

# Automation NOTEBOOK®

Your guide to practical products, technologies and applications

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Fall 2016 | Issue 36



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"...We like the idea that all the drive parameters are stored on the CPU, and can be downloaded to a drive when needed which is great for the maintenance staff (no more having to scroll through menus to configure the drive!)" Todd in ONTARIO, CA

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# Automation NOTEBOOK

Your guide to practical products, technologies and applications

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For those who prefer to speak with us in person, please call 1-800-633-0405 x1845. Thanks for your interest, and we look forward to hearing from you.

## Editor's Note

"Are you ready for some football?"  
It's that time again. It's time for our kids to strap on shoulder pads every Friday night, gather on the gridiron, and work together to vanquish their weekly foe.

Instead of focusing on the position of the pigskin alone, take a look at the players. Notice how each player works in harmony with the others on his/her team. Next, consider what happens if any one of those players is not there. Not only is there a hole, but an additional way for the opponent to get through and overpower the defense.

Like the players on a football team, when it comes to automation equipment, everything must work together, in order for the end result to be successful. That's where AutomationDirect comes into play. With thousands of products, and award-winning technical support, your application will arise the victor.

This issue of NOTEBOOK is loaded with informative articles such as, our Tech Brief article which details our new custom enclosure cutout tool. We also have a great Cover Story on the advantages of buying direct. The User Solution show how the largest indoor model train display stays on track, and our Student Spotlight zooms in on engineering students at Walla Walla University and their nanofiber-producing machine. You'll also find information on our newest products, such as new enclosures, gearboxes, Ethernet communications modules, and lots more.

There's plenty more inside this issue. Once again, Chip McDaniel gives us more fun puzzles to solve in the Break Room. Once you solve them, compare your answers at [www.automationnotebook.com](http://www.automationnotebook.com)

TJ Johns  
Coordinating Editor  
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## INTEGRA POLYCARBONATE ENCLOSURES



AutomationDirect's enclosure offering now includes Integra polycarbonate enclosures. The Impact series enclosures are lightweight, making them easier to carry and install. The polycarbonate enclosures feature high impact resistance of up to 900 inch-pounds, UV light resistance,

and have a wide operating temperature range from minus 40 degrees F to 265 degrees F. All Integra polycarbonate enclosures are NEMA 4X-rated; many models are watertight and saltwater resistant, earning

them a NEMA 6P rating and making them marine friendly. The Impact series wall mount, single-door enclosures, starting at \$39.00, feature standard hinges for easy door removal, while permitting a full 225-degree door swing; models are available with clear or

opaque lids. Additional features include: integrated mounting flanges molded into the enclosure for easier mounting and an integrated latch to provide a clean look and easy opening; extra interior mounting bosses on the rear wall (and lid of opaque enclosures) provide multiple mounting options for DIN-rail, back panels, or other components.

Back subpanels, dead front panels and swing-out panels in aluminum, PVC, and white powder coated steel finishes are also available, starting at \$9.00; offered accessories include: DIN-rail kits, 10-piece screw packs, outdoor labyrinth vent, and pole mounting kits for 2-inch to 12-inch pole diameters.

Integra polycarbonate enclosures are UL approved, CE, RoHs, and REACH compliant.

[www.automationdirect.com/polycarbonate-enclosures](http://www.automationdirect.com/polycarbonate-enclosures)

## ADDITIONAL NEMA-RATED ENCLOSURES



The Hubbell Wiegmann line of enclosures has been expanded with additional NEMA 3R and NEMA 12 models. NEMA 3R enclosures, typically used in outdoor applications for wiring and junction boxes, provide protection against falling rain, sleet, snow, and external ice formation; they

protect against dripping water when used indoors. This style of enclosure does not have a gasketed sealing surface; some models have hasps for padlocking. New models include galvanized steel units, and larger sizes with

hinge covers. Most often used for indoor applications of automation control and electronic drives systems, NEMA 12 enclosures are designed to prevent the ingress of dust, water, and oil. Designed with gasketed doors to seal the enclosure's contents from airborne contam-

inants and non-pressurized water and oil, NEMA 12 enclosures are available in sizes from small wall mounts to two-door floor mount models.

[www.automationdirect.com/enclosures](http://www.automationdirect.com/enclosures)

# More enclosures...More savings!



## Hubbell/Wiegmann Enclosures

Not all enclosures are created equal, this is why AutomationDirect has teamed up with one of the largest enclosure manufacturers in North America, Hubbell/Wiegmann, to offer you quality built, highly reliable NEMA enclosures at great prices. Choose from over 2,000 Hubbell/Wiegmann enclosures across NEMA 1, 3, 3R, 3S, 4, 4X, 6P, 12 and 13 ratings, all at prices well below more traditional suppliers.

### NEW! Custom Cutout Enclosures

Now you can design your NEMA 4/12/13 carbon steel enclosure using the Customizable Enclosure Tool on our website at [www.automationdirect.com](http://www.automationdirect.com). Cutouts are factory made according to your specifications and your panel is delivered ready to install and use.



- 304 and 316L Stainless Steel Enclosures**  
 Perfect for electrical or high-tech electronic equipment indoor and outdoor.  
**Starting at \$114.00**
- 5052-H32 Aluminum Enclosures**  
 Ideal for applications where a lightweight, corrosion resistant enclosure is required.  
**Starting at \$126.00**
- Carbon Steel Enclosures**  
 Disconnect, padlocking, freestanding and dual access enclosure options available for harsh, dirty environments.  
**Starting at \$9.25**
- Fiberglass Enclosures**  
 Excellent for chemical and corrosion resistance.  
**Starting at \$30.50**
- NEW! More NEMA 3R and NEMA 12 Enclosures**  
 Over 140 NEMA 3R and NEMA 12 enclosures in new sizes, galvanized, no knock-outs, double doors and other features have been added to the lineup.  
**Starting at \$18.50 (NEMA 3R)**

Research, price, buy at:  
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# RECENTLY ADDED PRODUCTS

## IRONHORSE CAST IRON HELICAL INLINE GEARBOXES



New IronHorse inline gearboxes with cast-iron frames use helical gears to provide quiet startup and smooth operation. These gearboxes utilize C-face motor mounting interfaces and the universally interchangeable compact design ensures easy OEM replacement. Five gearbox frame sizes are available for NEMA motor frame sizes from 56C up to 254/6TC. Six gear ratios are available from 5:1 to 60:1 and the helical gearboxes are sized to handle motors from 1 to 20 hp. IronHorse helical gearboxes have a one-piece FC-20 cast iron housing and 1045 carbon steel shaft. Heat-treated and ground high-strength steel gears are AGMA Class 10 rated. Heavy duty bearings are used on the output shaft and an interior channel guides oil to constantly lube the bearings; double-lipped embedded oil seals prevent leakage. IronHorse helical gearboxes start at \$360.

[www.automationdirect.com/helical-gearboxes](http://www.automationdirect.com/helical-gearboxes)

## ETHERNET COMMUNICATION MODULE FOR C-MORE MICRO HMI TOUCH PANELS



The EA-ECOM communication expansion module provides Ethernet capability to the C-more Micro line of operator interfaces. Designed for all of the newer EA3-series of

6", 8" or 10" C-more Micro panels, the EA-ECOM adds an Ethernet (RJ45) port for programming and PLC communications at 10/100 Mbps. The module attaches to the rear of the EA3-series panel and requires no external power. The EA-ECOM module provides faster project download and firmware update speeds and supports multiple connections to multiple PLCs and protocols. The Ethernet port supports automatic MDI/MDI-X crossover detection for plug and play capability and allowing crossover or straight-through CAT5 cables to be connected. The EA-ECOM communication module is \$50.00. Software and firmware version 4.0 or later is required.

[www.automationdirect.com/cmcore-micro](http://www.automationdirect.com/cmcore-micro)

## FLEXIBLE, LIQUID-TIGHT METALLIC AND NON-METALLIC ELECTRICAL CONDUIT



Liquatite® flexible, metallic, non-metallic and shielded electrical conduit has a wide range of uses in the electrical industry from motors to lighting, enclosure wiring and more. Type NM is a liquid-tight flexible non-metallic conduit that offers excellent protection to wiring from abrasion, sunlight, mild acids, alkaline, and oils. Type LA steel conduit offers outstanding protection against wet, oily conditions and is designed for use in exposed or concealed locations. Type ATLA steel conduit is designed specifically for extreme hot or cold environments. The PVC jacket remains flexible at low temperature and is flame retardant. Type SLA shielded conduit is designed for wiring applications requiring protection of sensitive electronic circuits. Starting at \$28.00 and available in 25, 50, and 100-foot rolls, Liquatite conduit is UL Listed (US and Canada) and made in the USA.

[www.automationdirect.com/liquid-tight-conduit](http://www.automationdirect.com/liquid-tight-conduit)

## ADDITIONAL MAGNETIC PROXIMITY SENSORS



M-series cylindrical magnetic DC proximity sensors are now available in 8mm, 12mm, and 18mm sizes. With 10 models available, the magnetic sensors feature stainless steel shielded housings, are offered as NPN or PNP models with normally-open or normally-closed outputs, and are available with standard sensing distances of 0 to 70mm. M-series sensors are IP65/IP67 or IP68/IP69K-rated and come with built-in overload protection. Starting at \$44.50, models are offered with an attached 2-meter axial cable or with an M8 or M12 connector; proximity sensor damping magnets are also available, starting at \$4.00.

[www.automationdirect.com/magnetic-sensors](http://www.automationdirect.com/magnetic-sensors)

## RHINO POWER SUPPLIES GET 48V OUTPUT



The RHINO PSB series of DIN rail power supplies now includes the PSB48-480S single-phase input, 48VDC output power supply. The low-cost 480W power supply is perfect for basic DC voltage applications offering high performance and reliability without all the additional features of higher-cost full-featured power supplies. The power supply features removable finger-safe terminal blocks, output voltage status LED indicator, conformal coated circuit boards,

and approval for Class 1, Division 2 hazardous locations. The aluminum housing easily installs with integral 35mm DIN rail mounting adapters. Priced at \$170.00, this high-quality power supply includes overload, overvoltage and thermal protection, and is UL 508 listed, UL 60950 recognized, CSA certified, CE marked and RoHS compliant.

[www.automationdirect.com/  
dc-power-supplies](http://www.automationdirect.com/dc-power-supplies)

## FORK SENSORS



PS-series fork sensors, also referred to as “slot” or “U” sensors, are offered in visible red light and laser models. Available in PNP and NPN styles, and designed for easy installation, the rugged metal one-piece construction assures constant alignment. The high-resolution PS-series fork sensors feature glass optics, selectable light on/dark on operation, adjustable sensitivity potentiometers, high switching frequencies, and are fitted with M8 connectors with 360-degree viewable LED indicators. Starting at \$86.00, the visible red light fork sensors feature easy setup and have a sensing range from 5mm to 220mm, depending on model. Starting at \$137.00, the laser fork sensors feature a Class 1 laser to detect small objects and have a sensing range of 30mm to 120mm, depending on model; certain models are available for transparent objects. All PS-series fork sensors are IP67-rated, have cULus approval and are CE, RoHs and REACH compliant.

[www.automationdirect.com/  
fork-sensors](http://www.automationdirect.com/fork-sensors)

## RUKO COUNTERSINK BITS



The RUKO line of countersink bits now includes bits to accommodate UNC, or imperial (inch), fasteners. The round shank, 82-degree taper countersinks are CBN ground from fully hardened, high-speed steel blanks which creates a sharper and more durable cutting edge with precise tolerances. Combined with axial relief grinding, this guarantees a smooth, low-heat, chatter-free cut up to 30% faster than competing countersink bits.

RUKO countersinks are suitable for standard industrial materials, such as steel, cast iron, stainless steel, non-ferrous metal, thermoplastics, and duroplastics.

Available in diameter sizes ranging from ¼-inch to 1-inch, and in individual pieces or a five-piece set, prices start at \$10.00.

[www.automationdirect.com/  
hole-cutting-tools](http://www.automationdirect.com/hole-cutting-tools) ■

# Low-cost Linear Motion

Actuator assemblies, sliding components and accessories

## NEW! SureMotion® Linear Slides and Actuators

Get reliable linear motion components at low prices with the award-winning customer service and support you expect from AutomationDirect! Our new line of linear motion products is designed to provide smooth, precise and durable linear actuation. With supreme versatility and low maintenance, these affordable, motor-ready actuators can meet both your linear motion and budget requirements.



Starting at:  
**\$789.00**  
LAVL-60T06LP2

### Value Line Linear Actuator

Low-cost, versatile linear slide actuator with hard-coated aluminum guide shafts. Unit can be mounted horizontally, vertically, or inverted without loss of load capacity.

- Max load capacity: 110 lb
- Max speed: 15 in/sec
- Travel: 6, 12, 18, 24 inches
- Ready for NEMA 17 motor

Starting at:  
**\$1,129.00**  
LACP-16T06LP5

### Compact Linear Actuator

Self-contained linear slide actuator designed for light loads in harsh or wet conditions in a very small package.

- Compact design
- Stainless steel lead screw
- Max load capacity: 125 lb
- Max speed: 20 in/sec
- Travel: 6, 12, 24, 36 inches
- Ready for NEMA 17 motor

Starting at:  
**\$2,399.00**  
LARSD2-08T12BP2C

### Twin Round Shaft Actuator

Continuously-supported round rail slide with ball screw actuation provides a very robust precision linear motion.

- High-accuracy ball screw
- Continuously-supported guide rails
- Max load capacity: 920 lb
- Max speed: 6 in/sec
- Travel: 12, 24 inches
- Ready for NEMA 23 motor



Starting at:  
**\$269.00**  
LARSA1-08L12C

### Linear Slide Components

Round-shaft sliding elements can be combined with other elements to build a huge variety of machine mechanisms. Available in both continuously- and end-supported shafts.

- Linear ball bearings
- High-quality clear anodized aluminum blocks
- Carbon-steel shafts



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[www.automationdirect.com/motion-control](http://www.automationdirect.com/motion-control)



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# MAKING ENCLOSURE CUTOUTS... THERE'S AN APP FOR THAT?

By Jim Krebs,  
Technical Marketer, AutomationDirect

**B**efore we answer this question, let's talk about how we normally make a cutout on a carbon steel enclosure. Many of us have been there; we begin with making a drawing, schematic or diagram of how the system is going to work and the components that will be needed. As part of the system, we decide to use an enclosure to house controls, wiring and other electrical or electronic components safely and securely.

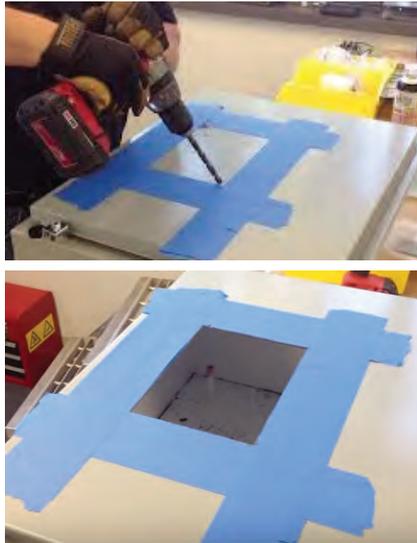
We then determine if pushbuttons, HMI's or other human interface components are required for this enclosure. We assess whether thermal management components (air conditioners, fans, heaters, etc.) will be needed to maintain proper temperature and humidity levels in the enclosure.

Then another schematic or two are made to show how all these components will be laid out in and on the enclosure. Once we know all this information, we carefully select the minimum required overall width, depth and height size for this enclosure, ensuring that all required components will fit comfortably and meet all specified tolerances.

When the enclosure and all its components arrive, the fun begins. It's time to drill, bore and cut holes to properly install all the required enclosure components. This means we need drill bits, jig saw blades and other special tools that can cut through steel efficiently. In addition to the tools, we need careful measuring, skill and patience to ensure all cuts are done correctly. If cutouts are required and made in the wrong place or the wrong size, the enclosure may be ruined. If you're lucky, you might locate replacement components that will fit securely in the botched cutout or maybe find some kind of an insert to make it all fit.

Now, we carefully measure and mark the cutouts to be made on the enclosure and make sure all the markings are aligned and properly spaced. Then all the drilling, sawing and cutting is done.

Remember to smooth out all the rough edges by filing or sanding areas where cuts were made, clean up all the metal debris, and erase any leftover markings on the panel.



**Manual cutting of enclosure holes can be time-consuming**

It is also very important to touch up all metal surfaces where cuts were made with a rust-inhibiting paint since these cutouts are now unpainted, and at risk of corroding.

If we did things correctly, we now have a nicely done enclosure ready for assembly.

## There's an App for that?

Ok, let's not get too carried away. There is no downloadable smart phone app that will shoot some type of laser ray and make the enclosure cutouts automatically... yet. However, there is another option available that provides a customized enclosure with perfectly made cutouts from your exact specifications.

AutomationDirect and Hubbell-Wiegmann have partnered to offer a series of customizable carbon steel enclosures currently available in ten different sizes. These enclosures can be customized with cutouts made to your specifications using our new customization utility.

This utility allows users to select from eleven cutout types/sizes and place them on any of the available customizable enclosures. These customized enclosures are built to order from flat sheet metal and are

painted after cutouts are made, ensuring the best possible protection against corrosion. This means no more mess or hassles, and no more messing up cutouts. You receive a custom made enclosure ready to add all required components, a 3D model of the enclosure, and a PDF of a dimensional 2D drawing.

Keep in mind that customized enclosures cannot be returned unless there are manufacturing defects or shipping damage. Therefore, make sure to carefully design your cutouts with the correct measurements, specifications, and requirements.

So in a way, there IS an app for that thanks to our new customization utility.

## Customize It!

To use the utility, from your browser, go to [www.automationdirect.com](http://www.automationdirect.com). You must login with your username and password. If you need to register as a user, click on the "Register" link located on the top of the Home Page and follow the registration instructions.

Once logged in, select "Enclosures/Subpanels/Thermal Management/Lighting" from the "Shopping Categories", and "Enclosures" from the available page selections. From the Enclosure page, select "Custom Cutouts". Scroll down and select one of the available customizable enclosures listed. From the selected enclosure page, click the green "Customize" button.

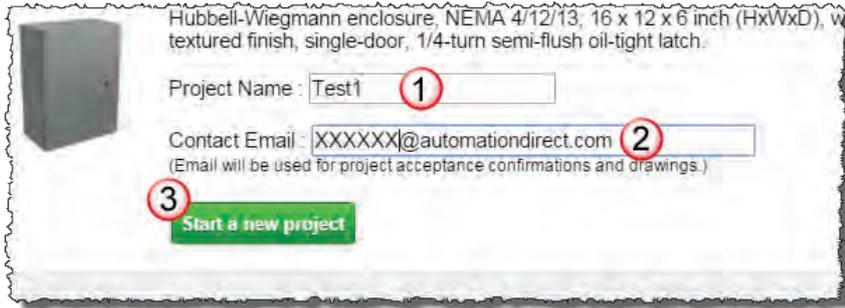
We recommend that you watch the "How To Use Enclosure Cut-out Tool" video to learn how to use the utility. When you finish the video, you can begin customizing by clicking on the "View Project Listing link on the bottom of the window.

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continued from p. 9

## Customization Utility Overview

Begin your new customization project:



Customization tool on AutomationDirect Web site

1. Assign a "Project Name"
2. Enter your email
3. Click on "Start a new project"

The customization window opens. From this window you can see all the available customization tools and a drawing representing the enclosure you selected. Here is a quick overview of the tools and features available for customization:

**a. Enclosure Diagram:** This is a representation of the selected enclosure. Cutouts can only be placed inside the dotted lines to prevent placing holes too close to edges, hinges, latches, etc. Active cutouts are depicted in blue.

**b. Max Cutout Count:** The maximum number of cutouts allowed is 25. The number displayed here is the amount of cutouts still available.

**c. Save:** Saves your work.



**Save As:** Saves with a new file name.



**Approve:** Submits your customization for approval.



**d. Enclosure Face:** Click the down arrow to choose the face of the enclosure to be displayed.



**Cutout Alignment:** Align multiple cutouts horizontally or vertically. A checkbox to the right of this selection turns this option ON or OFF.

**e. Cutout Type:** Select between the categories of Pushbutton, Standard DIN, or C-more HMI cutout to be added.



Go to [automationdirect.com](http://automationdirect.com) today to try this customization utility. Remember, before you start, watch the "How To Use Enclosure Cut-out Tool" video. This video provides a more comprehensive explanation and provides an example of the utility in action. After that, create a test customization and see for yourself how easy and convenient it is to use.

**22 mm Push Button** **Cutout size:** Select the desired size for the selected cutout category.

**f. Cutout Placement:** Click to allow placement of the selected cutout on the displayed enclosure face.



**Delete:** Select a cutout to delete and click this icon to completely delete it from project.

**g. Coordinates:** Enter or edit the X and Y coordinates in the fields. Click the checkmark to apply coordinates to the active cutout.



**h. Cutout Rotation:** Click the icon to rotate the active cutout 90° clockwise with each click. You may also use the pull-down to select other rotation angles.



**i. Grid ON/OFF:** Click to turn the grid ON or OFF.



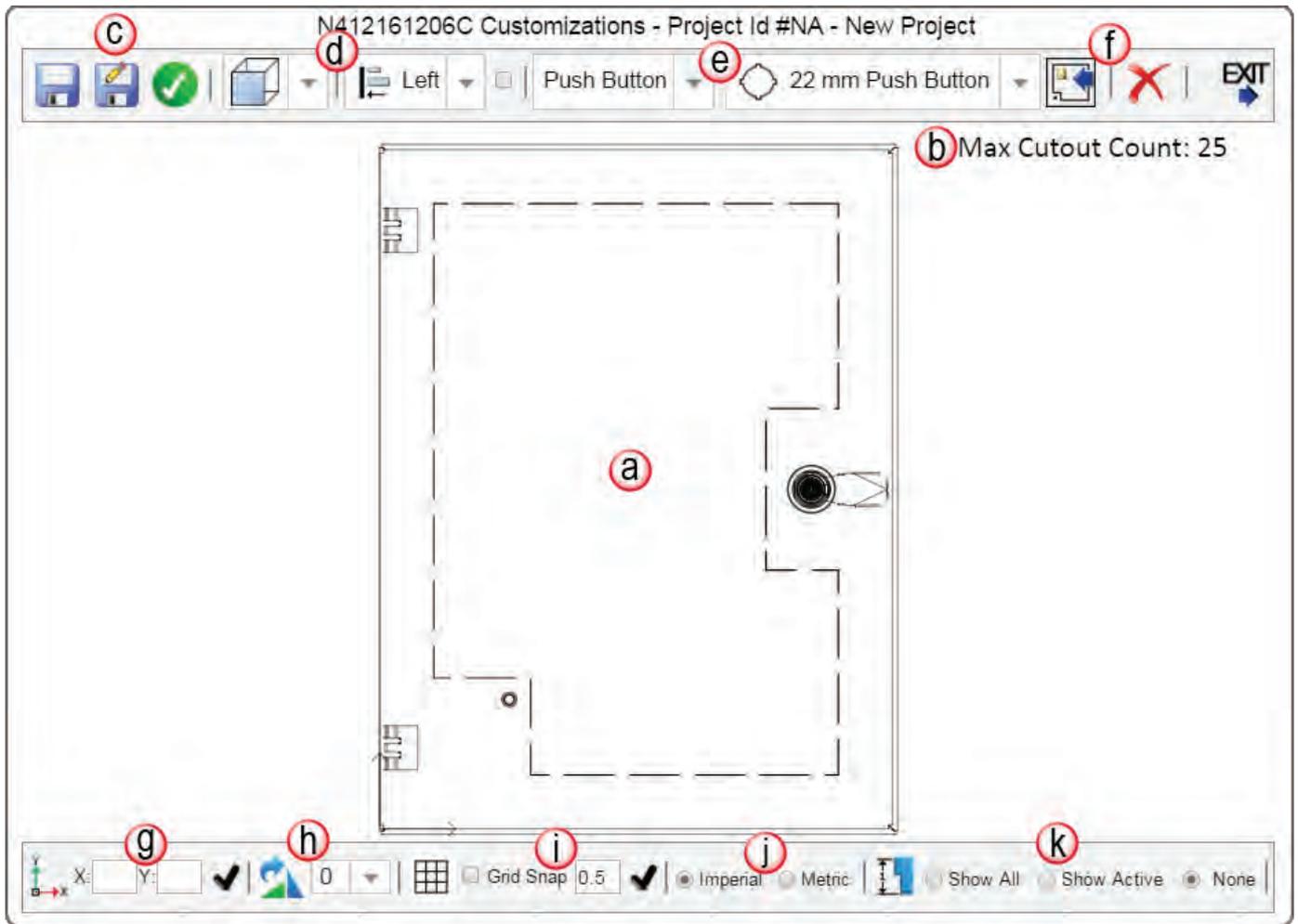
**Snap to Grid Value:** Enter a snap to grid value and click the checkmark to



accept the value.

**j. Imperial or Metric:** Select the desired unit of measure to use for your customization.

**k. Show/Hide Cutout Dimensions:** Click the icon to display the cutout dimensions. Select to "Show All", "Show Active", or show "None."



Visit [www.automationdirect.com/custom-enclosures](http://www.automationdirect.com/custom-enclosures)

# SHOULD YOU PURCHASE DIRECT?

By Dan Hebert, PE

Online purchasing has taken over much of the consumer goods sector, and is now a viable option for many industrial automation products.

The automation products used by machine builders, integrators and end users can be purchased either directly from the manufacturer, through distributors, or from an online store offering a variety of products from different manufacturers. Each approach has its advantages and considerations, and these were examined in detail in Control Design magazine's March 2016 cover story titled "Why Buy Direct?"

What follows is a summary of the cover story, with the goal of providing assistance to those charged with deciding just how to specify, buy, implement and support their automation products.

## Buying from a Manufacturer

Manufacturers know their products, which confers certain advantages. "The main advantage of buying direct from the manufacturer is the deep product knowledge," said Lyle Rusanowski, CEO at Delta Technology, a custom machine builder in Phoenix, in the cover story. "Going direct usually makes sense when you are buying an end product that will be integrated into a complete system."

But, not all manufacturers are up to speed on application-specific issues. "Since the manufacturer is mainly concerned with the product, its focus tends to be deep, not broad," explained Rusanowski. "Most do not have application engineers that are focused on going broad and applying the products in many applications. If the conversation becomes application-specific, a detailed

review of the requirements and specifications is necessary to ensure the products can do it."

However, buying direct from the manufacturer can be expensive since there is often no volume to leverage the sale against, cautioned Rusanowski in the cover story. The manufacturer has to cover all of their overhead and other costs through what's often a small-volume sale, so prices can be high for all but very high-volume purchases.

But, results may vary depending on the particular manufacturer. "I've had the opposite opinion in certain cases," related Leon Krzmarzick, senior manager of control engineering at Delta Technology, in the cover story. "Festo's applications guys have been very good, and they've been able to offer us very good discounts. But we've never purchased Festo through a distributor. SMC, on the other hand, used to be direct,

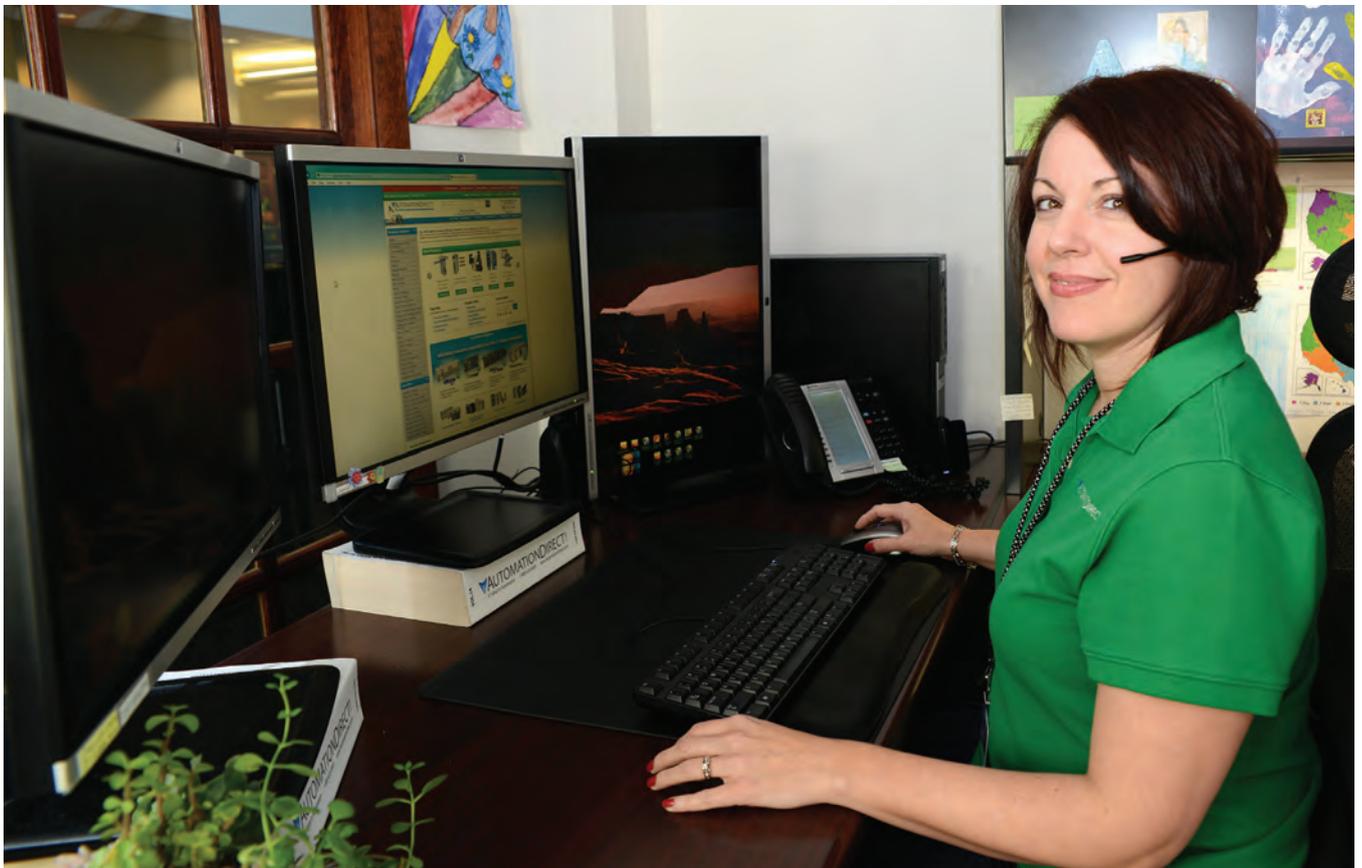
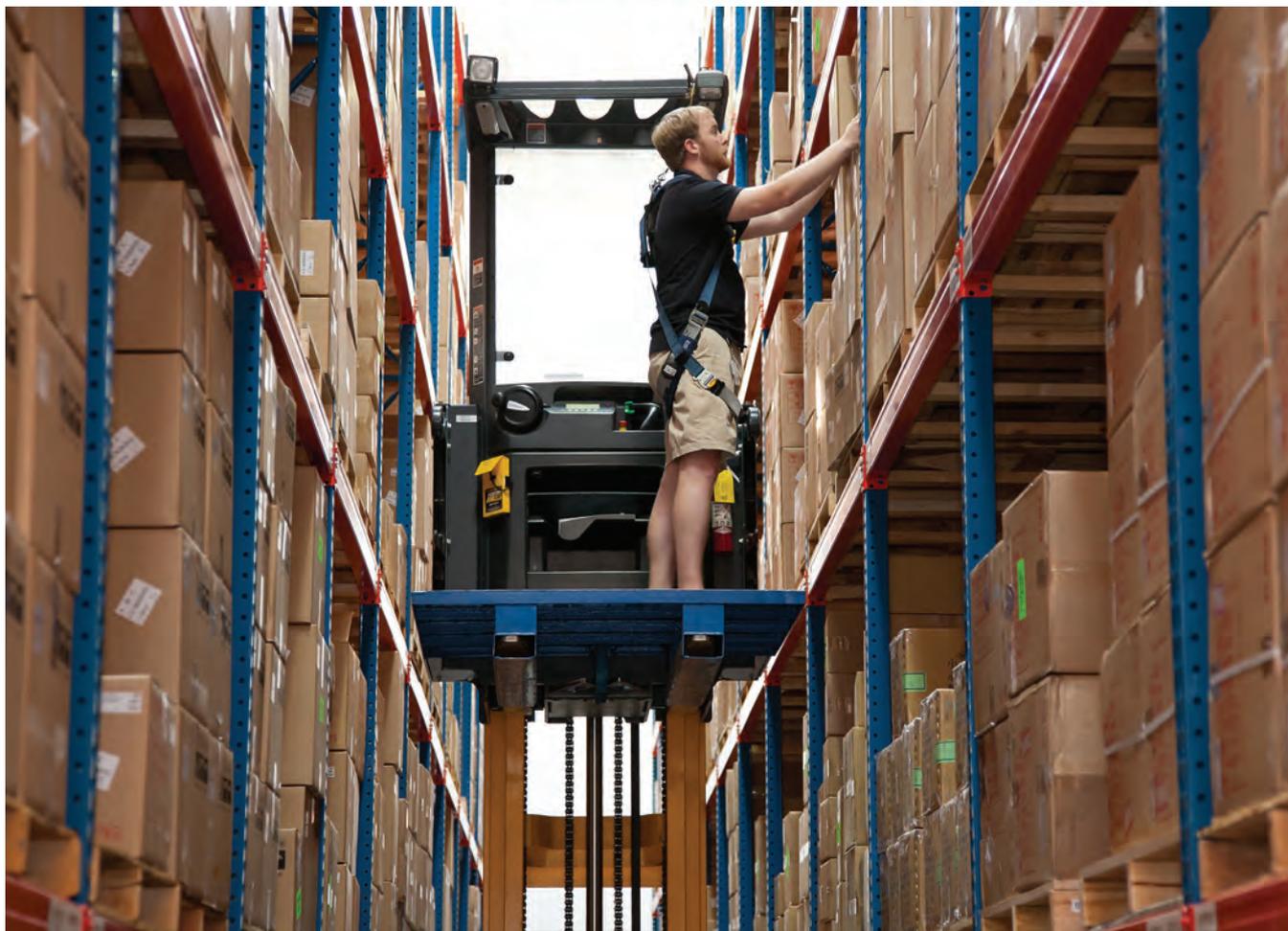


FIGURE 1: Ordering can be done directly from a website or via a catalog and an 800 number.



**FIGURE 2: Direct sellers need to carry very large inventories for quick order fulfillment.**

and now we are getting better pricing through distributors.”

“And then you have Allen-Bradley, who I noticed has relabeled other manufacturers’ products, and not being cheap, even with distributors,” added Krzmarzick in the cover story.

## Factory-Direct

“At c3controls, we have found, the more control we have over every step of the development process, manufacturing, fulfillment and service, the greater the benefit is to the machine builder, said Geoff Taylor, president and CEO at c3controls in the cover story. “Our vertically integrated and factory-direct approach is innovative in its application to the electrical-controls marketplace where the vast majority of transactions are processed through legacy distribution channels or impersonal online warehouses.”

Taylor continued in the cover story. “We are able to offer expert support because we design and manufacture the products; and we are able to offer pricing that provides tremendous value,” he said. “This represents an electrical control product and supplier option that impacts the machine builder’s bottom line by improving cash flow and profitability—a business case that is unmatched in the industry.”

Factory-direct delivers the best value, noted Taylor in the cover story. “To accomplish this, you can’t attempt to be all things to all people by offering more and more products,” he related. “Attempting to do so without processes in place to ensure quality, availability, price and expert service will lead to diminishing outcomes for the customer.”

Factory-direct implies direct interaction with the manufacturer, but may include distributors. “This does not necessarily exclude the distributor,” said Taylor

in the cover story. “A customer researching products is more likely to gain greater insight into the technology quicker by engaging the manufacturer of the product. They are best positioned to provide expert product and application support.”

Distributors can often provide service in some instances, but not without concerns. “Challenges arise when distributor affiliations with specific manufacturers or suppliers exclude products from consideration that would benefit the machine builder, both in the application and the bottom line,” said Taylor in the cover story.

“We have numerous productive OEM, manufacturer and distributor relationships across the country and internationally that are predicated on customer value,” concluded Taylor in the cover story. “No single manufacturer is able to supply and service all of the products used by the machine

continued p. 15 >>

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continued from p. 13

builder, system integrator or end user in their applications and operations.”

Buying direct from a manufacturer has its advantages, but other approaches may work best depending on the purchaser’s needs.

### Purchasing from Distributors

“Distributors are interested in moving as much volume as they can,” noted Rusanowski at Delta Technology in the cover story. “This drives lower volume discounts and improves margins, so their focus shifts to applications.”

“Distributors are able to leverage volume, so we usually get much better pricing, and, if we can consolidate purchasing of many products through the same distributor, we get further discounts,” he related in the cover story. “The distributor’s account representative also usually tracks down and helps resolve any issues, should they come up.”

“A big advantage to using distributors is that they can get involved in, and be responsible for, proper product selection,” observed Krzmarzick in the cover story. “For example, servo-motor sizing applications can become complex, but a good distributor will help to size all components in the application and then stand behind that solution.”

We’ve looked at purchasing direct from manufacturers and through distributors, now let’s examine the third approach, buying from an online store.

### The Online Option

“Purchasing from online stores is typically the lowest pricing that you can get, but you don’t have the face-to-face support like the distributors,” said Delta’s Rusanowski in the cover story. “Since we are a custom integrator, we usually need more support than the online stores can provide. However, for commodity type products, online stores are very cost effective, and we use them quite a bit.”

Rusanowski says not all online stores are equal. “Some sites do not make it easy to buy multiple products or multiple items, so we generally will move away from them. If sites have items in stock and we can get them quickly, we will buy from that site,” noted Rusanowski in the cover story.

“Another advantage of good online stores is that CAD models and technical specifications and manuals are readily available,” pointed out Krzmarzick in the cover story. “It is very convenient to go to a website, select the product and then immediately have access to the CAD model for the configured or selected product. Websites with good selection, configuration tools and accurate CAD models will continue to get our business.”

### The Online Leader

AutomationDirect’s sales in the United States and Canada are direct via Internet and catalog, with international distribution in other areas of the world.

Tech support is a focus for the company. “Our technical support staff is fully trained on our own products and has won

gets too tough, our support staff has product engineers and developers at their disposal to provide answers in a quick and efficient manner as a backup.”

AutomationDirect provides information such as product specifications, manuals, certifications and pricing 24/7. “For most products we have product videos available that show a customer how a product is used or how it is programmed,” noted Marchuk in the cover story. “We offer 2D and 3D drawings of most products up front for evaluation and also provide the manual for free in downloadable form. For most programmable products, we allow the user to download the programming software for free to evaluate on their own time. In this day of instant information, we believe this is what most purchasers want.”

Online automation purchases are



**FIGURE 3: Quality tech support can be provided by direct seller’s personnel because they have access to the same products being purchased by their customers.**

awards 15 years in a row for our main programmable products—PLCs and HMIs,” said Gary Marchuk, business development director at AutomationDirect, in the cover story. “Since our staff is supporting our own products, via phone or online, if the question

being considered with increasing regularity, observed Marchuk in the cover story. “With higher Internet bandwidths and customer access to the Internet, they can get anything they want the instant they want it,” he said. “There is little that most

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**FIGURE 4: Getting the right product to the right purchaser depends on dedicated and detail-oriented people.**

customers need that they cannot get from our Web store."

## What's Best for You?

Delta Technology compares their purchasing experiences. "Having the distributor's application support is like having extra engineers in-house to help you to solve problems," said Rusanowski in the cover story. "When looking at costs, I can evaluate in terms of what value the distributor provides

and compare that to the amount of time my team needs to spend to get the same information."

Delta also purchases online. "The tools available from placing large orders to the tracking capabilities make this much easier to keep control of our supply chain," he pointed out in the cover story. "Sales representatives and phone support are important when there are issues or when learning about line cards, but when you look at pur-

chasing, I would estimate more than 90% is done via online orders."

Some system integrators prefer online ordering. "My preference is to purchase online whenever possible, preferably direct from the manufacturer," said Marshall Miles in the cover story. Miles is the managing director at system integrator Global Controls in Saint Charles, Illinois. "I like the immediate access to the specifications, pricing and availability, and anonymous access is the best without the need to register to use the portal. Whenever I have to talk with someone, they typically have an agenda and want to find out more about the project, usually fishing for something else to sell."

Like many others in the automation industry, Miles's time is limited, so he looks for the most efficient purchasing process. "Once I have a clear path for a solution mapped out, the best way through is to stay hyper-focused and get that solution implemented," he said in the cover story. "Anything else is a distraction. Distributors and manufacturers are almost always biased, and perhaps they should be. However, in my experience technical reps and sales engineers often have little practical knowledge to offer to our complex applications."

"In my opinion, supply chain management is the most critical factor in delivering a project on time," said Rusanowski in the cover story. "We work closely with suppliers that can help us to manage the supply chain and reduce its variability. By managing these relationships and building partnerships where possible, it helps to lower the overall project risk and improves the ability to satisfy the end customer."



*Dan Hebert, PE is an automation industry veteran with over 30 years' experience in engineering, management and editorial positions. He has worked*

*for end user, system integration, OEM and publishing firms. He is presently a Principal with ControlsPR, a content creation agency. Dan holds a BSEE degree from ULL and an MBA from UCI, both granted with honors. He holds a patent for a Control System for Flue Gas Conditioning, and is a registered Control Systems PE in California and a registered Electrical Engineering PE in Louisiana. He is a member of Beta Gamma Sigma (MBA Honor Society), Eta Kappa Nu (Electrical Engineering Honor Society), ISA and Mensa.*

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# KEEPING THE WORLD'S LARGEST MODEL TRAIN DISPLAY ON TRACK

By Brian Kienlen,  
Fluid Power and Mechanical Products  
Master Electronic Operations Director at Entertainment Junction

**W**ith over 80 trains, 50 individual tracks and more than 1200 cars, Entertainment Junction's complex control system keeps the trains on time.

Ahhh... model train displays. There is just something about walking into a showroom with model trains in operation. But what does it take to control the world's largest indoor train display with over 80 model G-scale trains and 50 individual tracks laid down over two miles? Start with a 25,000 square foot facility, and add six AutomationDirect Terminator-based Do-more PLCs with discrete and analog I/O, each one responsible for operating an area of the building. Then network the PLCs together and add programming to allow multiple trains to operate together, some sharing the same tracks and sidings—you now have a complex yet easy-to-operate control system for every model train hobbyist's dream come true.

## Living the Dream

Entertainment Junction ([www.EntertainmentJunction.com](http://www.EntertainmentJunction.com)) is the fulfilled dream of owner Don Oeters, a successful Cincinnati businessman and train enthusiast. His vision was to create something unique, a one-of-a-kind family entertainment center that would entertain, educate and promote railroading in a magical environment (Figure 1).

The attraction would be home to the world's biggest model train layout and would take visitors on a virtual train journey via an indoor kid's playground, a railroad museum, a gift shop, and more.

Don's plan for the museum was simple—make it about the history of railroading, make it interactive, and make it for all ages. The concept drawings were produced by Bruce Robinson, a local architect whose resume includes most of the Ripley's Believe It or Not museums in the world. Bruce took Don's concept and created what can only be called an indoor theme park. Response to the draw-

ings was strongly positive and Don decided to move forward with this unusual Cincinnati attraction. Major construction began in early 2007, and work continues to this day as new elements are constantly added.

Don continues to push his vision, always adding new structures and train controls to the train display. In June of 2013, phase 2 of the train display was completed on the mezzanine level. The historic Cincinnati Coney Island, circa 1965, was built in G-Scale with rides running and music playing (Figure 2).

## Large Scale Simulates Real-World

Entertainment Junction uses G-Scale model trains throughout the layout, with the 1:24 scale representing the ratio of the model to real-life size. The G-scale model train is the largest of the mass-produced trains, with 1 inch on the model equating to about 2 feet in real life. These big, burly model trains oper-

ate on 2-rail track, use DC power, and can run indoors or outdoors.

Currently, there are over 80 trains operating on 50 individual main lines with electrically-isolated and segregated blocks. This allows for multiple locomotives to be controlled independently within a single track line. In some cases, a single line will have up to seven trains operating at the same time. The turnouts, railroad switches used to change tracks, are controlled by a small 12 VDC rotary motor that is always either pushing or pulling against the switch via a connecting rod. A relay controls the polarity of the voltage being delivered to the DC motor, therefore controlling the direction of rotation. The continual applied pressure from the connecting rod to the switch allows for secure positioning, eliminating derailments from unsecured rails within the switch.



FIGURE 1: A modern diesel locomotive moves carefully through a hand-crafted city with scratch-built buildings featuring intricate details.



**FIGURE 2:** A new addition at Entertainment Junction is the historically accurate Cincinnati Coney Island, circa 1965, complete with rides running and music playing.

## Upgrading the Control System

Local volunteers and enthusiasts designed and manufactured the original control system by hand. The custom printed circuit boards with resistors, diodes, transistors, capacitors and other electronic components were all soldered and assembled on site (**Figure 3**). Each track had its own control panel containing all the parts and pieces that make up the control system. 45 control panels were originally made, and more were eventually added to accommodate the growing business.

A single computer ran the original circa 1970s C programming language, written before C++ was even developed, and power to the trains was regulated in an analog fashion via a single capacitor and several transistors.

After running well for six years, maintenance on the original control system became very problematic. When something wore out, broke or failed, it had to be repaired by hand. Replacement parts were not available for much of the hardware or components.

A more flexible control system was needed for this large distributed control application, and AutomationDirect was selected as the primary supplier. I chose AutomationDirect because of my favorable experiences with the company in the past.

Several reasons include the abundant supply of equipment to choose from, fast delivery and great customer support. It really is a pleasure knowing that you can get what you need quickly, with any support you may need just a phone call away.

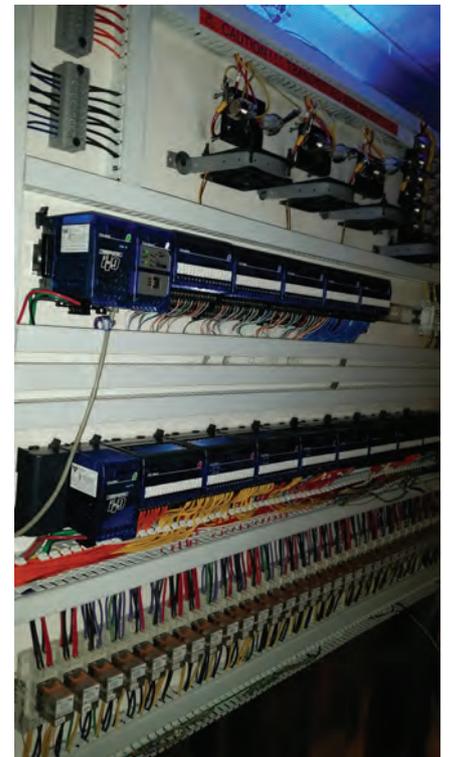
The new control system is a 100% retrofit, completely replacing the older control hardware with AutomationDirect components



**FIGURE 3:** The original custom circuit boards were difficult to troubleshoot and repair, which drove the facility to seek a better alternative.

(**Figure 4**). Up to eight AutomationDirect Do-more PLCs are planned, each one using 55 discrete 16-point input modules, 40 discrete 16-point output modules, and 30 analog 16-point 0-10 VDC input and output modules.

The control system simultaneously monitors over 850 magnetic reed sensors and control buttons, over 640 12VDC relays and indicator lamps, and over 500 individually controlled blocks. It also provides voltage control for the engines. Other control functionality includes bridge up/down, traffic signals, switches, speed changes, stops and starts.



**FIGURE 4:** This electrical panel contains AutomationDirect Do-more PLCs for control of the 2000 I/O points in the model train system.

The new control system is responsible for controlling multiple trains on multiple tracks simultaneously. In most cases, multiple trains are operating together on the same tracks, with state logic programming coordinating the locations and speeds of each train. The old system had a single control panel for each train, operating independently from the rest of the layout. The new configuration ties every train and track together into one main

continued p. 20 >>

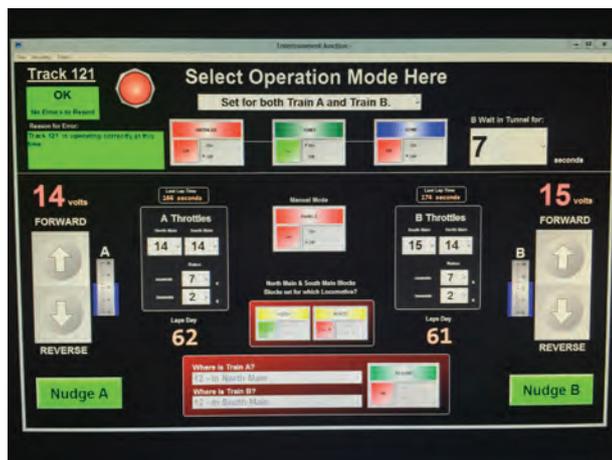
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control system, which allows for much more diversity in how the trains can operate, both individually and in relation to each other.

The old system controlled the voltage feeding the track using a combination of NPN transistors, optical amplifiers, resistors and capacitors. The acceleration and deceleration for the locomotives was provided by adjusting analog potentiometers on the control board, thereby increasing and decreasing resistance in the circuit.

With the new control system, all analog voltages are controlled by the PLCs. Each PLC has a built-in web server, allowing speed control voltages and other values to be set using a web thin client running on an iPad or Surface tablet (Figure 5). Acceleration and deceleration rates can also be adjusted, along with many other parameters. The web client also provides a comprehensive view of train operation, along with the ability to drill down to more detailed levels as required by the operator.

Several of the tracks in the layout have grade changes, requiring the trains to travel both uphill and downhill within a single lap. With the old system, only one voltage level could be set for the whole lap. The new system is always monitoring the resistance load on the locomotive, and will increase or decrease the supplied voltage automatically based on if the train is travelling uphill or downhill. This allows the trains to operate at a constant speed.



**FIGURE 5:** This tablet-based HMI screen enables changes to the PLC settings and programs from any location along the two miles of track.

## Keeping an Eye on the Train Schedule

While running over 110 trains, there is a high demand for retrieving information. For data acquisition, the PLCs count laps for each train and record fastest lap time, slowest lap time, average lap time, voltage input versus voltage output (allows for resistance detection), and the locations of the trains.

By using trend views inside the Do-more programming software, voltage spikes and dips can be detected (Figure 6). This vital information lets the staff know when a track needs to be cleaned, or if a train is drawing more amps than it should. Voltage spikes on a graph indicate points along the track where the locomotive briefly lost continuity with the rail, indicating dirty track or wheels. On the other hand, voltage dips indicate heavy resistive loads, perhaps due to a stock car's wheels shorting out while in motion, or bad motor brushes on a locomotive engine.

The PLC is programmed to automatically recognize these issues and alert Entertainment staff via email if a track needs cleaning or if there are any issues with rolling stock. In extreme cases, the PLC will automatically shut down an operating line if a voltage dip exceeds a threshold over a set period

of time, for example, dead shorts lasting longer than 0.5 seconds.

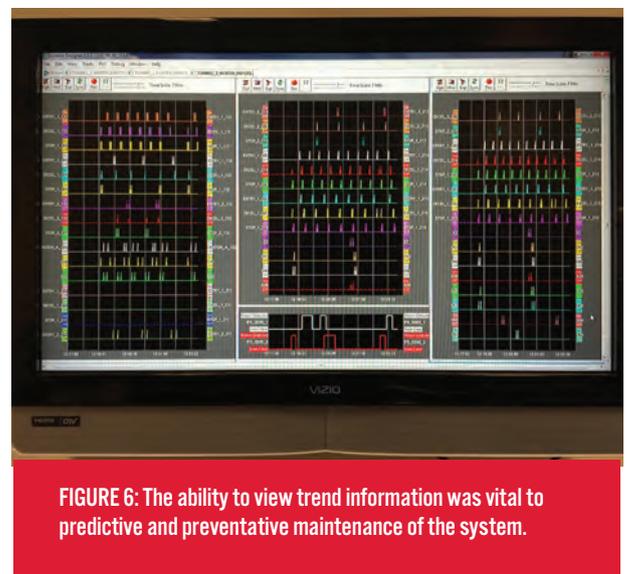
## Controlling a Speeding Train

Analog signals are used to control the voltages supplied to the rails on the tracks, which then power the locomotives. It's imperative that trains accelerate and decelerate at certain rates so damage does not occur to the locomotives. The PLC's analog voltage output modules are rated 0-10 VDC on all systems. The train's operating voltage is between 0 VDC and 24 VDC, with an average amp load of anywhere from 2 amps to around 5 amps.

Since the analog output modules are not designed to handle this high of load, a custom amplifier board was designed, converting the low-level 0 to 10 VDC output to an amplified, high-current 0 to 24 VDC output. This amplified voltage then feeds a 40 amp power transistor that drives the power to the locomotives. The power transistor is doing the work of supplying the current to the locomotive, with the PLC simply providing a control voltage which regulates the transistor's output.

The PLCs monitor the track's segment block voltage by converting the 0 to 24 VDC operating voltage to 0 to 10 VDC using four meg-ohm resistors. Using a math function in the PLC, the scaled 0 to 24 VDC railroad

continued p. 22 >>



**FIGURE 6:** The ability to view trend information was vital to predictive and preventative maintenance of the system.

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track voltage is monitored. With Ohms law and the fact that a DC motor running with a steady load will look resistive to a steady-state DC supply, train engine operation can be effectively monitored. The resistance of the locomotive can also be determined, providing a solid representation of the power draw on the track.

This power draw information gives an indication of where there are continuity issues such as a dirty track. A lower voltage return indicates a higher resistive load. A threshold is set within the control system, and any reading higher or lower than the threshold will cause the train to shut down and send a text message to an operator's phone for immediate investigation.

The control system monitors the voltages continuously to catch overload issues, often before the circuit breaker trips. Rolling stock cars have axles that often wear and cause shorts, and inputs to the PLC's analog modules detect when that behavior is present and stops the train.

The supervisory control and data acquisition (SCADA) system was launched with the help of Steve Caar and Larry Koehl, volunteers from Greater Cincinnati Garden Railway Society. They helped transfer all the variables and resources needed from the old system to the new one. The new SCADA system consists of AutomationDirect's Point of View PC-based operator interface software with four web thin clients. Each thin client provides mobile access on Apple iPads or Microsoft Surface Pros. The SCADA system had just as much if not more programming time involved than the PLC programming, as it provides a comprehensive operator interface to the entire train system.

PEERLINK for Ethernet was used as the communication network, allowing all the PLCs to talk to each other, either directly or through the SCADA system. The PEERLINK instruction makes it simple to share data over Ethernet between multiple Do-more CPUs, with transparent data sharing using peer logic variables in a designated memory area.

## Train Program on Schedule

During the design stage, a test track was set up in a remote location and several months were spent coming up with solid, tested PLC programs.

State logic programming is the primary backbone for all the programs in this model train system. On the tracks themselves, there are magnetic sensors located throughout the entire track line, and some tracks may have up to 36 sensors. A rare earth magnet is mounted on both the front and the rear of each train to activate these sensors. Each time a magnet sensor is hit, the state of that particular train is changed.

From there, the programming possibilities are almost endless. For example, the system can detect if a train is broken in two simply based on if a magnet sensor is activated while the train is under a given state assignment.

If a train hits a sensor under incorrect state parameters, the system will shut down that train, preventing operating malfunctions or potential train collisions. A message will then be sent to the SCADA system describing the error and the location of the train. Usually within seconds, the problem is identified and a plan is established to correct the mishap.

## All Aboard

AutomationDirect was very helpful in providing troubleshooting techniques in the research and design phase of the project. Many people were involved in making this retrofit successful, both at our facility and at AutomationDirect, and results have exceeded all expectations.

Troubleshooting a train problem now takes minutes instead of hours. Receiving email alerts when there is a problem, rather than waiting for a guest to tell us, is also very helpful.

The new control system will pay for itself in just three years, and this doesn't take into account the improved operation, just the maintenance and repair savings. With the added motion sensors, run time on the trains is less than half what the old system was, more than doubling the life expectancy of the locomotives.

The most challenging aspect of the whole project was transitioning to the new control system one track at a time, so that only one or two trains were down during a given day. At the end of the line, with AutomationDirect and all the people who helped us at the facility, the train arrived at the station on time.



*Brian Kienlen has over 14 years of experience working with PLCs operating animation and coasters. Kienlen studied Aviation*

*Technical Engineering at Bowling Green State University in Ohio. In addition to Entertainment Junction, he works with the Kings Island amusement park equipment and animation, and at Rozzi's Fireworks for their pyrotechnic displays at Cincinnati Reds games.*

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- 32K color TFT displays are available in 4-inch, 6-inch, 8-inch and 10-inch models
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- Free programming software with simulator
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## NEW! Ethernet Communications Module (EA-ECOM):

- Adds Ethernet port for programming / PLC communications
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- Faster project download speed
- Faster firmware update speed
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# MACHINE PRODUCES NANOFIBERS FOR BIOMEDICAL RESEARCH

By Thomas Lemon, Bioengineering Major,  
Walla Walla University in College Place, Washington

If you can't buy it, you have to build it. This was the situation our group of engineering students encountered when we needed to grow vascular tissue for a bioengineering project at Walla Walla University, and found existing solutions were not acceptable.

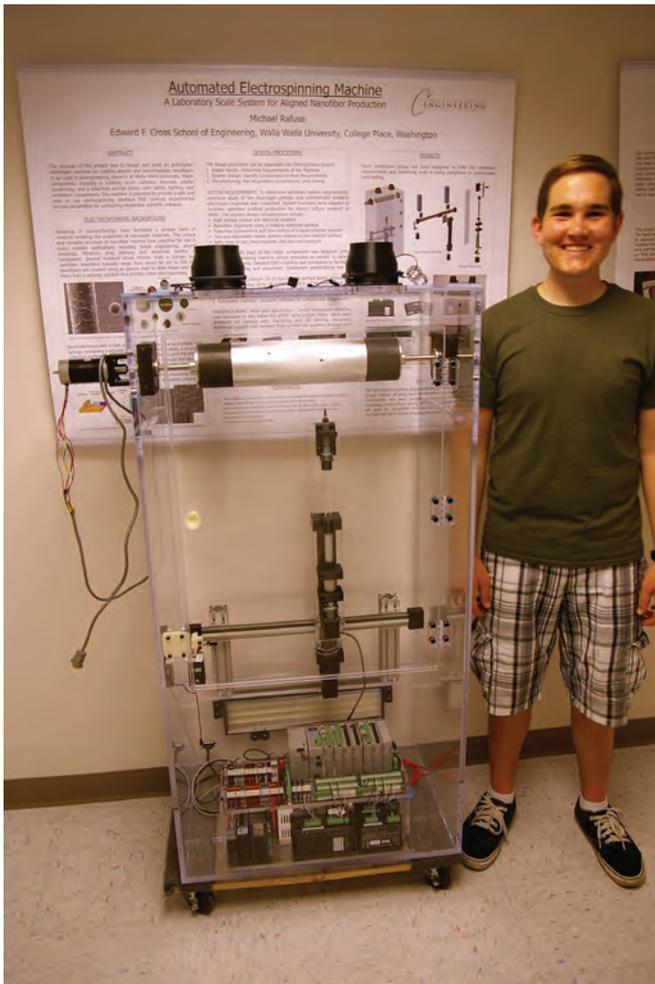
In addition to our team, others needed the machine for their research projects, which provided additional motivation. We built a new machine to meet our needs, and anyone involved in tissue engineering or biomaterials research at a university or a biotech company might find our method of nanofiber production (electrospin machine) particularly useful (**Figure 1**).

The electrospin machine is located at Walla Walla University (WWU), a private university founded in 1892, and home to the Edward F. Cross School of Engineering. The construction of the machine was initiated by Michael Rafuse, a graduate of WWU. The machine was his senior project, and he did the majority of the mechanical and automation system design, build and commissioning of the machine. I installed the operator interface, programmed the motion system and operator interface, and performed some experiments to optimize the machine for our polymer solutions.

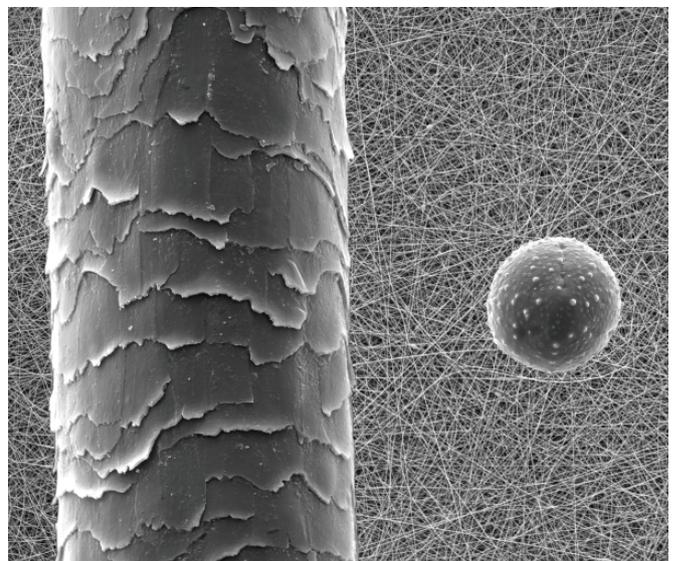
This is not a new process. Electrospin machines are widely used in the research community for producing fiber mats for culturing cells. These mats consist of tiny polymer nanofibers, each mere nanometers in diameter (**Figure 2**), which mimic the human extracellular matrix by providing a 3D structure, called a scaffold, where cells can grow into human tissue. The electrospin machine is used to make these scaffolds, which are then used to fabricate tissue engineered vascular grafts.

## Scaffold Construction

The electrospin machine uses a rotating drum collector to create a biocompatible aligned nanofiber mesh. Features include a syringe and needle automatically positioned in horizontal and vertical directions, and a tube-free syringe pump.



**FIGURE 1:** Electrospin machine with Michael Rafuse. The electrospin machine was designed and built by Michael as his senior design project at Walla Walla University



**FIGURE 2:** Hair versus nanofiber: The human hair on the left and the pollen grain on the right highlight how small nanofibers, shown in the background, actually are.

The machine provides a safe and simple interface for operation, and can be quickly modified as required.

Electrospinning requires high voltage, a grounded collection surface and a polymer solution to produce fibers as small as nanometers in diameter. The polymer solution is loaded into a syringe with a blunt-tip needle and a high voltage electrode is attached to the metal tip. The syringe is set at an adjustable distance, typically 20 cm away from a collection surface.

The collection surface is a rotating drum that is connected to an electrical ground. When the high voltage source is turned on it creates an electric field that induces a charge in the polymer solution, and repulsion forces propel the polymer solution towards the grounded collection surface. As the polymer flies through the air, the solvent evaporates and leaves a fine fiber

that is mostly dry when it reaches the collection surface.

A two-axis gantry configuration holds the needle and is positioned using stepper motors. One stepper motor is used to control the vertical distance between the collection surface and the needle tip, and a second is used to control the horizontal position of the tip. A third stepper motor is used to control the extrusion rate of the polymer solution flowing through the needle tip. The collection surface rotating drum is the fourth axis of the machine, and it is spun at speeds up to 4000 rpm using a brushless DC motor.

## Machine Control Components

The main automation system components are all AutomationDirect products and include a Productivity2000® programmable controller, a C-more EA9 series 10" touch panel human machine interface (HMI) and SureStep® stepper motors and drives. The controller, HMI, stepper motion control and related linear actuators enable precise and configurable control of the electrospinning process. AutomationDirect's Rhino power supplies (5V, 12V, and 24V), GCX series selector switches and pushbuttons, and ECX series indicator lights were also used.

The controller has a high performance CPU with plenty of memory, five communication ports including USB and Ethernet, and can control up to 480 local I/O points. We programmed it using AutomationDirect's free Productivity Suite programming software. This software allows user-defined tag-based programming for easy I/O naming, and provides task-based organization of ladder logic code. The electrospin process is primarily viewed and adjusted using the HMI. Several buttons, switches and indicator lights are also provided for control and status indication (Figure 3).

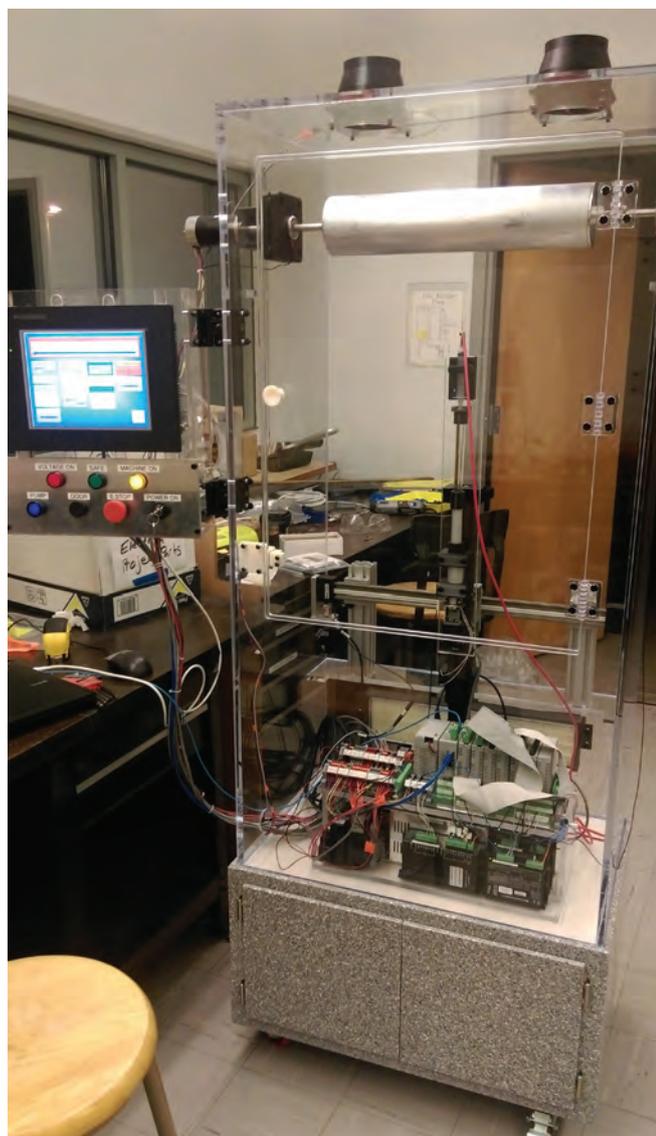
## Variable Electrospin Control

Many of the variables affecting the process and resulting fiber production are adjustable via the HMI. Variables need to be finely tuned to create consistent nanofibers with a particular surface morphology to meet research or application requirements. The rotating drum collector speed, needle positioning and syringe pump are the critical systems. Closely monitored and controlled and commonly modified variables include collector surface speed, needle-to-collector distance, polymer solution flow rate, and high voltage level.

The drum collector is rotated using a brushless DC motor and drive. Drum speed is set by a 0-5 VDC analog output from the controller, and direction is controlled via a discrete output. Speed control is closed loop, with feedback provided by hall-effect sensors. Drum starting and stopping, along with speed adjustment, is performed with the HMI.

Needle positioning can be varied using the horizontal belt drive and vertical screw drive slide table systems. Stepper motors power the slide tables and provide precise positioning control for horizontal and vertical movement. Horizontal and vertical travel distances are 50 cm and 25 cm respectively.

continued p. 26 >>



**FIGURE 3:** Adding HMI.

Peripheral devices such as the AutomationDirect C-more HMI are connected to the AutomationDirect P2000 to provide control and monitoring of the electrospin machine.

continued from p.25

The distance from the needle to the collection surface is one of the most significant variables in the electrospinning process. Position of the needle is controlled using a high-speed output module.

The syringe pump is the third critical system, and it consists of an electrically isolated syringe mount with precision adjustable flow rate control using a stepper motor and linear actuator. It is attached to the vertical screw-driven needle position slide.

The syringe pump uses a stepper motor and linear actuator to precisely control plunger movement; end-stop switches are installed in the linear actuator. Syringe flow rate is controlled using step signals sent from the controller to the stepper drive. Its target position is controlled using the HMI, and flow of the polymer solution is adjusted to maintain a droplet at the needle tip for uniform fiber deposition.

### Final Results

My part in the project included wiring of the peripheral equipment, controller programming and related tasks. Some mechanical fine tuning, primarily balancing of the rotating drum, made the machine operational. I then spent much of my time refining the stepper motor control logic and optimizing the electrospin process parameters. After taking the time to learn how best to operate the control system, and with some persistence, we've been running the equipment successfully since spring of 2016.

Ralph Stirling, the WWU professor involved with this project, comments. "The AutomationDirect Productivity 2000 controller and C-more touch screen are both fantastic units. I would love to upgrade all the controllers I use in my class to Productivity 2000s as they are significantly easier to program, especially for stepper motor applications."

The benefits of the new machine are significant and measurable. Larger and thicker fiber mats can now be produced, and our production rate has increased. The machine can also be modified to test different collection methods. With extensive testing of the machine in progress, much more fiber will be produced in the near future. ■

# BRAINTEASERS

## 1.) Ostrich Wrangling



An eccentric ostrich rancher claims that an enclosure made from four of his straight fence sections is just large enough to display one of his ostriches with relative comfort for the bird. One day he decides to take fifteen ostriches to the county fair. *Given the required amount of space that he has determined for each bird, what is the minimum number of these identical fence sections that he can use to contain the fifteen birds while at the fair?*

## 2.) Five Star Seamstresses



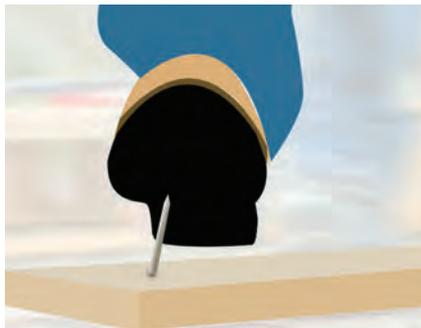
There is a way to fold a piece of paper (or cloth) so that a single straight cut will produce a five pointed star. *Can you figure out this fold-and-cut technique for yourself (no Googling)?* And a bonus trivia question: *This technique is commonly attributed to a famous American seamstress – any idea who that might have been?*

## 3.) Letter Boxing

A	B	C	D	E	F

If you try to fill up the remaining boxes in the grid above\* with additional copies of the letters A, B, C, D, E, and F, without having any two of each letter in the same row OR column OR on a diagonal with another, you may become frustrated – because it is not possible. *But how many of those letters CAN you place according to the constraints given?*

## 4.) Nailed it!



My friend Scott once worked for a telephony company, and he was directing a crew to install phone and other cabling for a large commercial account. The installation was in a new mall, prior to its opening, and there was a fair amount of construction debris lying around. As Scott walked through the future retail space pointing and explaining how the cables should be routed, he suddenly

stepped on a huge nail protruding from a board.

The nail came through at an angle and over an inch of the nail was visible sticking up from between the laces of his work boot. All the nearby workers gasped at the sight. But what they couldn't see – was that the nail had passed between Scott's big toe and the adjacent toe – and by some miracle, hadn't even broken the skin. Scott calmly placed his other foot on the board to hold it down, and wrenched his perforated boot from the nail. The onlookers were sure that a trip to the hospital was in order, but Scott simply pointed back up to the ceiling and said, "Now make sure to pass the cables to the left of that ductwork..." and continued as though nothing had happened. His co-workers found new respect for his grit and work ethic.

\*This issue's puzzles are based on the work of Henry Ernest Dudeney (1857-1930) – any errors are ours.

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