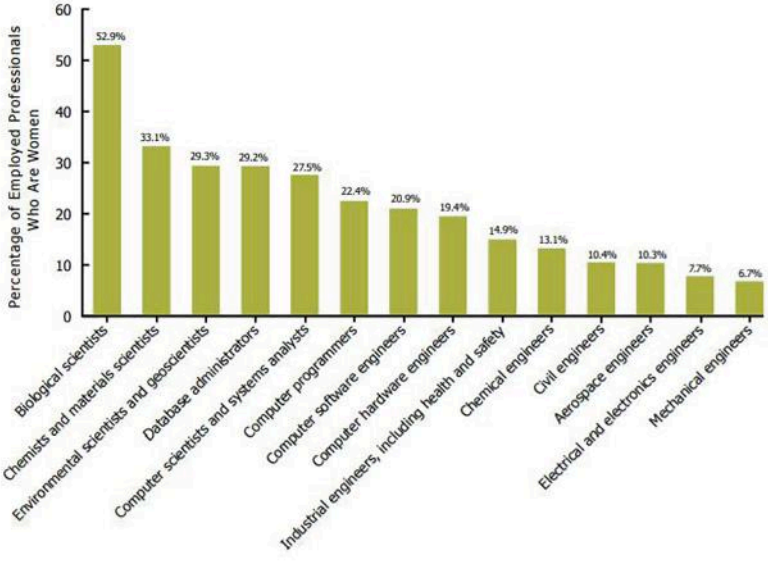
How can small manufacturers make a difference? Numbers like these show that manufacturing has an obvious perception problem. But what can we do to see real change? Most of us work at companies with fewer than 100 employees, which make up 94% of the manufacturing companies in the U.S. We are struggling to fill the two to three key positions needed to keep our lines moving and products shipping.

As a female president of one of those manufacturing companies, I have worked for years on various national, regional, and local committees to help

Mechanical, chemical, and civil engineering are among the top three engineering degrees earned among women in 2017. *(Credit: Society of Women Engineers)*

change some of the alarming skills gap stats. And while that work is important and is helping to make a difference in the big picture, I believe it is up to each individual company to do their part in helping make a change. I encourage all manufacturers, big and small, to help change the perceptions of manufacturing—and in turn increase the number of female employees—by focusing on these five areas:

- Working with educators and parents to differentiate myths from realities
- Serving as mentors and role models
- Providing hands-on experiences
- Showcasing innovation/technology
- Highlighting meaningful work



Women in STEM Occupations reported in 2008 show that very few pursue jobs in engineering or manufacturing, focusing on life sciences instead. *(Credit: U.S. Department of Labor, Bureau of Labor Statistics)*

EDUCATORS AND PARENTS: LET'S TALK

While I talk with high school and college-age students as often as possible, I've come to realize that the real target audience needs to be the school staff and parents. Students can be fascinated by the opportunities in manufacturing, but unless they have support from counselors and parents, they will not consider this industry as they make their future plans.

In the 2015 public perception report by Deloitte and The Manufacturing Institute, Americans are reluctant to choose careers in manufacturing, and thus, they aren't encouraging the next generation to pursue these jobs either. Manufacturing offers a strong career path and multiple benefits without requiring four-year degrees, but many

My fellow females: We are the ones needed to be mentors and role models to this new group of women in manufacturing. We need to take time to answer questions, give guidance, provide real-life answers to their questions, and be visible role models.

schools focus only on universities and colleges.

While these are clearly great learning institutions, they aren't the only option. I meet so many students who would be tremendous assets to the manufacturing community but didn't realize it was even an opportunity. I share with educators and parents the Top 20 Facts list from the National Association of Manufacturers (NAM) as it includes the latest number on salaries, health benefits, and job security, which are all positive.

MENTORSHIPS AND ROLE MODELS

Mentors are another important factor in bringing in more women to this industry. According to "Why So Few?" by the American Association of University Women in 2010, "Mentorship is often cited as a key strategy for exciting, supporting, and keeping students, young scientists, and engineers in the fields of STEM. This is particularly true for individuals who haven't historically participated in these areas—such as young women and underrepresented minorities."

The Million Women Mentor program was developed for "Advancing Women and Girls in STEM Careers Through Mentoring," and it found that 20% of current female high school students interested in a STEM discipline said they would like to learn more about mentoring and motivational programs to help prepare them for the future.

My fellow females: We are the ones needed to be mentors and role models to this new group of women in manufacturing. We need to take time to answer questions, give guidance, provide real-life answers to their questions, and be visible role models.

HANDS-ON EXPERIENCE

Increasing STEM education participation and proficiency for girls starting in elementary school is a critical step. Manufacturers must come together to create positive exposure and experiences for women at a young age. When

Industries that are the most attractive to women in manufacturing as of 2015. *(Credit: Deloitte and the Manufacturing Institute)*

students have some knowledge of the opportunities in manufacturing, their interest in pursuing it as a career rises exponentially. One successful program is the FIRST Robotics Competition, which provides hands-on learning using math and engineering to promote STEM-based learning. According to FIRST statistics, of those who have participated in FIRST:

- They are twice as likely to major in science or engineering
- 33% of girls plan to major in engineering
- More than 75% are in a STEM field as a student or professional

Events like National Manufacturing Day, Junior Achievement job shadowing, career fairs, and more all play a role in showcasing the benefits of manufacturing and providing hands-on, real insight that could change the minds and career paths of a significant number of young women.

INNOVATION AND TECHNOLOGY

Manufacturing in 2018 means technologically advanced machinery and modern buildings designed to help teams of employees collaborate and communicate more easily. It includes use of robotics, 3D printing, artificial intelligence (AI), virtual reality, augmented reality, and the Internet of Things (IoT), just to name a few components. Millennials have been raised with technology as part of every aspect of their lives, and understanding that it plays an important role in manufacturing will help them see this as a more viable career option. From hardware to software and everything in between, the technology advancements in manufacturing are constant and require workers who can keep adapting.

Manufacturing isn't a career where you check your brain at the door. It needs great problem-solvers who can work to meet current customers' needs, while also developing new innovations for future concerns. A 2014 Deloitte/The Manufacturing Institute report found that 78% of Millennials said their decision to work at a company was influenced by how innovative they considered the company to be. Don't miss that number or its importance. The majority of young workers are selecting their future employers based on perceived innovation. Manufacturing is all about innovation—it's what we do all day, every day.

MEANINGFUL WORK

Millennials also value the chance to make a difference. Talking with the engineers at my company, they have all said—many times—that what they most love about the manufacturing industry is the ability to take their schooling and innate interests and make a difference by creating something new that can help a customer. This is what we all want and manufacturing has this. We need to be shouting this out much louder!

No matter the size of our manufacturing companies, we can make a difference in the skills gap issue, specifically when it comes to women in this industry. When we focus on sharing the great realities of manufacturing with educators, parents, and students—providing mentorship and role models, as well as hands-on experience—I am confident we will see women hit a true growth stage of impact and influence within this sector. And if we start now, we won't have to wait another 100 years to enjoy the success women can bring to this industry. md

PAMELA KAN is president of Bishop-Wisecarver, a family of WBENC-certified companies that works with manufacturers to engineer, manufacture, and build linear and rotary motion solutions, custom complex assemblies, and optimal embedded intelligence systems through the integration of mechanical, electrical, software, control, and systems design engineering expertise.

NASA AIMS TO Alter an Asteroid's Course

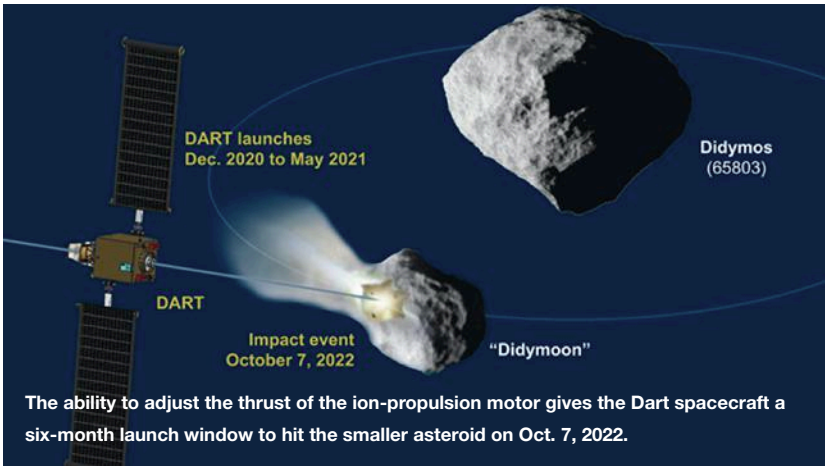
NO NATURAL DISASTER is as catastrophic and as seemingly unavoidable as having a good-sized asteroid or comet crash into the Earth. It's well known and accepted that asteroids of all sizes have been hitting the Earth for millions of years, sometimes with devastating results. They are widely credited with driving dinosaurs to extinction and instigating a global ice age.

NASA says asteroids, specifically those over one kilometer in diameter, are the greatest threat to life on Earth. The agency knows another large asteroid is bound to hit the Earth eventually. That's why NASA and other space agencies around the world spend millions of dollars tracking asteroids that could be threats—in particular, those more than 30 meters in diameter that will come within 0.05 AU (4.65 million miles) of Earth.

NASA-funded efforts to find and track potentially deadly asteroids (> 460 ft in diameter) identifies 500 of them annually. Estimates place the total number of such asteroids at about 25,000. So, the threat is real.

But currently there's little that can done even if they do discover one on an imminent collision course with Earth. But space agencies have been working on contingency plans.

One such plan will be tested on Oct. 22, 2022. That's when NASA's Dart (double asteroid redirection test) spacecraft is scheduled to crash into the smaller asteroid of the binary pair called Didymos (Greek for "twin"). The hope is that the impact will alter the smaller asteroid's course and give astronomers and engineers hope they can safely divert an Earth-bound asteroid from hitting its initial target.



The ability to adjust the thrust of the ion-propulsion motor gives the Dart spacecraft a six-month launch window to hit the smaller asteroid on Oct. 7, 2022.

THE TARGET

The Didymos asteroid pair was discovered in 1996 but it wasn't until astronomer's got telescopes and imagers with greater resolution (2006) that they realized it was a binary system of asteroids. It turns out there is a smaller, sister asteroid orbiting 3,870 ft from the larger one once every 11.9 hours. (About one-sixth of the known asteroids near Earth are binary or multibody systems.)

The larger asteroid, Didymos A, is about 2,625 ft in diameter, while the smaller, Didymos B (also known as Didymoon) measures 490 ft in diameter. They orbit the sun in a path that circles out to 2.27 AU at its farthest from the sun and sweeps in to within 1.01 AU at its closest approach. It takes 2.11 years for the two to circle the sun. In October 2022, they will be roughly 6.6 million miles away from Earth and within sight of many Earth-based telescopes and radars.

NASA chose Didymos as the target for Dart because of its configuration as a binary double-asteroid system. As the smaller one revolves around the larger, it changes the amount of sunlight reflected to Earth by 10% twice—once when the moon goes in front of the larger and blocks some of the sunlight, and once when it moves behind the larger and its reflection is blocked.

This phenomenon lets astronomers closely time the orbit of Didymos B around Didymos A. So, after the 1,100-lb Dart rams into the smaller asteroid at 3.7 miles/sec., the asteroid should slow down from its current 7 in./sec. around Didymos A by 0.016 in./sec. This should add roughly 10 minutes to its orbital time around Didymos A. Astronomers on Earth will immediately notice this as the changes in reflected sunlight will change frequency (from twice every 11.9 hr to twice every 11.83 hr).

There are several reasons Didymos B makes a good target for the test of the anti-asteroid Dart:

- The binary system lets Earth astronomers measure changes in the target's motion without having to send a secondary observer satellite to tag along.
- As a binary system, when Dart deflects the smaller asteroid, it will remain stay in close orbit around the larger one. So, the path of the two around the sun will be relatively unchanged.
- Spectroscopy indicates Didymos B is an S-type asteroid with a composition similar to common chondrite meteorites. Consequently, it should have the same physical properties as many of the potentially hazardous asteroids. It's also roughly the same size as the asteroids that make up the most likely threat to the Earth.
- Perhaps most importantly, Didymos is not an Earth-crossing asteroid (Its orbit around the sun never intersects Earth's orbit around the sun), so there's no possibility NASA's experiment will put the asteroid on a collision course with Earth

THE SPACECRAFT

Unlike the sci-fi movie "Armageddon," NASA is not sending a nuclear explosive

to hit Didymos B and change its orbit. Instead, Dart is a kinetic impactor and it relies on its mass and velocity (i.e., momentum) to physically knock Didymos B into another trajectory.

As stated before, the 1,100-lb Dart will be travelling 3.7 miles/sec. when it smacks into the asteroid, which should be going roughly the opposite direction at 7 in./sec. (0.00011048 miles/sec.).

NASA wanted to be sure it does not hit the asteroid too hard. Astronomers do not know the make-up of the Didymos B, so it could be a loose aggregate of gravel and boulders traveling in close formation. A really big hit could break the smaller asteroid into several or several hundred pieces. Then there might be a host of not-as-large asteroids heading toward Earth.

NASA astronomers theorize that an asteroid will remain intact if its speed is not changed by more than its own escape speed. Those types of speed changes are in the range of human technology.

So, Dart's mission is elegantly simple: fly directly into Didymos B after building up speed to 3.7 miles per second. It will steer itself using a sun sensor, star tracker, and a 20-cm aperture camera. The camera is called the Didymos Reconnaissance & Asteroid Camera for OpNav (DRACO for short) and is based on the high-resolution camera developed for New Horizons, the spacecraft that went to Pluto in 2015. The camera will aid in navigation and targeting, as well as picking out a target site and examining the geological content of Didymos B.

Engineers at Johns Hopkins Applied Physics Lab developed the software that will use the camera and sensor inputs to autonomously steer and control Dart's main engine and eight thrusters. The software, called Small-body Maneuvering Autonomous Real-Time navigation (Smart NAV), as part of the larger Guidance, Navigation, and Control (GNC) algorithm. Smart NAV also handles fuel management, determining the proper times for course corrections so that the limited supply of propellant is used efficiently.

Dart will be powered by a single NASA Evolutionary Xenon Thruster C (Next-C). The thruster uses xenon as the propellant, first ionizing it and then accelerating ions out the engine at up to 90,000 mph using electric fields. This lets the Next-C generate up to 137 mN of thrust (about 0.031 lb) of thrust, which is not much. But the thrusters can operate 24/7 for weeks at a time, letting velocity build.

NEXT engines are smaller, lighter, simpler, less-expensive, and more fuel-efficient with a specific impulse (Isp) of 4,100 sec., much higher than traditional chemical rockets. (Isp is the ratio between the thrust and the mass of the fuel needed to create that thrust). For comparison, the Merlin 1C rocket engine on Space X's Heavy Falcon has an Isp of 336. And a Next-C engine consumes 1,918 lb of xenon to generate the thrust created by conventional chemical rocket engine burning 22,000 lb of fuel. Dart can carry 334.5 lb of xenon but will only need a fraction of that to complete the mission.

The low cost of the ion thrusters, coupled with Dart's relatively small size, should let the mission be launched as secondary payload on a scheduled commercial launch. This should keep the mission price down to $250 million.

NEXT engines can also be throttled so that their thrust can be controlled, letting it put out anywhere from 0.5 to 6.9 kW of power. This will let Dart adjust its speed to ensure is hits Didymos B on Oct. 22, 2022 no matter when it launches in a generous launch window that stretches from Dec. 2020 through May 2021.

Current plans are to launch as soon as possible in the summer or 2021 when the Earth and Didymos are in close proximity. There are at least 21 dates in this period and NASA can slide the mission launch to one of the later slots if there are weather or maintenance delays.

Though Dart will carry a lithium battery, it will only supply electricity to the spacecraft until it can unfurl its solar arrays.

Those solar arrays represent new technology getting their first real mission. Dart will carry two Roll Out Solar Arrays (ROSAs), components that were tested on the Space Station in 2017.

ROSA uses flexible, blanket-like solar panels that can be rolled up like a sleeping bag and stowed in a smaller container for launch. It no longer relies on heavy and stiff glass panels that need to be equipped with hinges and unfolded in orbit using motors and other mechanisms. Each array has a center wing that supports the string of photovoltaic cells. The arrays also have narrow high-strain composite booms running the length of the array. When stowed for travel, the booms are coiled up lengthwise and act like springs: They want to unwind and deploy the blanket of solar cells as they do so.

So once in space, the arrays self-deploy with no need for a motor, and the booms click into place, locking the arrays in their unfurled configuration. The wing carrying the arrays measures 7.5 ft wide by 28.2 ft long; all together they provide 242.5 ft^2 of solar cells that will generate 5.4 kW at one AU from the sun when brand-new. It is larger than a conventional solar array of the same power, but weighs 20% less and rolls up into a volume one-fourth the size of conventional arrays when packed into the spacecraft. It's estimated that a ROSA-equipped Next-C could power a Dart-sized satellite to 201,000 mph, five times faster than the Voyager 1's top speed.

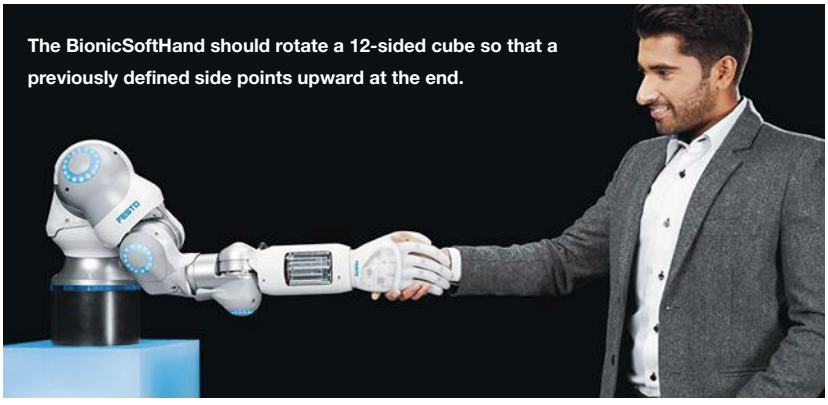
There are also plans for Dart to carry a CubeSat dubbed Licia (Light Italian CubeSat for Imaging Asteroids) built by the Italian Space Agency. It will "jump" off Dart just before it crashes into the asteroid and to take pictures of the actual impact and the crater Dart leaves behind. It's estimated Dart will leave a 20-m crater on the face of Didymos B. Mapping the shape of this crater will provide unique information to validate the numerical impact models necessary to design asteroid-deflection missions in future.

The European Space Agency also has a spacecraft, Hera, that will make a flyby of the Didymos Asteroids a few years later. It will carry out a more detailed reconnaissance, including more accurately measuring the velocity change and orbital shift in the Didymos binary system due to the impact from Dart. ■

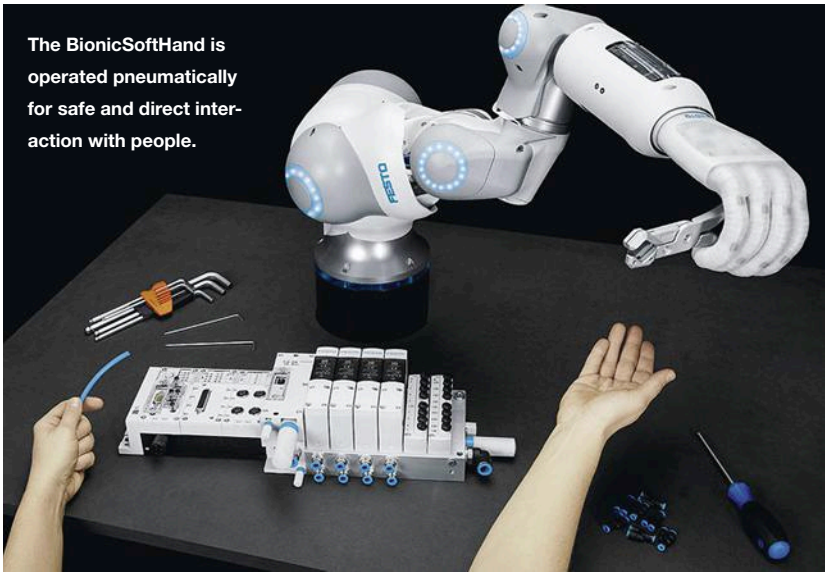
FESTO BIONICSOFTHAND AND ARM Pairs with AI

THE HUMAN HAND boasts a unique combination of power, dexterity, and fine motor skills. We use it everyday whether its grabbing, holding, turning, touching, or pressing objects. In the world of robotics, trying to replicate human motion has always been a goal because it makes integrating them into human work environments easier. Several robotic arms have grippers that can replicate at least one aspect of the human such as picking, grabbing, turning, or applying force.

To help create a more complex end effector, Festo will be demonstrating their new robotic hand the BionicSoftHand at Hanover Messe Fair 2019. With its new robotic hand, Festo looks to introduce a new tool for human and robotic collaboration.



The BionicSoftHand should rotate a 12-sided cube so that a previously defined side points upward at the end.



The BionicSoftHand is operated pneumatically for safe and direct interaction with people.

THE BIONICSOFTHAND

The BionicSoftHand is a pneumatically operated end effector that mimics the hand motion of a human being. It will operate in conjunction with Festo's Future Concept BionicSoftArm. Both the hand and arm are safe to interact with due to their pneumatic operation method. Mimicking the motion of the human hand is no easy feat and using pneumatics provides a more controlled and detailed movement profile. The hand's fingers consist of flexible bellows structures with air chambers. The bellows are enclosed in the fingers by a 3D textile coat knitted from elastic and high-strength threads. The textile allows engineers to determine exactly where the structure expands and generates power, and even where it is prevented from expanding. The hand can exert strong forces while still being light and flexible.

The key pneumatic component which allows for minimal tubing is the digital control proportional piezo valve terminal directly mounted on the hand. The tubes for controlling the gripper fingers do not have to be pulled through the entire robot arm. Rather, they can sit at the hand, making it easy for quick disconnect; they are operated with only one tube each for air supply and air exhaust. The piezo valves enable precise control over the finger's movements.

THE BIONICSOFTARM

The BionicSoftArm is continuation of Festo's work on the BionicMotionRobot. The SoftArm is more compact and can be combined with up to seven pneumatic bellows segments and rotary devices. This provides a long range of flexibility, reach, and mobility, allowing it to work around tightly spaced obstacles. The pneumatic actuation, just like in the SoftHand, allows for safe operation around people.

Direct human-robot collaboration is important in developing new automation segments. The BionicSoftHand and Arm can be used in SCARA applications, such as pick-and-place tasks, and in cobot applications with direct human interaction. Work ranges are continuing to see increases in overlap and collaborative work spaces are increasing in the automation field.

USING FEEDBACK LEARNING FOR PROGRAMMING

Positive and negative based feedback are how both humans and machines learn. We each require feedback to refine our previous actions. Using machine learning, the BionicSoftHand uses reinforced learning to create more efficient movement.

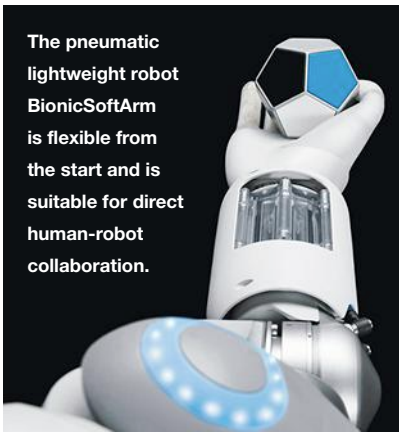
The AI built-in the SoftHand uses the trial and error method to achieve its goal.

For example, the robot is told to rate a 12-sided cube so that a previously defined side is pointed upward at the end. The necessary movement strategy is taught in a virtual environment via a digital twin, which is created with data collected from a depth-sensing camera via computer vision and the algorithms of artificial intelligence. The hand will rotate the cube and—based on positive and negative feedback from the robot—will teach itself the correct sequence, optimizing its actions until the task is complete.

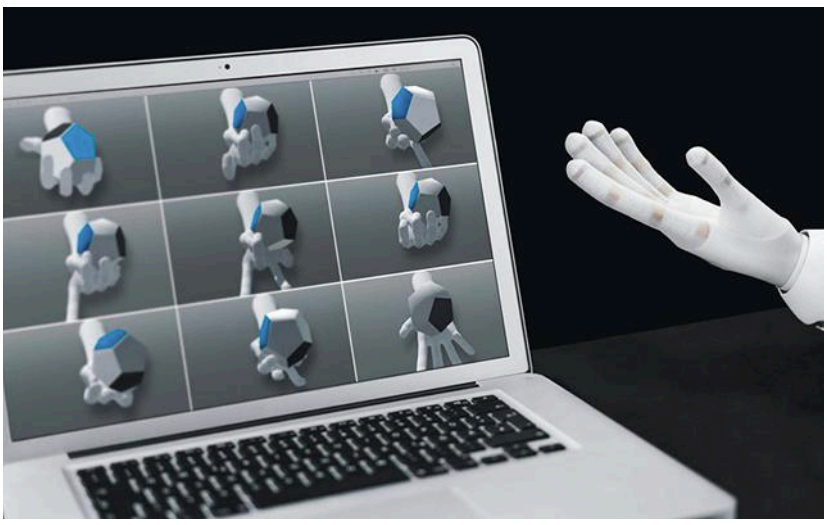
"The topics of analytics and artificial intelligence will enormously influence our product portfolio in future," explains Dr Frank Melzer, a member of Festo's management board. "For simple analysis tasks, AI algorithms can run directly on the component in real time; we then speak of field level or on-edge.

"If I want to analyze the data flows of an entire machinery unit or even a production hall, the processing power within the component will of course not be sufficient," Melzer continues. "The servers for the more complex calculations can be integrated into the production network. The advantage: My data remain within my protected infrastructure and are not communicated via the internet. It is only in the processing of very large volumes of data with complex analyses and reference series that communication with the cloud is necessary and appropriate."

The robotic arm is becoming the go-to tool for collaborative environments. The main hurdle preventing faster adoption is its flexibility. Festo hopes to solve this problem by introducing human-like movement features to the robotic design. The BionicSoftHand and Arm's flexible kinematics make it easier for it to adapt to different human-based takes while also making it safer to interact with human workers. The inherent safety of the robotic arm also helps to eliminate costly safety devices such as cages and light barriers, lowering conversion times and enabling flexible use. ■



The pneumatic lightweight robot BionicSoftArm is flexible from the start and is suitable for direct human-robot collaboration.



The BionicSoftArm as a classic SCARA application with a pick-and-place task: It can work in the tightest of spaces around obstacles. It also learns via feedback based machine learning.

Machine Performs Laser Cutting, Ablation, and Surface Modification

THE NEW ULTRA 9 platform from Universal lasers Inc. performs laser cutting, laser ablation, and laser surface modification. When configured with patented MultiWave Hybrid technology, it combines the laser energy of up to three wavelengths—9.3 µm (CO_2), 10.6 µm (CO_2), and 1.06 µm (fiber) – by independently controlling each spectral component of the beam. This lets users select the best wavelength or combination of wavelengths based on the material. It also features high-accuracy beam positioning and auto-focus, collision detection, and smart path planning. It works on materials including films, industrial fabrics, engineering plastics, laminating adhesives, foams and composites from global manufacturers such as 3M, DuPont, Henkel, Rogers, SABIC and Saint- Gobain.

Universal Laser Systems Inc., (800) 859-7033, www.ulsinc.com

Toughened Epoxy is Also Fast Curing

THE NEW 10-3041 toughened epoxy from Epoxies Inc. is dry to the touch within minutes after application and develops a 3,000 psi lap shear strength within four hours. The 10-3041 high performance epoxy adhesive bonds to a variety of plastics and metals. It also acts as an outstanding electrical insulator and therefore is suitable for many electronic bonding applications. For easy application, the adhesive is packaged in the convenient TriggerBond system which eliminates weighing and mixing a two-part epoxy. Samples are readily available and ship within three days.

Epoxies Etc., (401) 946-5564, www.epoxies.com

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THE RG M SERIES includes single-phase, solid-state relays and contactors with monitoring features. The relays consist of solid state switches with monitoring features for quick and timely failure detection, and switching. The relays will detect mains loss, load loss, SSR open and short circuit, SSR internal fault, and supply out of range. It is also equipped with an alarm LED for visual fault indications, plus an alarm transistor output for remote signaling. The relays are available with or without a heatsink. Ratings go up to 660 V ac, and the relay is controlled with a 4- to 32-V dc input signal and powered with 24 V dc.

Carlo Gavazzi, (847) 465-6100, www.GavazziOnline.com

Gradient Valves Have Less Internal Volume and Better Mixing

THE NIV SERIES gradient valve from Clippard can have several 2-way, normally-closed solenoids connected around its central body. This provides significant reduction in internal volume with enhanced mixing capabilities. Each actuator operates independently, letting the flow of various media be mixed or for one media to be split into several streams. These compact, lightweight multi-channel gradient valves are useful for solvent selection, stream splitting, flushing, and other automated applications. The bidirectional valves feature individually controlled flow paths, low power consumption, minimal dead volume, all wetted areas are PTFE and compatible with corrosive and aggressive fluids, and in operation they have high cycle lives and fast response times. Common industries that use these valves for the benefits of isolating fluid from a mechanical valve include: drug dispensing, laboratory equipment, waste water, medical devices, chemical, food and beverage equipment, ceramic/glass/plastic, and bulk and solids handling.

Clippard, (513) 521-4261, www.clippard.com/link/hp2651139

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THE DTM110-C8 CLASS II (no earth ground needed) external power supply from TDK Lambda meets DoE Level VI and EU Tier 2 v5 standards for efficiency and off-load power. It is also certified to the medical IEC 60601-1 and industrial IEC 60950-1 standards, making it suitable for a variety of hospital and home healthcare applications, plus industrial test, measurement, and portable equipment. It is housed in a rugged, IP41 rated, vent-free enclosure measuring 63 x 140 x 33 mm (W x L x H). AC is applied through a standard IEC 60320-C8 (2-prong) socket and the output DC cable is fitted with a 4-pin Power-DIN connector as standard, with other connector types available. The adapters feature over-voltage and over-current protection. The 105- to 110-W adapters accept a 90 to 264 V ac input, and are available with 12-, 15-, 19-, 24-, 28-, 36-, and 48-V outputs. They operate in ambient temperatures ranging from –20 to +60°C (derating linearly to 50% load from 40 to 60°C). They meet DoE Level VI and EU Tier 2 v5 requirements with an average efficiency of greater than 89% and have an off-load power consumption of less than 0.15 W.
TDK-Lambda Corp., (800) 526-2324, www.tdk-lambda.com

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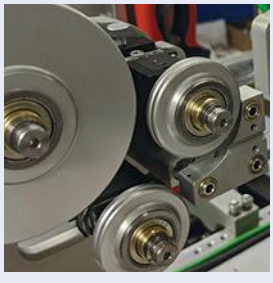
Piab, (800) 321-7422, www.piab.com

Vacuum Ejector is Ready for Industry 4.0

piCOMPACT23 SMART toughened epoxy from Epoxies Inc. is dry to the touch within minutes after application and develops a 3,000 psi lap shear strength within four hours. The 10-3041 high performance epoxy adhesive bonds to a variety of plastics and metals. It also acts as an outstanding electrical insulator and therefore is suitable for many electronic bonding applications. For easy application, the adhesive is packaged in the convenient TriggerBond system which eliminates weighing and mixing a two-part epoxy. Samples are readily available and ship within three days.
Piab, (704) 527-5052, www.piab.com



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THE WHISKER SERIES of micro-wire handling components for guiding from Bold Automation works with wires ranging in sizes from 35 (0.0056 in. in diameter) to 50 (0.001 in. in diameter) gauge. The series includes idler and drive pulleys, guide spindles, tensions towers, wire-wrap indexing modules, and rewind stations. Pulleys with diameters of 1, 2, and 3 in. are standard, pulleys are 6 in., and other modules are available as components or customized sub-system assemblies. The components can handle insulated wires used in catheters and have options for magnetic wire used in electric vehicles.
Bold Laser Automation, Inc., (603) 493-2579, www.boldlaserautomation.com

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Yaskawa America, Inc., (800) 927-5292, www.yaskawa.com

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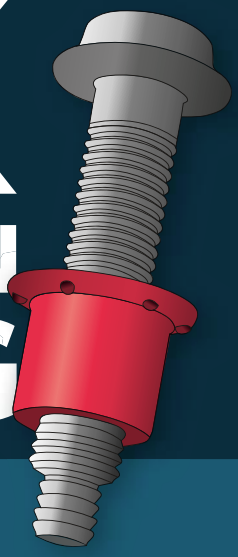
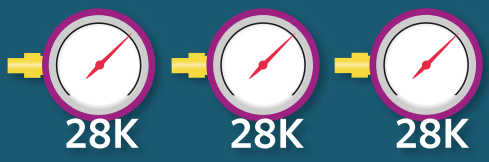


CONSISTENT CLAMP



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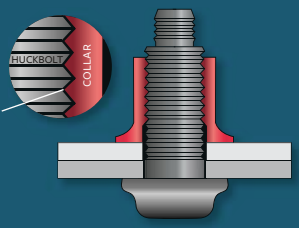
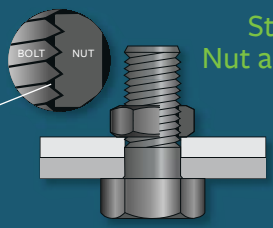


Standard Nut and Bolt

Gaps Cause Nuts to Loosen



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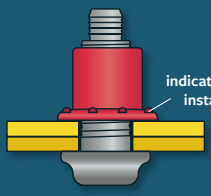

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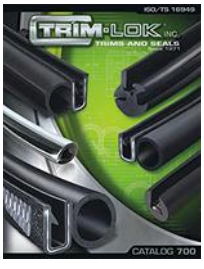

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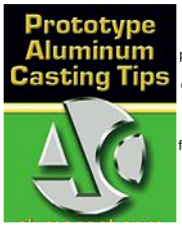
Aluminum Prototype Casting Tips For Design Engineers



The casting tips are accumulated wisdom and lessons learned from the school of hard knocks. All are presented to help the engineer tasked with designing a part that will eventually be die cast. The intent is to help you avoid career-limiting decisions and make your job a little less stressful. Consider Aluma Cast for your next prototype casting project.

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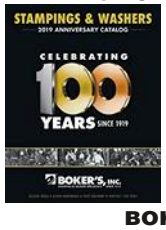

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A History of Product Design

It's time to pick your spots, specialization has begun.

In the 15th Century, as the Middle Ages were transitioning into the Renaissance, people in European population centers wanted to have the same items in their homes and workplaces. News of these useful or desirable items soon spread along trade routes to the far corners of the civilized world.

Emerging Design Centers: Large workshops began to emerge in places such as Florence, Venice, Nuremberg, and Bruges where groups of collocated artisans replicated designs in larger volumes. Apprentices took 7 to 14 years to learn and become a Master. Demand growth quickly outpaced this approach as a solution.

Pattern Books: The use of drawings to act as instructions on how to construct something was first developed by architects and shipwrights during the Italian Renaissance. By the early 16th Century competitive pressures led to the emergence of "pattern books" in Italy and Germany, which were collections of engravings illustrating decorative forms and motifs for application to a wide range of products. And, importantly, the design took place well in advance of manufacturing.

Emerging Industrial Centers: In the 17th Century, growth in monarchies led to large government-operated centers epitomized by the Gobelins Manufactory, opened by Louis XIV in Paris in 1667. Hundreds of craftsmen, artists, decorators, and engravers turned out everything from tapestries and furniture to metalwork and coaches. This model was replicated in many cities, including the famous Meissen porcelain factory near Dresden in 1709. As long as reproduction remained craft-based, however, quality declined as scale increased.

The Industrial Age: The emergence of industrial design as a discipline mirrored the growth of industrialization and mechanization in Great Britain in the mid-18th Century. The term "industrial design" was first used in 1839 to describe how the school of St. Peter instructed draftsmen how to prepare patterns for silk manufacture.

Industrial Design: The first attributed use of the term "industrial design" in 1919 is credited to Joseph Claude Sinel, a self-proclaimed "industrial designer." However, many argue that the discipline began at least a decade before. Christopher Dresser is generally considered the first independent industrial designer. Then there is the *Practical Draughtsman's Book of Industrial Design*, printed in 1853. Together, these data points anchor the beginning of design as a profession between 1850 and 1900.

Common Design Skill Sets: The Rhode Island School of Design was founded in 1877. But, it was not until the Carnegie Institute of Technology opened its design program in 1934 that historians began to recognize design as a profession. For the next 50 years, until the appearance of consumer electronics devices, the profession remained in the hands of individuals whose talents were sought as employees or consultants.

The Design Industry: By the 1980s, business demand for design skills had grown to the point where profitable design consultancies could be formed. Firms like Alessi (1921), Teague (1926), Design Concepts (1967), Frogg Design (1969), and others pre-date this period, but then growth exploded. Driven by broadening consumer electronics markets, the advent of global competition, shortening product life cycles, and the rapid evolution of CAD into 3D design and surface modeling, design grew from a profession into an industry. RKS (1980), Continuum (1983), Seymourpowell (1984), KartenDesign (1984), IDEO (1991), and dozens of other companies were in business by the mid-1990s.

Design Specialization: During the past 30 years, User Interface Design has already separated from generalized Industrial Design as a specialty. Sustainable Design is close behind and Additive Design is on the doorstep as 3D printing matures into Additive Manufacturing. Meanwhile, Design for the IIoT and IoT and Design for Big Data Analytics will both soon distinguish themselves as well. If you are a designer, or an engineer who does a lot of designing, this would be a good time to read the tea leaves and pick your spots accordingly. Trade schools and academic institutions now offer specialty degrees, and history tells us that is a meaningful development. md

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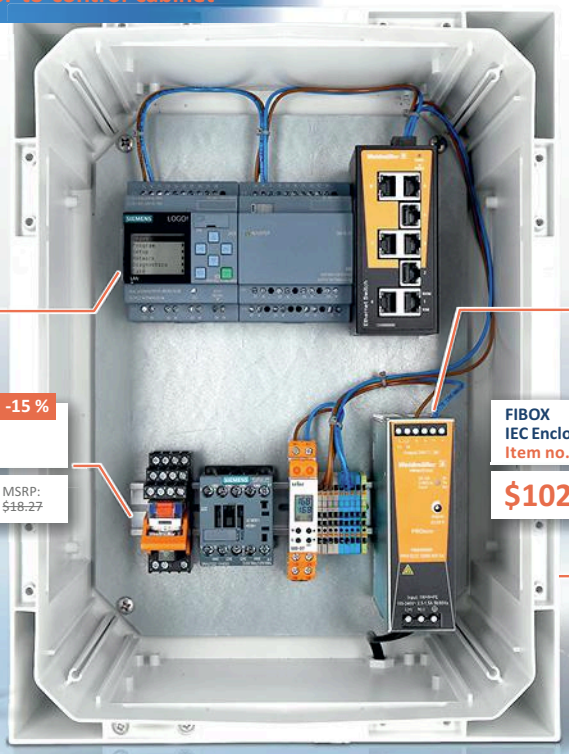

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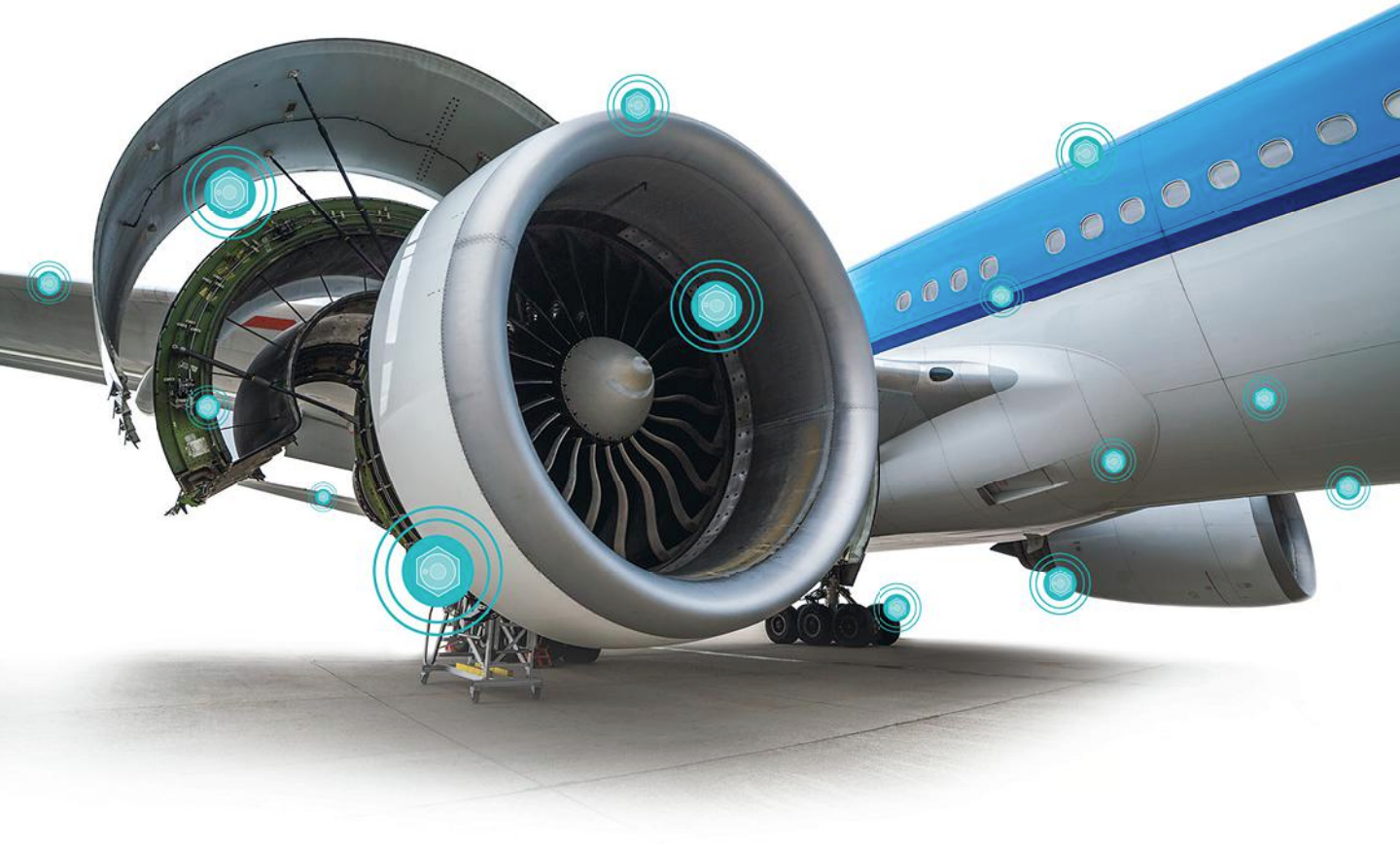

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