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## DEPARTMENTS



### DESIGN & AUTOMATION



## FEATURES

### COVER STORY




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**Eric Brothers** // Editor // EBrothers@gie.net

# Where manufacturing CFOs are focusing now

Last April, I shared the results of a BDO survey of manufacturing chief financial officers (CFOs) and what they viewed as important to increase supply chain resilience. Their strategies included reshoring, improving talent availability, and leveraging tax credits. This year's survey reveals manufacturing CFOs are now focusing on accelerating growth, shifting from defensive, lean operations to go on the offensive with strategies aimed at growing revenue and improving profitability. (For more details, see this month's Gaining Altitude, page 11.)

Again, I asked BDO's Manufacturing Industry National Leader Bill Pellino to explain what changed CFOs' priorities.

He believes the need for resiliency hasn't changed, but there's more uncertainty about reshoring, near-shoring, or friend-shoring.

"The question now is where and why do you want to move your supply chain?" Pellino says. "We're finding it's more about strategy and whether the reason is proximity to customers or suppliers and securing your supply chain." The survey was conducted before tariffs became top of mind, but Pellino notes, "With tariffs, or the threat of tariffs, manufacturers want to know the rules and what they need to plan appropriately." Uncertainty may explain why supply continuity and access to materials remain the top supply chain challenges.

Has there been any incremental improvement in the talent shortage? "This isn't a problem that can be fixed easily," Pellino replies. "It's a challenge manufacturers are going to need a lot of different strategies to solve."

One strategy is automation, Pellino notes. "In the past two to three years, a lot of investments have been made in automation to fix internal processes, and that's why we're optimistic 2025 will be a year where we shift from defense to offense as companies look to grow profitably, rather than spending on resiliency."

Pellino says leveraging tax credits is still underutilized. "One of the biggest opportunities manufacturers have is taking advantage of tax credits and incentives available on the state and local level. Think about opportunities to reduce total tax liability, rather than just thinking about federal and state income tax or franchise tax. Too many companies think of it at the end of the year when it's too late."

Artificial intelligence (AI) figures prominently in the new survey. About 63% of respondents have used generative AI. Pellino cites as a good use case a company using generative AI to translate supervisors' instructions into multiple languages simultaneously so workers can hear them in their own language. Using AI increases productivity and throughput.

Pellino advises manufacturers to make sure to start with the strategy. Automating something that doesn't need it won't move your business forward; for example, using AI to help with predictive maintenance on a machine that rarely goes down because it's already well monitored. "Is that a strong use case? Make sure what you're doing is something that's impactful for the organization." What he's already seeing is the adoption of AI in finance and the back office, which positively impacts revenue and profitability. – *Eric*

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## BAE Systems completes acquisition of Ball Aerospace

BAE SYSTEMS

Ball Aerospace has become BAE Systems' Space & Mission Systems business. The acquisition from Ball Corp. brings space, science, and defense capabilities, adding more than 5,200 U.S. employees.

Ball Aerospace brings customers in the intelligence community, U.S. Department of Defense, and civilian space market.

Its history dates to 1956 when Edmund F. Ball, son of one of the founders of Ball Corp., partnered with physicists from the University of Colorado to create the aerospace segment later known as Ball Aerospace. The company began building pointing controls for military rockets and later won a contract to build NASA's first spacecraft, the Orbiting Solar Observatory (OSO-1) satellite. The company also built visual imaging cameras launched aboard NASA's Voyager I, delivered corrective optics to repair the Hubble Space Telescope, built the Kepler planet-hunting spacecraft, and developed the advanced optical technology and lightweight mirror system of the James Webb Space Telescope.

In August 2023, BAE Systems proposed acquiring Ball Aerospace for approximately $5.55 billion and received regulatory approvals to complete the acquisition in February 2024. https://www.baesystems.com

## Appointments


Morris

Cloud software company **iBase-t** appointed **Chris Morris** vice president of professional services. He has more than 30 years' experience in professional services, customer success, and enterprise software sales. Before transitioning to enterprise software, Morris began his career as a design engineer and project engineer at Pratt & Whitney. https://ibaset.com

**The L.S. Starrett Co.**, manufacturer of precision metrology systems, appointed **Roger N. Amrol Jr.** as president and chief executive officer (CEO), **Barry D. Laughlin** as chief operating officer (COO), **Allen E. Look** as global chief information officer (CIO), and **Jon-Michael Raymond** as chief revenue officer (CRO).

PHOTOS COURTESY OF RESPECTIVE COMPANIES


Amrol


Laughlin


Look


Raymond

Amrol joins the organization from Robert Bosch Tool Corp. North America where he was president and CEO and succeeds Douglas A. Starrett whose career with Starrett spanned 48 years as president and CEO.

Laughlin was most recently COO with Group DEKKO. Previously he was with Navistar for 26 years; his last position was director of global manufacturing and custom products.

Look brings more than 25 years of information technology experience with skills in data analysis and cybersecurity.

Raymond brings more than 17 years' experience in industrial markets where he's held sales and finance roles and was previously Starrett's North American sales and marketing director for industrial products. https://www.starrett.com

**OnRobot**, a provider of robotic systems programming software, appointed **Tom Herndon** as sales manager for the Americas and Canada. He brings 25 years of experience in manufacturing and automation. https://onrobot.com


Herndon

Enterprise cloud and industrial artificial intelligence (AI) software provider **IFS** appointed **Matt Breslin** as president, North America, to take over the position from David Spencer as he retires. Breslin joins IFS from Upland Software where he held the position of chief revenue officer (CRO) and led functions including sales, marketing, strategic alliances, and customer success. https://www.ifs.com


Breslin

# UNDERSTANDING CNC WHEEL DRESSING MACHINES

**BY ERIC SCHWARZENBACH**

*About the author: Eric Schwarzenbach, founder of MyGrinding Inc., retired as president from Rollomatic Inc. – global builder of CNC grinding and laser cutting machines.*

In the grinding industry, CNC superabrasive wheel dressing machines are gaining widespread adoption. Traditionally, wheel dressing was performed manually, requiring skill and precision. However, CNC technology offers a more efficient and precise alternative.

A quick note on truing vs. dressing: While truing restores a grinding wheel's geometry, dressing maintains its cutting ability. In practice, however, the two processes often happen simultaneously. Whenever a worn diamond or CBN wheel is removed for dressing, it undergoes truing and dressing. Eventually, the wheel's shape becomes uneven due to wear, while grinding debris and swarf accumulate, clogging the surface and preventing worn diamond crystals from shedding. As a result, what's commonly referred to as the dressing process is both truing and dressing.

The market offers two types of CNC dressing machines: semi-automatic and fully automatic. Semi-automatic machines are typically used for single-wheel dressing and require an operator to be present during the process. Fully automatic machines feature additional CNC axes, allowing for complete automation without manual intervention. These machines are capable of dressing entire wheel packs – multiple wheels mounted on a single arbor, commonly used in tool grinding.

The dressing wheel is made from conventional abrasives, typically aluminum oxide (white) or silicon carbide (green). During the dressing process, both wheels rotate against each other at different peripheral speeds.

The wear ratio between a diamond grinding wheel and the dressing wheel is influenced by several factors, including linear and rotary speeds, abrasive type, and bond material. In general, the wear ratio between the dressing wheel and the superabrasive wheel ranges from 10:1 to 100:1, meaning the dressing wheel wears 10x to 100x faster than the superabrasive wheel. However, this wear is inconsistent and difficult to predict with precision. Ensuring accuracy in fully automatic machines requires continuous compensation. This is achieved through automatic gap detection using an acoustic emission (AE) sensor to detect contact between the wheels. This detection process must be performed after every dressing pass to maintain optimal performance.

CNC programming for a fully automated dressing process requires pre-measuring the wheels before dressing. Then, the operator must input the desired final shapes into the control system. Most automatic multi-axis machines can precisely dress angles and radii, achieving seamless intersections between the two.

An essential step in the automatic dressing process is the final preparation of the bond. During dressing, the bond is eroded to allow worn diamond crystals to detach, but the process also leaves the wheel's surface closed, limiting its grinding efficiency. To restore optimal performance, new, sharp crystals must protrude from the surface – a process known as opening or sharpening. CNC dressing machines can achieve this by adjusting the rotary speed parameters of both wheels after dressing.

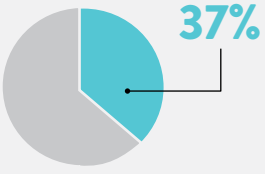
Finally, these machines require a continuous supply of coolant oil to ensure optimal performance. Due to the high volume of conventional abrasive grits produced during the dressing process, paper filtration systems are typically used to maintain clean and efficient oil filtration.

**MyGrinding Inc.**
https://www.mygrinding.com

Do you have any manufacturing challenges? Email me so I can address them in a future column: eschwarzenbach@mygrinding.com.

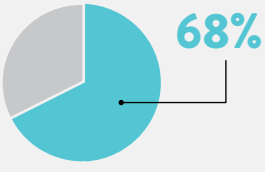
# MANUFACTURING
## CHIEF FINANCIAL OFFICER OUTLOOK

### HIGHLIGHTS



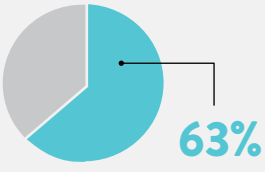
37%

WILL INCREASE INVESTMENT IN U.S. EXPANSION



68%

EXPECT REVENUE TO INCREASE



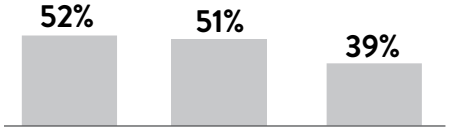
63%

EXPECT PROFITABILITY TO INCREASE

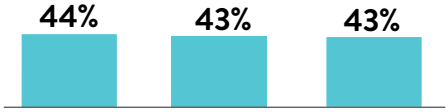
25% expect their profitability to increase by at least 10% this year

BDO's latest survey found manufacturing leaders transitioning from defensive, lean operations to offensive, growth-oriented strategies.

### TO GROW REVENUE




### TO IMPROVE PROFITABILITY



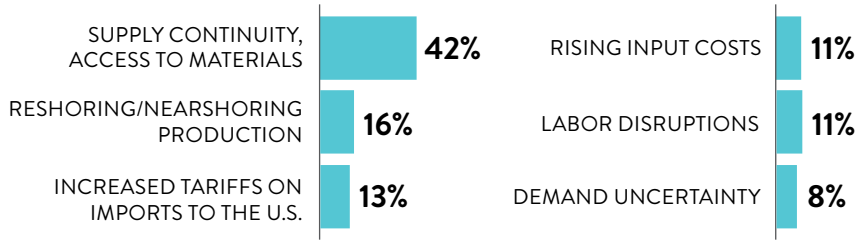

### BARRIERS TO USING DATA TO DRIVE BUSINESS DECISIONS

**34%** report lack of a codified data security program

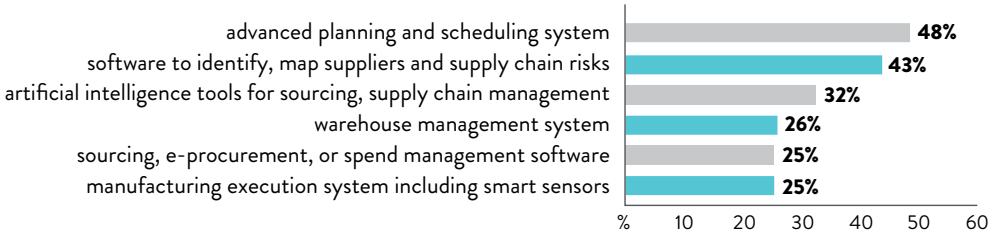
**32%** cite data quality and/or governance issues

**29%** say lack of leadership buy-in/ support for technology initiatives

### SUPPLY CHAIN CHALLENGES




### SUPPLY CHAIN TECHNOLOGY INVESTMENTS




Source: https://www.bdo.com/insights/industries/manufacturing/2025-bdo-manufacturing-cfo-outlook-survey

ICONS: ADOBE STOCK

## ASK THE EXPERT

# QUESTIONS WITH MARKUS LÖHE

Schwäbische Werkzeugmaschnen GmbH / SW-Machines' Global Key Account Manager – Aerospace talks about how SW can help with challenges aerospace manufacturers face.

**1 What are some of the circumstances presenting challenges for today's aerospace manufacturing companies?**

After Covid, aircraft manufacturers tried to ramp up the monthly production. However, it has been very challenging for the supply chain to follow this attempted ramp-up. Due to the rising material, labor, and incidental cost there's a big need for more productive manufacturing systems. Finding the right machine tool partner is key to helping increase manufacturing for precision parts in the aerospace industry.

**2 What technologies are available that can help manufacturers navigate these challenges?**

SW delivers technology such as high-speed multi-spindle and 5-axis milling machines that enable increased production by more than 50% through investing in the right machining technology. Our machine technology enables manufacturers to economically produce interior components, structural components, wing ribs, turbine blades, and more with precision and reproducibility.

**3 What challenges can be overcome by incorporating automation into the aerospace manufacturing process?**

A safe process is paramount in the aircraft industry. As a global market leader for multi-spindle machining centers SW smart manufacturing systems offers manufacturers a fully automated solution that can run 24/7 with important features such as traceability and data-driven insights for every component produced and for every processing step. SW's Smart Manufacturing Solutions offer our customers the perfect mix of standardized and highly customized elements.

**4 What can a customer expect from a partnership with SW as their manufacturing solutions provider?**

Manufacturers that partner with SW will have a long-term partnership with a machine tool builder that delivers the best cost per part calculation. In addition, SW delivers technology and service support at the highest level – support throughout the entire lifecycle of the machine. SW offers the right production solution for every workpiece.

**5 What differentiates SW machines from other machine tool technology in the market?**

SW machines are among the fastest machines on the market. They have very high acceleration values of up to 2g and rapid traverse speeds of up to 120m/min. With SW, users reduce non-productive times and increase productivity. This high production speed combined with a weight-optimized design ensures minimal non-productive times compared to axes with servo motors, allowing users to manufacture parts highly productively with the shortest cycle times. Users can produce 5-axis components made of aluminum, titanium, alloys, hybrid materials, or carbon without microcracks or stresses in the components, delivering quality parts time and again.

**For more information**

https://sw-machines.com/us/industries/aerospace/

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Edited by Clare Scott

# Software-based cell control technology TARGETS THE USER EXPERIENCE

Mazak's PMC NEO allows shops to maximize output of the company's PALLETECH automation cell.

Mazak PALLETECH system

PHOTO COURTESY OF MAZAK

The roots of palletized cell controller systems have remained similar in nature for quite some time in terms of functionality and optimizing cell throughput. Most provide for scheduling what pallet goes into which machine and when, but older legacy systems typically involved macro-based programming for doing so, while today's systems are now software based.

Software-based systems have opened the door for significant functionality enhancements, and during the past decade, many cell-controller enhancements have targeted the user experience. Through the incorporation of graphical user interfaces, machine tool manufacturers such as Mazak have made palletized cell controllers much more user-friendly and capable due to advancements in cell scheduling and setup, 3D simulation, and remote connectivity.

## Introducing the PMC NEO

Mazak's PMC NEO software-based control allows shops to further maximize output of the company's modular, pre-engineered PALLETECH automation cell. The software helps shops create a schedule and prioritize jobs within that schedule. It'll also look ahead within the schedule and check that all necessary requirements – such as tooling, material, and fixturing – for the jobs are in place, and will notify operators if anything is missing or needs attention.

The software's display/navigation bar provides simple workability for data input. It allows users to easily refer to information, and it displays items required for data registration with red asterisks. In case of input errors, a caution message appears, prompting an input correction.

To streamline entered data searching and organizing, PMC NEO software provides a searching bar and sorting function. If the user wants to delete unnecessary data, they simply check the modified date, and the software records the date and time when that data was changed or used for automatic operation. This helps users decide if they should delete the data.

The PMC NEO's touch screen also displays a 3D simulation of a shop's PALLETECH cell. This allows users to manipulate the image, making the system layout more understandable for improved data input. With the PMC NEO's Smooth Simulation function, shops can check machining progress and tool resources for up to one week in advance during automatic operation, which is beneficial for long-term unmanned operation.

For cell pallet setup and to ease operator burden, PMC NEO's setup guide display provides a continuous 12-hour simulation based on actual operation and displays notices in chronological order of setup work at PALLETECH loading stations. A dedicated touchscreen shows when a pallet arrives at the station, then displays photos and instructions on how to load and fixture the job for that pallet. There's also a feature that'll notify the operator as to which pallet is coming next to the loading station so they can be prepared for it with any special tools or material.

## Stay connected

When shops connect PMC NEO software to their enterprise resource planning system for instance, they can remotely schedule and control the PALLETEC cell using an office PC and view schedule

information from a tablet or smart device.

When problems are found in the system, early detection and restoration is possible through the PMC NEO's Notice application sending notifications to a smart device. The software's Set-up Starting Time application shows when it's time to start the next setup, allowing operators to perform the task promptly.

The PMC NEO Alarm Notification application notifies shops in the event of an alarm on the machine or system. This eliminates the need to constantly monitor the system because operators receive the alarm number on their smart devices.

### Managing data, jobs

A growing number of shops are tying their cell controllers into larger enterprise-wide systems, reducing the need for highly skilled personnel on the shop floor adjusting cell schedules. Plus, one individual can schedule multiple pallet cells if needed.

In high-volume production of the same workpiece/job, the amount of input data when creating a schedule is relatively small, but in high-mix, low-volume production, the amount of input an operator must load increases significantly. Using the PMC Open Database Kit of the PMC NEO software and connecting to a host system, shops can automatically enter parts and schedule data normally entered manually.

In the past, when connected to a host system, cell software couldn't retain pallet data if the pallet was removed from the system so it was deleted. However, with Pallet Management Outside the PMC feature, the PMC NEO system keeps such data even after a pallet is removed, eliminating the time and repetition of re-registering the data if a pallet is brought back into the system.

Additional features of the PMC NEO include a Tool Carry system and Material Supply function. Tool Carry is designed for oversized tools or exceeding a machine's tool magazine capacity. The system automatically retrieves and returns these non-standard tools stored in a special stocker within a PALLETECH cell.

Material Supply is used for raw material management. Shops can store basket-type workpiece pallets within the PALLETECH cell, reducing the need for temporarily storing materials on the floor.

Automated palletized cell controllers continue to advance as machine tool original equipment manufacturers incorporate software-based technology. These controls improve the operator experience, making the job easier and less time consuming while also optimizing the efficiency and output of palletized cells. D&A

**Mazak Corp.**
https://www.mazak.com

# Vertical machining center with integral rotary 2-APC

The MF-46VA vertical machining center (VMC) offers a double-column structure with an integral rotary 2-pallet automatic pallet changer (2-APC) for high accuracy and high production in a compact footprint. Thermo-Friendly Concept is standard on this machine for dimensional stability throughout long, continuous runs. The VMC is equipped with a high-speed, high-power 40-taper 8,000rpm spindle with a 15hp liquid-cooled integral motor. Its rotary style 2-APC requires less space than shuttle-style APCs. A high-speed 20-position automatic tool changer (with options for 32 or 48 tools) features 1,574ipm rapid traverse. Tool breakage detection and auto tool compensation check the integrity of tools to maintain high-quality parts and less scrap generation. Twin augers remove chips from the machine tool quickly in high-production, automated environments.

**Okuma America Corp.**
https://www.okuma.com


PHOTO COURTESY OF OKUMA AMERICA

## At-a-glance

**Max machining volume:** 30.00" x 18.11" x 18.11" (762mm x 460mm x 460mm)
**Table size:** 29.92" x 18.11" (760mm x 460mm)
**Spindle speed:** 6,000rpm [12,000rpm optional]
**Spindle motor power:** 15/10hp (11/7.5kW)
**Pallet size:** 29.92" x 18.11" (760mm x 460mm)
**Footprint (W x D):** 94.72" x 129.00" (2,406mm x 3,277mm)
**CNC control:** Okuma OSP open-architecture operating system

Download the MF-46VA SPEC 48 flyer for detailed equipment information, highlights, and specifications.


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Part of the 30th anniversary celebrations, the Taipei 101 skyscraper featured a TIMTOS light show. PHOTO CREDIT: TAITRA

# TIMTOS 2025

## TAIWAN'S MACHINE TOOL SHOW EMBRACES 'INTEGRATE TO INNOVATE' THEME.

By Eric Brothers

Celebrating its 30th edition since 1975, the Taipei International Machine Tool Show (TIMTOS 2025) brought together more than 1,000 exhibitors in 6,100 booths across three venues. Co-organized by the Taiwan External Trade Development Council (TAITRA) and the Taiwan Association of Machinery Industry (TAMI), the six-day event in March welcomed 4,163 international buyers from 90 countries – a 5.1% increase from the previous edition.

Unified by the theme Integrate to Innovate, the event focused on the numerous ways in which artificial intelligence (AI), smart manufacturing, and green sustainability could be brought together by precision machine tools using intelligent automation, digital twins, in-process metrology, expanded machine monitoring, machine vision, and energy saving components to reduce carbon emissions.

The importance of the event was evident by the presence of Dr. Ching-te Lai, president of Taiwan, during the opening ceremony. In his remarks, Lai said the attendance of more than 1,000 exhibitors shows the machine tool and manufacturing industries in Taiwan are growing ever stronger.

PHOTOS BY ERIC BROTHERS UNLESS NOTED



## Onboard with AI

James C.F. Huang, TAITRA chairman, said AI and automation are key to the next wave of industrial transformation, but industrial progress lies not only in technology but also in the next generation of AI talent.

David Chuang, TAMI chairman, whose 2,700-member strong organization is celebrating its 80th anniversary this year, noted TAMI has a history of promoting AI applications and net-zero carbon emissions and will work to help keep the industry in sync with international trends.

Raymond Greene, director of the American Institute in Taiwan, Taipei office, noted Taiwan is entering another age of innovation with AI. He emphasized the many economic ties between Taiwan and the U.S. and added the supply chain offers investment opportunities from both sides.

Dr. Jyh-Huei Kuo, Taiwan's minister of economic affairs, noted AI and automation can help solve the labor shortage and improve product quality.

## Keynotes

The second day of TIMTOS 2025 featured keynote presentations from THK Chairman & CEO Akihiro Teramachi, who spoke about the role of manufacturing in the AI era and what it'll take to develop the talent resources needed. Techman Robot CEO Haw Chen introduced Taiwan's collaborative robot (cobot), developed from a vision-based robot arm transformed by AI to create a range of future smart robots. The addition of AI expands the cobots' ability to position, identify, and measure parts with capabilities to inspect, classify images, and detect anomalies and be integrated

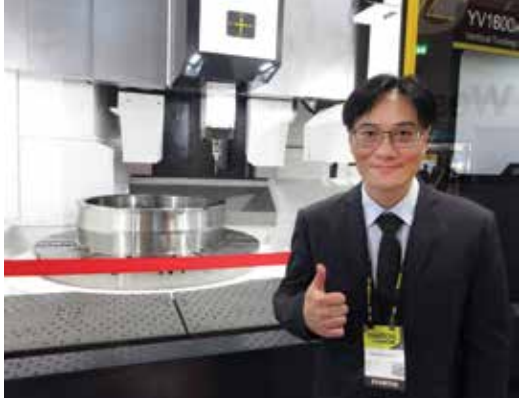
**CLOCKWISE FROM TOP LEFT:**
**Dr. Ching-te Lai, president of Taiwan, attended TIMTOS' opening ceremony.**

**Richard Wang from Dah Lih with the company's MCV-1050 vertical machining center and manufacturing cell. Its X-axis travel is 1,050mm, Y-axis 560mm, and Z-axis, 560mm. A maximum 8,000rpm spindle is standard and it produces rapid traverse rates of 36m/min in the X- and Y-axis and 24m/min in the Z-axis.**

**Elyn Huang, Palmary Machinery sales manager, describes the PCB-3015-3 CNC centerless grinding machine. Palmary Machinery Co. Ltd. (Palmary America in the U.S.) offers centerless, cylindrical, internal, vertical, surface, and special purpose CNC grinding machines.**

with autonomous mobile robots (AMR). By integrating more sensors to see and AI to think, Chen explained robots can act to perform tasks throughout a factory in a real-time, closed-loop system. AI will drive smart manufacturing with layout, programming, and simulation with digital twins and provide quality data for training and deployment. Chen added future robots will be more flexible and more intelligent, allowing inspection and assembly with low-complexity setup.





You Ji's Jerry Wu with the YV1600ATC+C vertical turning center, suitable for machining jet engine casings.

Hitoshi Yoshida, chairman and CEO of Tokyo Seimitsu Co. Ltd. and chairman of the Japan Precision Measuring Instruments Manufacturers Association, spoke of the ongoing trend of shifting measurement from the inspection room to the production site. Automation using robots will enable 100% inspection of all parts as they're being produced, a process reduced from minutes to seconds by non-contact optical roughness measurement.

Paul Chen, VP business development of Fair Friend Group (FFG) MAG Automotive, based in Michigan, spoke about implementing innovative strategies to achieve exceptional results. Christine Herbst-Kubitz, GM, Siemens Taiwan Digital Industries stressed how integrating real and digital worlds via AI and digital twins allows manufacturers to readily scale up operations. All four speakers participated in a forum answering attendees' questions.

## Exhibits

In the two Nangang Exhibition Center (TaiNEX) exhibit halls, national pavilions featuring the United States, Germany, and Switzerland shared space with Taiwan-made machine tools. The U.S. pavilion included representatives from Pennsylvania and West Virginia, along with familiar international brands in machining, cutting tools, and software: Mastercam, OSG, Rollomatic, Siemens, Heidenhain, FANUC, Mazak, and Mitsubishi. Domestic companies included TTGroup, Quaser Group, Vision Wide, YCM, You Ji, and Chmer, plus Palmary, Charles Machine, Kinwa, Wei Hong, Alex-Tech, and Ken, among others.

During TIMTOS, the 17th ceremony of the Taiwan Machine Tool Industry Awards for Excellence in Research and Innovation presented Dah Lih Machinery

PHOTOS BY ERIC BROTHERS UNLESS NOTED

Industry Co. Ltd. the award of eminence for its DMC-650 portal-type machining center and manufacturing cell.

Dah Lih, founded in 1960, is a Taiwan machine tool manufacturer of vertical, horizontal, double-column, and 5-axis machining centers. Richard Wang of Dah Lih's international operations department explains the cell's smart automation reduces cost, increases production efficiency, and improves product quality.

"Smart automation isn't as simple as replacing human labor with automation," Wang says. "The premise is mechanical equipment must have intelligent capabilities such as fault prediction, precision compensation, and automatic parameter setting, plus machine networking, data collection and analysis, and intelligent manufacturing process improvement." He adds the company has also been committed to developing software for intelligent operation, energy saving, and carbon reduction for environmental sustainability.

"In addition to smart software for single machines," Wang says, "Dah Lih Machinery has developed its own iMonitor remote monitoring software that can connect machines through a network to achieve visibility in factory management."

Other energy and carbon saving improvements include smart meters that can generate statistics to provide machine operators with reference data on power consumption. Adaptive feedrate control and energy saving – where the hydraulic motor and spindle cooling unit stop running in standby mode and the oil injection interval is ignored when the machine isn't running – are other functions that can save processing time and reduce $CO_2$ emissions.

Techman Robot CEO Haw Chen.

Jerry Wu, deputy section manager for overseas sales at You Ji, says automation is frequently integrated into machine tools for faster cycle times to increase production. You Ji makes vertical and horizontal grinding machines; vertical milling, turning, and grinding machines; and vertical and hori-

zontal lathes. You Ji's vertical turning center YV1600ATC+C has a 1,600mm table diameter and maximum turning diameter of 1,800mm with 16-tool automatic tool changer (ATC) while the YV800ATC+C has a 32" 3-jaw hydraulic chuck and 900mm maximum turning diameter with a 12-tool ATC.

## Successful matchmaking

TAITRA's potential purchaser matchmaking event during TIMTOS enabled 315 sessions between 75 international customers from 22 countries and 102 exhibitors. Buyers came from the U.S., Canada, Mexico, Brazil, Germany, France, Italy, Spain, Japan, Poland, Vietnam, India, Israel, and Ukraine. A specialized networking event for the cutting tool sector introduced buyers from 14 countries, including the U.S., Germany, Mexico, and India. Exhibitor MEGA Machine reported a 70% order placement rate, with instant orders from Bulgaria and the Middle East, according to TAITRA.

New to the show, the Taiwan Excellence Pavilion and Taiwan Patent Go Pavilion showcased Taiwan's innovation in smart machinery and cross-industry applications. These pavilions attracted significant interest from international buyers, the show's organizers reported.

The next TIMTOS is scheduled for March 2027 in Taipei. **A**

**American Institute in Taiwan**
https://www.ait.org.tw

**Dah Lih Machinery Industry Co. Ltd.**
https://dahlih.com.tw/en

**Palmary Machinery Co. Ltd.**
https://www.palmary.com/en

**TAITRA**
https://www.taitra.org.tw/en

**TAMI**
https://www.tami.org.tw

**Techman Robot**
https://www.tm-robot.com/en

**TIMTOS**
https://www.timtos.com.tw/en/

**You Ji Machine Industrial Co. Ltd.**
https://www.youji.com

*About the author: Eric Brothers is editor of GIE Media's Manufacturing Group publications. He can be reached at 216.393.0228 or EBrothers@gie.net.*

## Grooving tool

The Groov·tec GD G5011 grooving tool body accepts double-edged GD26 cutting inserts with a double serration clamping profile for positively secure locking in the insert seat, increasing the stability and process reliability. In addition to longitudinal and copy turning, the tool is suitable for a variety of applications, including radial grooving, recess turning (groove turning), offset grooving, chamfering, parting off with an inclined edge cutting insert, and parting off with a straight cutting insert. Geometries CE4, CF5, and CF6 are for parting off and grooving; UA4, UD4, and UF4 for parting, grooving, and groove turning; and RD4 and RF8 for operations using the full radius.

Inserts are available for grooving widths of 2.5mm, 3.0mm, 4.0mm, 5.0mm, and 6.0mm. Indexable insert clamping can be operated from both sides. For optimum tool stability, there are two grooving depths of 12mm and 21mm. The corresponding tool holder shank sizes are 0.625", 0.750", and 1.00" as well as 16mm x 16mm, 20mm x 20mm, and 25mm x 25mm.

The new serration profile and precise coolant delivery to the tool/workpiece interface enables increased cutting parameters, and the tool can be used with or without cooling.

**Walter**
https://www.walter-tools.com/us

## Pro version Scan-to-CAD software

The Scan-to-CAD Pro application module integrated within the Creaform Metrology Suite can streamline and enhance reverse engineering workflows more concisely.

3D scan data processing software creates a simple, easy-to-use bridge between the 3D scan acquisition and CAD or 3D printing software. The Pro module comes with advanced algorithms to extract information from meshes, flexible alignment, optimized mesh editing tools, and enhanced selection capabilities.

With 2D sketching and 3D modeling tools, the software serves as a gateway between 3D scanning and CAD software. It speeds up the process of converting a 3D scan data to a mesh to a highly detailed CAD model, and in some cases even allows for the complete workflow to be done within the software module.

**Creaform**
https://www.creaform3d.com

## Twin-spindle, CNC turning center


Designed for bar-fed machining applications, the Muratec MT1065EX features two spindles and two live-tool turrets, with Y-axis functionality in the upper turret for versatility. It accommodates 6" or 8" chucks powered by an 18.5kW left spindle motor and a 15kW right spindle motor for demanding applications.

Each turret offers 12 tool stations with 24 index positions, allowing independent machining operations or synchronized pinch-turning and milling. The MT1065EX's compact design optimizes floor space.

**Murata Machinery USA Inc. (Muratec USA)**
https://www.muratec-usa.com

### Key features

- **Thermal compensation system:** 11 sensors allow for long-term stability, accuracy during extended operations
- **Versatile axis configuration:** Both turrets can access either spindle for operational flexibility
- **Advanced software:** Simplifies programming, optimizes tooling paths for reducing material waste, integrates production scheduling, provides real-time monitoring
- **Compact, flexible design:** Configurable chip conveyor supports right-side or rear discharge

PHOTOS COURTESY OF RESPECTIVE COMPANIES

# EMBRACING AI IN AEROSPACE MANUFACTURING

## Data-driven decision making with iBase-t's Solumina artificial intelligence (AI) platform.

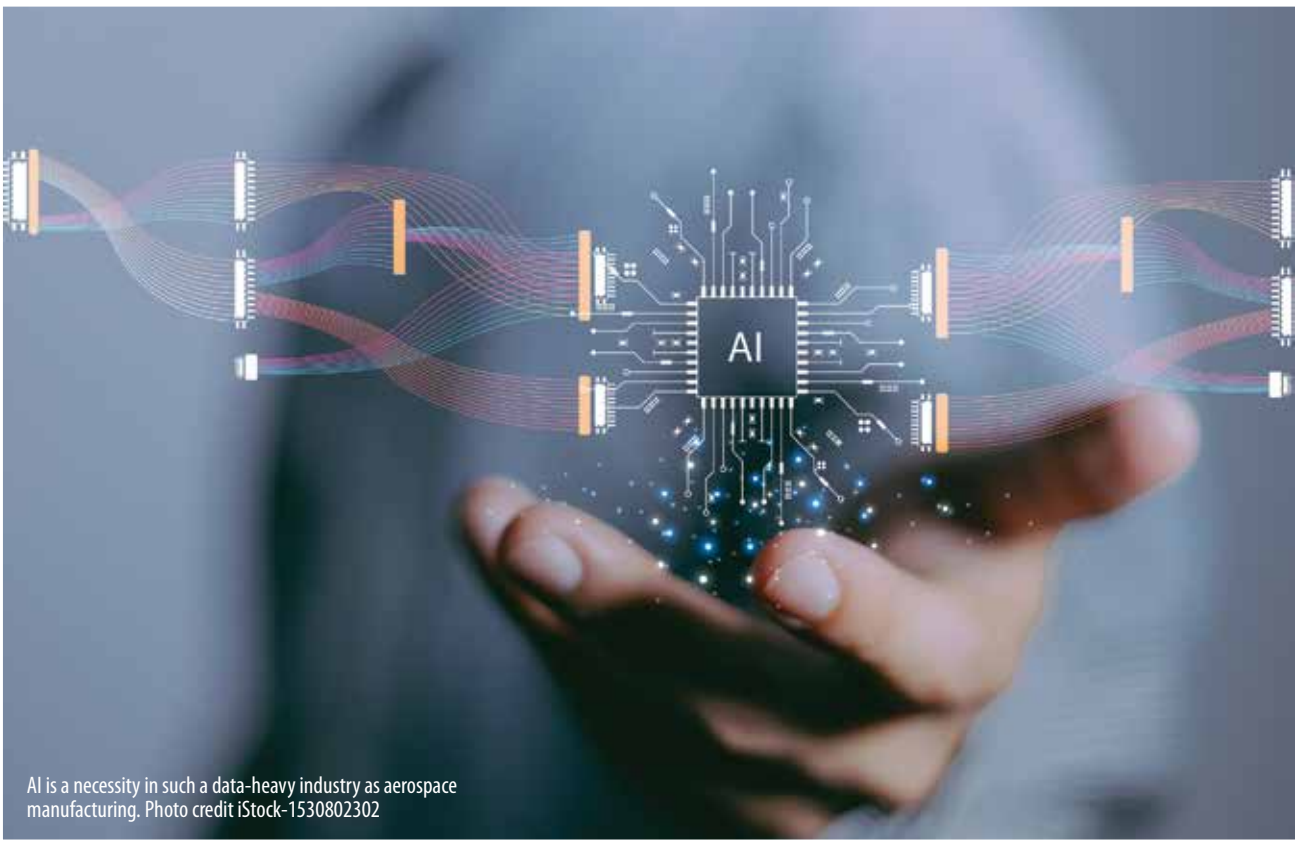
By Clare Scott

Ask anyone in manufacturing what the future of the industry looks like and you're likely to get one answer: automation and artificial intelligence (AI). While many have legitimate concerns about the technology – i.e., will it replace human workers? Does it have the potential to be dangerous? – it's clear that to survive in the industry, manufacturers must shift their thinking toward automation and AI.

"AI is not going to replace you, but you're going to be replaced by someone who knows AI," says Sung Kim, chief technology officer at cloud software developer iBase-t.

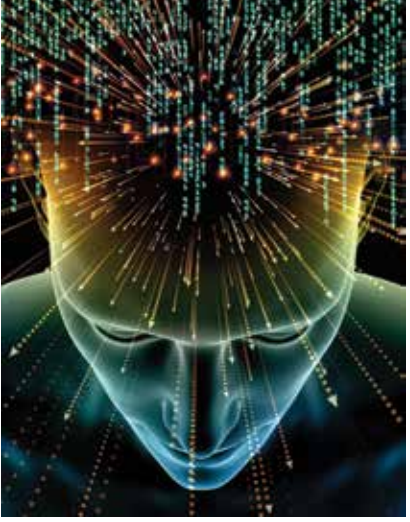
It's a blunt truth, but it's true, especially in such a data-heavy, competitive, highly regulated industry as aerospace manufacturing. When it comes to processing and tracking all that data, AI is a necessity.

iBase-t's flagship product, Solumina, is a manufacturing operations platform to help manufacturing companies, particularly in the aerospace & defense sector, simplify their operations, ensure precision, and standardize production processes through advanced technology. Toward the end of last year, the company introduced an AI element into the platform. Solumina AI includes a digital assistant, large language model, Industrial Internet of Things (IIoT) integration, and other features for process optimization.




AI is a necessity in such a data-heavy industry as aerospace manufacturing. Photo credit iStock-1530802302

PHOTOS COURTESY OF IBASE-T UNLESS OTHERWISE NOTED



Even sophisticated AI requires human oversight. Photo credit iStock-1156272127

### A digital knowledge base for each company

The decision to pursue AI-based solutions was an easy one for iBase-t.

"The great minds in aerospace and defense manufacturing are retiring with the tribal knowledge they've gained for decades," Kim says. "You don't want to lose that data, and it's going to take a lot of resources, time, and budget to retrain the younger workforce. So this is a really great time to put that domain knowledge into a scalable format, which is AI models."

While Solumina AI leverages generative AI, it's specifically designed to be trained on the user's manufacturing data rather than public data, making it a knowledgeable manager for shop floor operations. It integrates with product lifecycle management (PLM) and enterprise resource management (ERP) software, as well as gathering data from operational technology (OT). These integrations allow it to track production steps, material origins, and everything else involved in the manufacturing process to create a detailed digital thread.

Many aerospace manufacturers are gravitating toward this type of vertical generative AI, Kim says, as well as the more active, autonomous agentic AI (which is designed to take actions, rather than generating outputs) working alongside human workers. "Alongside" is the key word, as even the most sophisticated AI requires human oversight.

"There's always a human being involved, because at the end, we're going to be accountable for any action taken, so the humans will have to approve and make it better and take it further," Kim says.

### Ensuring data security, accuracy

In addition to the fear of being replaced by AI, the other major concern among consumers is cybersecurity, which iBase-t takes very seriously. The company is working closely with regulations such as NIST 800 171 and International Traffic in Arms Regulations (ITAR) to ensure compliance. It implements data encryption in transit and at rest, and employs strict access control measures as well as regular audits. The company is also working to detect AI hallucinations, or incorrect answers, and ensure factual consistency.

Kim is confident people will become increasingly comfortable with AI – as with any emerging technology, there's mistrust at first, but that lessens as the safety and efficacy of the technology is proven.

"We need to wait a little longer to see the maturity of the data handling on the AI side, and not just the maturity, but the transparency and visibility," Kim says. "We have to know what's going

## SOLUMINA AI APPLICATIONS IN AEROSPACE MANUFACTURING


Solumina AI has numerous applications in aerospace manufacturing.

- **Digital thread and traceability:** AI can leverage Solumina's collection of manufacturing data to create a digital tapestry of an assembly's history, including the origin of raw materials, components, and every step in the production process.
- **Dynamic production planning:** AI can streamline production workflow planning by analyzing real-time data and historical trends to optimize task sequencing, resource allocation, and machine usage. It can dynamically adjust schedules based on shop floor conditions, minimizing bottlenecks and downtime.
- **On-demand dashboarding and reporting:** With AI-enabled on-demand dashboarding, manufacturers can generate interactive dashboards in real time without technical expertise. Users can query vast datasets in natural language and get instant responses in the form of charts, tables, or dashboards to view key performance indicators (KPIs) or trends.
- **Predictive quality control:** AI can predict potential quality issues before they arise by analyzing factors such as material properties, environmental conditions, and process parameters.
- **Predictive maintenance execution:** By analyzing the maintenance data in Solumina, AI could identify trends in the type and frequency of overhaul or modifications needed for specific complex assets, enabling smarter predictive maintenance scheduling and execution. It could also recommend additional services during maintenance and inspection execution, flag recurring issues, and identify potential design flaws for investigation.
- **Automated discrepancy management:** Analyzing data from sensors and logs, AI can detect a component outside of acceptable tolerances or a process that's deviated from the norm, and either generate corrective actions or escalate the issue to human operators with detailed recommendations.
- **Enhanced supplier quality management (SQM):** AI can analyze vast amounts of supplier data in real time to detect trends in quality performance, generate more intelligent supplier ratings, and dynamically adjust inspection requirements in response.


iBase-t's Solumina AI solution leverages generative AI specific to the user's manufacturing data. Photo credit iStock-1498477422

on so we can actually do better."

The large scale of AI operating within a facility is a concern, he continues, because if a human being gives an incorrect answer, it likely impacts a few people or operations, but if AI gives a hallucinated answer, it can impact thousands of operations. That's why the manufacturing industry must improve its factual consistency checking and monitoring techniques.

## Autonomous technology, human-machine collaboration

The recently introduced Solumina AI model is just the beginning for iBase-t. Currently, the company is working with data intelligence, which uses an AI technique to harness the power of Solumina data and develop better data-driven decision-making capabilities. It's also pursuing more agentic AI applications, such as small Solumina agents to act upon the data and decisions to improve shop floor efficiency and guide best practices. Kim also envisions training AI to continually update itself according to the latest regulatory policies and ensure the digital artifacts it creates are in compliance.

The development of AI technology is moving fast and could look drastically different in just a few months, Kim says. One of the keys to progress is increased data integration – with digital twins, with IIoT, allowing AI access to multiple record systems so it can accurately guide an agent or chain of agents. The dream of the manufacturing industry is the lights-out, smart factory, which we're leaning toward as agentic AI integrates data to become more autonomous.

"I've seen a use case where, when the equipment is about to fail or in failure mode, (the AI agent) actually detects the root cause based on the data that equipment generates, as well as the past repair history or maintenance history, and points toward how to fix it," Kim says.

He reiterates, however, that humans have an active role to play in the continued development and operation of AI, and that when AI takes over tasks such as data entry or troubleshooting, it frees up human brainpower for innovation and creation. Manufacturing will become a team effort between humans and AI.

"We all have to monitor what's going on," Kim says. "We have to be auditors of what's happening in the AI space and to make sure we're using it correctly, to enhance the humans' ability to carry out tasks so we can actually do more meaningful stuff at the end of the day." **A**

**iBase-t**
https://ibaset.com

*About the author: Clare Scott is associate editor for GIE Media's Manufacturing Group of publications. She can be reached at CScott@GIE.net.*

## AV expands US manufacturing operations

AeroVironment (AV), a provider of multi-domain robotic systems, uncrewed aircraft, and ground systems for government and defense customers, is establishing FreedomWerx, an advanced manufacturing facility in Salt Lake City, Utah.

By maintaining multiple, strategically located production sites, AV plans to mitigate risks from natural disasters, security threats, and geopolitical disruptions.

Located near Salt Lake City International Airport, the facility offers access to key transportation hubs, optimizing logistics and supply chain efficiencies. AV anticipates creating more than 500 high-paying jobs, enhancing Utah's position as a leader in defense innovation and advanced manufacturing. The company anticipates FreedomWerx will begin production in H2 2025.

**https://www.avinc.com**

PHOTOS COURTESY OF RESPECTIVE COMPANIES

## Skydio wins drone contract from Spain

San Mateo, California-based drone manufacturer Skydio was awarded a contract by Spain's Ministry of Defence to supply autonomous small uncrewed aerial systems (sUAS) to the Spanish Armed Forces. In partnership with Paukner Group, a Spanish defense and security product distributor, Skydio will deliver Skydio X10D drones in a contract worth up to $18.7 million.

The X10D incorporates onboard artificial intelligence (AI), autonomy, and sensors to be resilient in contested environments for intelligence, surveillance, and reconnaissance (ISR) applications.

During the past five years, Skydio drones have been chosen by every branch of the U.S. Department of Defense (DOD), plus those of 25 allied nations. The Spanish Army will deploy the X10D for a wide range of missions, including force protection, reconnaissance, facility security, crowd control, target acquisition, and command post support.

Skydio X10D

**https://www.skydio.com**

## Skyryse, United Rotorcraft partner on helicopter MRO services

Digitized aircraft operating system creator Skyryse and United Rotorcraft, a division of Air Methods LLC, are partnering, with United Rotorcraft providing FAA Part 145 maintenance, repair, and overhaul (MRO) services to Skyryse as it begins shipping its upcoming Skyryse One helicopters. Additionally, United Rotorcraft will support the introduction of Skyryse's SkyOS operating system into Airbus H-125 and H-130 helicopters and pursue integrating SkyOS into Black Hawk helicopter variants.

The partnership combines Skyryse's flight automation with United Rotorcraft's mechanical and implementation expertise advancing safety, automation, and operational efficiency across multiple aviation segments. Both companies' collaboration on additional Black Hawk utility variants includes those playing a critical role in wildfire suppression.

The agreement offers additional opportunities for expansion into other aircraft platforms and advanced avionics integration. Skyryse previously announced contracts with the Army and ACE Aeronautics to integrate SkyOS into the Black Hawk. **https://www.skyryse.com; https://www.unitedrotorcraft.com**



## Pratt & Whitney adds to GTF MRO network

RTX business Pratt & Whitney will expand its global network of GTF engine maintenance providers to include Sanad Group, the United Arab Emirates (UAE)-based global aerospace engineering and leasing solutions provider owned by Abu Dhabi's sovereign investor Mubadala Investment Co. PJSC. Sanad's state-of-the-art facility is expected to be completed by 2028.

The Al Ain-based facility will be the first Pratt & Whitney GTF maintenance, repair, and overhaul (MRO) network member in the South Asia, Middle East, and North Africa region and will service PW1100G-JM and PW1500G engines for the Airbus A320neo and A220 aircraft families respectively, as well as the PW1900G engine for Embraer E-Jet E2 aircraft with full MRO services and test capability.

The Pratt & Whitney GTF MRO network includes 20 shops across four continents. **https://www.prattwhitney.com; https://www.sanad.ae**

PHOTO COURTESY OF SKYRYSE AND UNITED ROTORCRAFT

# NAME THAT PLANE

Brought to you by
AEROSPACE MANUFACTURING and DESIGN

***Aerospace Manufacturing and Design*** welcomes all aircraft enthusiasts to join the fun and NAME THAT PLANE! Each issue, a new aircraft will be featured. Given a photo and a clue box, readers are encouraged to guess what plane is being described and submit their answers to **www.AerospaceManufacturingAndDesign.com/Form/NameThatPlane.**

## RAPID-FIRE FACTS

- Role: Experimental rocket plane
- First flight: January 19, 1946
- Number built, all variants: 7
- Primary users: U. S. Air Force, National Advisory Committee for Aeronautics

## SPECIFICATIONS

- Wingspan: 28ft 0" (8.53m)
- Length: 30ft 11" (9.42m)
- Height: 10ft 10" (3.30m)
- Max. speed: 1,612mph (2,594km/h)
- Engine: Reaction Motors XLR11

**January-February 2025 answer:** McDonnell Douglas F-15 Eagle

## JANUARY-FEBRUARY 2025 WINNER:

**Joseph Levin,** Mechanical Engineer,
Fastener Dimensions Inc., Pennsauken, New Jersey

**How long have you been in the aerospace business?**
10 years.

**How did you become interested in aircraft?**
As a child. Every child is fascinated by airplanes, and military aircraft are more exciting because of their performance and the maneuvers they can do.

**What is your favorite aircraft and why?**
The Lockheed C-130 Hercules. I was a passenger once and it was awesome the way it took off!

## RUNNERS-UP:

**Mike Harlan**
CEO
Whitworth Tool Inc.
Hardinsburg, Kentucky

**Brent Moyer**
Territory Manager
Pittman Industrial Marketing Inc.
Birmingham, Alabama

### SUBMISSION PROCEDURE

To enter the contest, visit http://www.AerospaceManufacturingAndDesign.com/Form/NameThatPlane and fill out the provided entry form. Only completed forms will qualify. A full set of rules is provided.

The entry deadline for this issue's contest is May 7, 2025. Winners will be announced in the June 2025 issue.

**Have fun, and good luck!**

PHOTO: NASA

## Look what Joseph won!

Enter today to win your own high-quality desktop aircraft replica!

**http://www.AerospaceManufacturingAndDesign.com/Form/NameThatPlane**

**Brought to you by:** AEROSPACE MANUFACTURING and DESIGN

## Collaboration to advance, scale metal AM

Fastech and Arc Additive announced a partnership combining their technologies to accelerate growth and innovation in the additive manufacturing (AM) industry. Both companies specialize in wire arc additive manufacturing (WAAM) technology. They'll develop large-scale, high-integrity metal AM solutions for a range of industries including aerospace.

Virginia-based Fastech and Scotland-based Arc Additive benefit from market expansion through the strategic partnership, along with addressing the growing demand for large, complex components. Arc Additive has developed proprietary WAAM Additive Production Cells for large parts made with out-of-chamber high-deposition titanium AM. Fastech's WAAM technology is up to 10x faster than conventional manufacturing methods, according to the company, and uses a broad range of materials.

PHOTO COURTESY OF FASTECH

**Arc Additive**
https://arcadditive.com

**Fastech**
https://fastech-engineering.com



## Aerospace Competence Center opens in Delft

Materialise has opened an Aerospace Competence Center in TU Delft's Aerospace Innovation Hub, a community of startups, students, academics, government, and industry professionals. Materialise, an additive manufacturing (AM) service provider for the aerospace industry, is the first AM company to establish a presence in the hub. It'll collaborate with TU Delft on projects where students and researchers can gain hands-on experience with AM while advancing developments in sustainable aviation.

"The opening of our new Aerospace Competence Center aligns with our commitment to support the aerospace industry through more than three decades of experience in AM and software solutions, as well as our pioneering role in producing certified parts," says Brigitte de Vet-Veithen, CEO of Materialise. "By joining this selective aerospace network, we can strengthen our capabilities, expand partnerships, and enable other aerospace leaders in this hub to accelerate innovation and explore new possibilities with AM."

**Materialise**
https://www.materialise.com


# 2025
# MANUFACTURING GROUP VIRTUAL EVENTS

## APRIL

| | |
|---|---|
| **April 9** | Spring Aerospace Outlook |
| **April 17** | Lunch + Learn |
| **April 23** | Intelligence About Artificial Intelligence Roundtable |

## MAY

| | |
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| **May 15** | Lunch + Learn |
| **May 20** | How Businesses Can Become Proactive |
| **May 28** | Machine Tool Builders Roundtable |

## JUNE

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| **June 3** | Ai-Enabled Multi-Domain Operations |
| **June 12** | Lunch + Learn |
| **June 25** | Shopfloor Connectivity Roundtable |

## JULY

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| **July 17** | Lunch + Learn |
| **July 23** | Hybrid Mfg. Roundtable |
| **July** | Defense |

## AUGUST

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|---|---|
| **August 13** | Laurie Harbour |
| **August 21** | Lunch + Learn |
| **August 27** | Cutting Tool Roundtable |

## SEPTEMBER

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|---|---|
| **September 10** | AI/ML Roundtable |
| **September 18** | Lunch + Learn |
| **September 25** | Archetype Consulting — Medtech |

## OCTOBER

| | |
|---|---|
| **October 16** | Lunch + Learn |
| **October 22** | Fall Aerospace Outlook |
| **October 29** | Leaders in Manufacturing Roundtable |

## NOVEMBER

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|---|---|
| **November 12** | Workforce Roundtable |
| **November 19** | Lisa Anderson — Supply Chain |
| **November 20** | Lunch + Learn |

## DECEMBER

| | |
|---|---|
| **December 11** | Lunch + Learn |
| **December** | Defense |

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AerospaceManufacturingAndDesign.com

TODAY'S MEDICAL DEVELOPMENTS
TodaysMedicalDevelopments.com

EV DESIGN & MANUFACTURING
EVDesignAndManufacturing.com

DEFENSE AND MUNITIONS
DefenseAndMunitions.com


PHOTO COURTESY OF HEULE TOOL

## Deburring tool for CNC operation

The DL2 is a small mechanical deburring tool for 1.00mm to 2.1mm bores in a wide range of materials including steel, stainless steel, titanium, aluminum, and composites. Constructed from just four components, the carbide blade is integrated into the spring to form a single unit. This ensures proper spring tension for the guiding and cutting forces of the blade, making it easy to change blades without tweezers or a magnifying glass. The DL2 uses a smart tool concept with internal blade cooling. Coolant is supplied through the tool and guided directly to the cutting edge of the carbide blade for optimal performance and process safety during high-volume operations.

The DL2 tool must be used in counterclockwise rotation and can be used for front and back deburring or back only deburring. Throughout the entire machining process, neither a change in the direction of rotation nor a stopping of the spindle is necessary. The tool cutting edge is positioned in rapid feed above the front of the hole to be deburred. At working feed, the edge is deburred on the front edge of the hole until the blade has fully retracted. In rapid/increased feed, the tool passes through the workpiece without damaging the surface.

**Heule Tool**
https://www.heuletool.com


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AEROSPACE MANUFACTURING and DESIGN

Edited by Clare Scott

# High-performance, nano-architected materials

Researchers at the University of Toronto's Faculty of Applied Science & Engineering have used machine learning (ML) to design nano-architected materials with the strength of carbon steel but the lightness of Styrofoam.

In a paper published in *Advanced Materials*, a team led by Professor Tobin Filleter, MIE, describes how they made nanomaterials combining exceptional strength, light weight, and customizability.

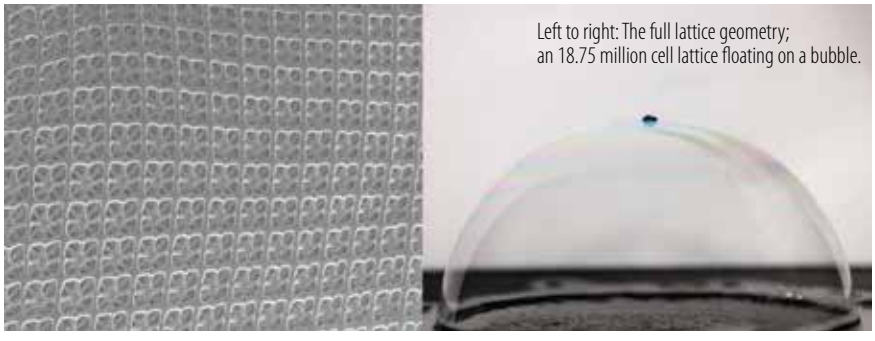
"Nano-architected materials combine high performance shapes, like making a bridge out of triangles, to achieve some of the highest strength-to-weight and stiffness-to-weight ratios of any material," says Peter Serles, Ph.D., the paper's first author.

"However, the standard lattice shapes and geometries used tend to have sharp intersections and corners, which leads to the problem of stress concentrations. This results in early local failure and breakage of the materials, limiting their overall potential."

Nano-architected materials are made of tiny repeating units measuring a few hundred nanometers – it would take more than 100 of them in a row to reach the thickness of a human hair. The carbon building blocks are arranged in 3D structures called nanolattices.

Serles and Filleter worked with Prof. Seunghwa Ryu and Ph.D. student Jinwook Yeo at the Korea Advanced Institute of Science & Technology (KAIST) in Daejeon, South Korea to design the material.

The KAIST team used the multi-objective Bayesian optimization ML algorithm to predict the best geometries for enhancing stress distribution and improving the strength-to-weight ratio of nano-architected designs. Serles then used a two-photon polymerization 3D printer to create prototypes. The optimized nanolattices created more than doubled the strength of existing designs, withstanding a stress of 2.03MPa for every cubic meter per kilogram of its density, about 5x higher than titanium.



Left to right: The full lattice geometry; an 18.75 million cell lattice floating on a bubble.

"This is the first time machine learning has been applied to optimize nano-architected materials, and we were shocked by the improvements," Serles says. "It learned from what changes to the shapes worked and what didn't, enabling it to predict entirely new lattice geometries."

ML is normally very data intensive, but the multi-objective Bayesian optimization algorithm only needed 400 data points instead of 20,000 or more. "We were able to work with a much smaller but an extremely high-quality data set," says Serles, who is now a Schmidt Science Fellow at the California Institute of Technology (Caltech).

"We hope these new material designs will lead to ultra-lightweight components in aerospace applications that can reduce fuel demands while maintaining safety and performance," Filleter says.

"If you were to replace components made of titanium on a plane with this material, you'd be looking at fuel savings of 80L per year for every kilogram of material you replace," Serles adds.

Other contributors to the project included collaborators from Karlsruhe Institute of Technology (KIT) in Germany, Massachusetts Institute of Technology (MIT), and Rice University.

**University of Toronto Faculty of Applied Science & Engineering**
https://www.engineering.utoronto.ca/

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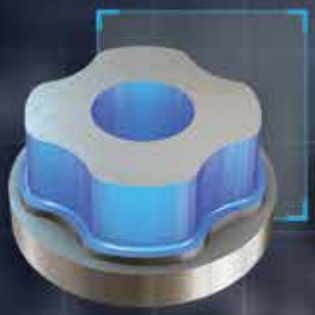

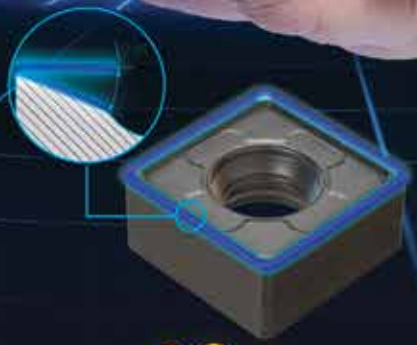

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