LIFT WA

Summer 2017

INNOVATION ISSUE

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The Washington Aerospace Partnership AFA

EDITOR'S NOTE

As a kid, I loved watching the popular cartoon, *The Jetsons*. I remember wondering how George Jetson's *aerocar* could run on whatever those molecular-module-thingies were instead of gas and if that could ever be reality. I also wanted to be able to twitch my nose like *Bewitched* and be anywhere in an instant. One of those childhood fantasies is nearing reality.

Our feature story this issue is about Kirkland, WA-based, Zunum Aero (zunum.aero), which has reimagined the future of air transportation with their hybrid-to-electric aircraft. In conjunction with and funding from Boeing HorizonX and JetBlue's tech venture arm, Zunum is on target to reinvent regional air travel as we know it. And, in a possible boon to Washington's aerospace suppliers, they plan on utilizing our state's established supply chain.

The aerospace industry has a long history of continual evolution. Now, more than ever, we are experiencing innovations in high tech, manufacturing, processes, materials, the IoT (Internet of Things), electronics, networks, and clean tech.

Individually or collectively, these innovations help design, create, manufacture, scale, reproduce, diagnose, maintain, connect, and create efficiencies and reduce expenses before, during and after production of parts and components and after the craft is flying.

Examples abound, such as 3-D printed parts (additive manufacturing), an emerging technology capable of making parts and tooling for all sectors of aerospace, from commercial space and UAVs to aviation. Layered over this is the introduction of newer, lighter weight, more efficient, and less expensive materials that can be utilized through this innovative manufacturing process. Challenges are also an integral part of the puzzle, not the least of which includes regulatory standards that will need to be addressed and overcome.

Automation and robotics, which are being used to create tooling, *as* tooling, and in production, are also driving much of the discussion about the future of aerospace. And advances in AR (augmented reality) and touch screen displays are leading to more efficient maintenance on the hangar floor.

But innovations aren't limited to the aircraft itself. Breakthroughs in design and construction materials for hangars, facilities and production plants are also changing the way business is being done. Even innovations strictly outside of aerospace, such as hyperloop transportation and medical devices, are having an impact on the aerospace supply chain since many of the skill sets, materials, processes, and technologies cross over industries.

Sustainability is an important driver in much of the innovation we're seeing today. The Port of Seattle, Alaska Airlines, and Boeing are working together to introduce sustainable aviation biofuels. One of the goals of the Port of Seattle is to eventually use this climate-friendly fuel to power every flight out of SeaTac.

These are only a few of many new and conceptual technological advances and innovations in aerospace. So, it would seem, *The Jetsons* were onto something all those decades ago, introducing us to a world where daily transportation was quite literally up in the air powered not by gasoline but imagination. It doesn't get much better than that, unless of course, you're *Bewitched*.

Sincerely,

Kelly Maloney
LIFT WA editor
AFA president and CEO

AFA
The Washington
Aerospace Partnership

LIFT WA

Your Complimentary Copy

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Photo courtesy of Kenmore Air

Zunum Aero's Hybrid Aircraft

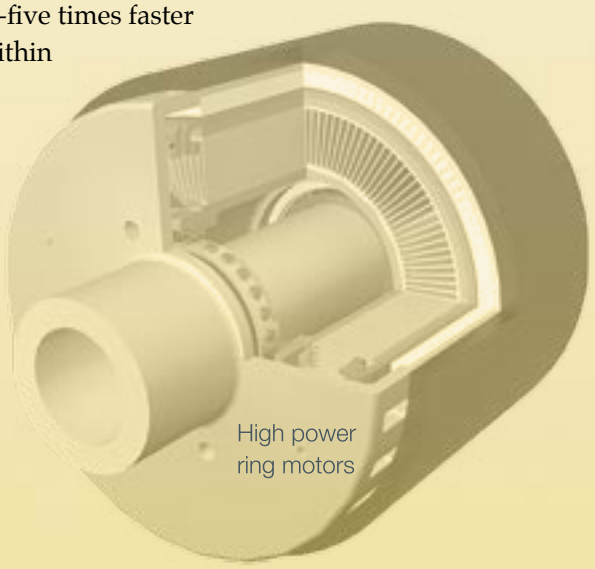
We are in a golden era of aviation with the State of Washington at the cutting edge via a staggering breadth of innovation that tops a century of leadership.

Reusable rockets, micro-satellites and affordable spaceflight are opening new horizons in space. At lower altitudes, vast new markets for global air travel are driving record order books for advanced airliners. Lower still, armies of drones, not content with transforming agriculture, surveying, security and imaging, are now plotting to deliver stuff to you right where and when you want it.

Yet, amid this innovation, vast intermediate altitudes of sky have emptied. Runways outside the hubs are much quieter, communities much less connected to the air system, and the time it takes to travel from Everett to Spokane hasn't improved in decades.

With support from our partners at Boeing HorizonX and JetBlue Technology Ventures, we at Zunum Aero are working to conquer this near horizon, bringing fast and affordable travel to every community. By so doing, we intend to establish aviation as the dominant mode for fast regional travel worldwide, and as a flexible, capital-light alternative to high-speed rail and highways.

Our mid-sized hybrid-to-electric aircraft, with cabins built for walk-on and walk-off service (no baggage belts, less TSA, like boarding a bus or a train), are tailored for mass transit to low service airfields. From 700 miles in the early 2020s, these quiet, green and comfortable flights will extend to 1,000 miles by 2030. Departures to communities across the Northwest will become as commonplace as flights to hubs from SeaTac Airport today, getting you there two-to-five times faster at a fraction of the fare. Many of the 64 NPIAS airports within our state will be lit up by point-to-point services and hub feeders, helping revitalize under-served communities, and multiplying in-state employment by carriers and airports.



High power ring motors

While this may seem improbable given the air system of today, recognize that the current merely reflects the economics of the jet engine. Larger aircraft are much more efficient, as are flights over longer ranges, than smaller aircraft or shorter flights. This has powered the

Zunum Founder and Aero CTO **Matt Knapp** has been the lead designer of innovative aircraft for over 20 years. Matt has a BS and MS in aerospace from MIT and is a certified flight instructor.

70-year transition of aviation to large, long-haul airliners and high-volume hubs. In contrast, our smaller hybrid-to-electrics fly as efficiently as larger ones, and mid-sized hybrids flying regionally are competitive with the largest airliners over these distances. The unique economics of the hybrids will transform regional air travel, with aircraft of a wide range of sizes emerging to provide fast, frequent service to large numbers of communities.

We are over three years into development of our first aircraft powered by quiet range-optimized powertrain and propulsion technologies, targeted for the early 2020s. Our multidisciplinary team is comprised of leading technologists from across the aircraft, aircraft engine and electric vehicle disciplines. To enable an early start of testing and staged development, we are progressing prototypes of all innovative systems, including the hybrid-to-electric powertrain, the quiet electric propulsor, wing sections with integrated battery modules and a rugged composite-metal airframe. Our key milestones are a flying test bed for the full-scale powertrain and propulsor within two years, leading to a non-conforming test article in four years, and a FAR Part 23 certification soon afterwards.

We are proud to be in Washington, and at the heart of the global aerospace industry. Our deep engineering bench, the concentration of leading aviation suppliers, and the global leadership of our companies, makes this the ideal environment for ventures like ours (and do not get us started on Northwest living!). We also see tremendous benefit from our aerospace tax incentives, and from leadership of our state on climate change. Building on these, we believe Washington will help establish the US as a leader of this new era of fast, affordable and green regional air, and once again, transform the lives of billions around the world.

SAVE THE DATE!

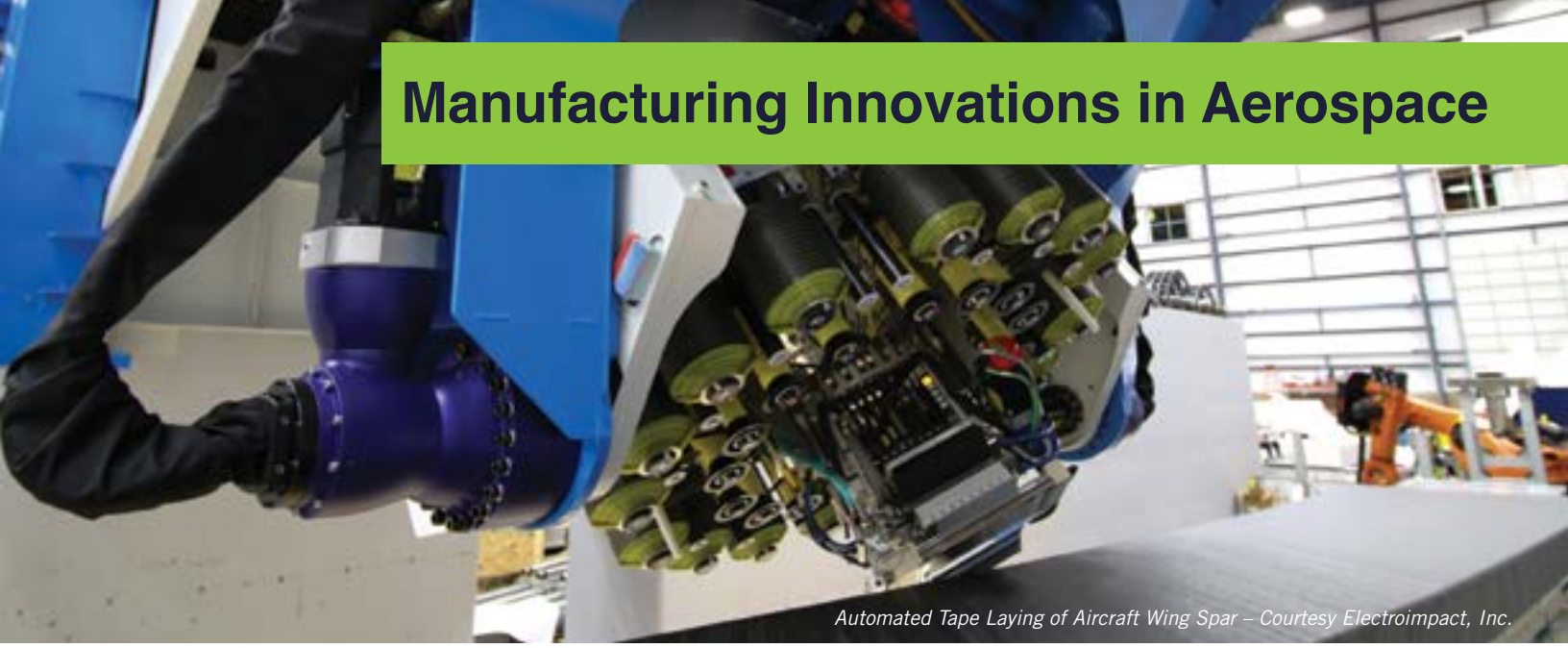
AFA's 12th Annual Governor's Aerospace Summit

Thursday, September 7, 2017

Lynnwood Convention Center

Contact info@afa-wa.com for more information.

Manufacturing Innovations in Aerospace



Automated Tape Laying of Aircraft Wing Spar – Courtesy Electroimpact, Inc.

It was not long ago that the primary focus in aerospace system design was performance – achieve the best performance with the best material using the best manufacturing method. Commercial and defense aviation are now very focused on cost reduction and manufacturing efficiency. Some performance can be sacrificed if the cost can be reduced.

This cost-benefit evaluation will be increasingly enabled by technology that computes, predicts, and validates performance with the aid of virtual simulations (computer enabled, such as performing finite element-based simulations of structural tests). Key technologies at the forefront of manufacturing costs will also be highlighted.

Additive Manufacturing

There is a lot of attention on additive manufacturing in the aerospace industry today. Additive manufacturing covers the manufacturing methods that can create a part from a material with little waste. The first real use of additive manufacturing was in aerospace where engineers laid-up fiber-reinforced laminated structural parts in the 1960s.

Traditional manufacturing with metals includes machining, casting, forging, and molding which can produce waste, require significant energy, and often needs expensive tooling. Additive manufacturing methods can create metal and plastic parts without tooling by either directly depositing or fusing the material just where it is needed. When parts and assemblies are designed taking advantage of the unique capabilities of additive manufacturing, companies can produce systems that can reduce weight, improve performance, reduce costs, and significantly streamline their supply chains.

The aeroengine industry is taking a leadership role in applying additive manufacturing to their systems and are showing dramatic business benefits from the use of this technology. However, much remains to be done in establishing thorough and rigorous pathways for certification and ensuring repeatability and part performance over the service lifetime. These are research topics currently being discussed and pursued by some academic institutions.

Automation

Additive manufacturing is an automated process but there are other automation methods that are making an impact in the aerospace market. Composites make up a significant percentage of modern airplane systems and the manufacturing of these structures is done largely with automated fiber placement (AFP) and automated tape laying (ATL) systems. These replace the hand lay-up methods that were used in the past to create laminated composite structures.

Automated systems for joining, fastening, and assembly operations are also becoming more mainstream. The aerospace industry is learning from the automotive industry about using more robots and mechanical systems to automate the manufacturing process. This not only improves efficiency but can have benefits on quality by making the process more repeatable and robust.

Again, certification of AFP and ATL structural components, understanding the manufacturing "signature" of the AFP and ATL methods which are process and machine specific will require much research to be done in the future. Combining advances in vision-based automation and the accuracy and repeatability of production via AFP and ATL methods, leads to several new areas for innovation in manufacturing of large aerostructures.

Digitalization

An emerging trend is the digitalization of the design, manufacturing, and operation of systems. The idea is that digital design feeds the manufacturing system, the manufacturing system records all steps digitally, and the completed system is continuously monitored for performance.

Another term used is the digital twin which means the physical system has

Dr. Robert Yancey is an independent consultant with a focus on helping companies transition from traditional materials and manufacturing to advanced materials and manufacturing including composite materials and additive manufacturing.

Dr. Anthony M. Waas is the Boeing Egtvedt Endowed Chair Professor in the William E. Boeing Department of Aeronautics and Astronautics at the University of Washington, Seattle, and the Department Chair. Professor Waas's research interests are: Computational modeling of composite structures, Automated manufacturability, and 3D printing in aerospace. Dr. Waas initiated the CCAM at UW.

a digital twin that has the complete history of the system from raw material to end of service. This can have a significant effect on the entire product lifecycle that can reduce design, manufacturing, inspection, quality control, and maintenance costs of a system.

For example, with the data being collected and stored throughout the lifecycle of the system, maintenance can be carried out when needed rather than on fixed schedules. Time consuming inspection processes can be replaced with in-line sensing of the manufacturing operation. This can also lead to constant improvement of the manufacturing process by using analytics to determine where and how the manufacturing process can be improved and made more efficient.

Pathways will yield new innovations

In the same way that the assembly line first implemented by Henry Ford revolutionized manufacturing for a century and more, and the introduction of the wind tunnel led to significant innovation in airplane design, we are in the midst of an industrial revolution that will yield dramatic improvements in the way parts, assemblies, and systems are manufactured and produced.

This will have an impact across many industries but probably the most impact in the aerospace industry that still relies on significant human labor. The technologies of additive manufacturing, automation, and digitalization will lower the costs of aerospace systems, change the skill sets needed for the future manufacturing workforce, and produce more fuel efficient and better performing systems through a pathway that will yield new and innovative designs thought impossible a few years ago.

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AIRLINES

Free Your Hands for Productivity

How the Industrial Worker Will Stay Relevant in the Age of Automation

Manufacturing is getting smarter. A lot smarter. Leading aerospace companies are using advanced manufacturing methods to enhance productivity and enable the realization of designs not otherwise producible with conventional methods. Automation, robotics, and additive manufacturing are displacing labor-intensive jobs in many industries. Beyond the gains enjoyed from improved quality and productivity, increasingly inexpensive access to improved sensors, machine learning and artificial intelligence (AI) will create opportunities to create new savings through not-yet-invented systems.

But make no mistake, highly skilled technicians will be needed more than ever. Decades of institutional knowledge are being lost due to retirements and there is a shortage of younger employees to replace them. Boeing Flight Services projects that 679,000 new commercial airline maintenance technicians will be needed over the next 20 years alone.

Less experienced workers need to become more capable and productive faster. They need to collaborate with experts, access documentation and information when and where it is needed, and begin to do that more effectively using augmented reality (AR).

According to TechTarget, “AR” was originally coined by Boeing researcher Thomas Caudell in 1990. Simply stated, AR integrates and overlays digital information with the user’s environment. We see this digital overlay every Sunday as the Seahawks play football and commentators telestrate scrimmages and first down lines onto the screen. Many Washington tech companies are working on developing software in this space from tech titans like Microsoft, to start ups like 8ninths in Seattle and Gravity Jack in Spokane.

Four things are increasing industrial interest in AR: first, ubiquitous high speed wireless internet; second, emerging access to massive data made possible by connecting edge devices to the Industrial Internet of Things (IIoT); third, the wider availability of software applications; and fourth, the digitization of work instructions, drawings and documentation.

Industrial use of AR has lagged the consumer world due to a lack of standards and low-friction tools that increase productivity. High value technicians must continue to work with their hands while interacting with any device. That means voice control is imperative. Just as we transitioned from key strokes and command lines to graphical user interfaces with mice, followed by touch screen and gestures, we are now seeing the widespread introduction of natural language processing as the next wave of computer interfaces. Amazon's Alexa? Microsoft's Cortana? Google Voice? Each enables hands-free information access in context whether you are cooking, watching TV or maintaining a jet engine.

What has been missing for industry is a ruggedized hardware tool that can be operated without impeding worker productivity. Smart Phones and Tablets can be ruggedized, but require the operator to stop what they are doing to use them. Their screens can be hard to read in some environments and may compromise safety if gloves or other personal protective equipment must be removed to operate them.

Washington start-up RealWear* has produced an industrial-quality, wearable voice-controlled Android tablet that avoids all of the challenges of working with a smart device while enabling three critical categories of applications:

1. Remote Mentoring
2. Read/Write Access to Real-Time Documents
3. Contextual Data Visualization

It is compatible with hardhats and other PPE. It's lightweight and doesn't interfere with vision thanks to a readable screen mounted on 6-axis boom. It works even in loud environments thanks to effective noise cancellation technologies.

Using only your voice you can use the HMT-1 to collaborate remotely, read a blue print, follow a work instruction, see data elements related to your physical location or proximity to equipment, or fill out a checklist.

The future of industrial work will consist of highly trained, connected workers collaborating and accessing information in real time using their voice and wearable tech. It's time to get ready.

Andrew Chrostowski is a senior executive and board member focused on the impact of advanced technologies and automation on industry, and the strategies for success needed in a world of digital disruption and technological transformation.

*Andrew is an adviser to RealWear.

COMPLETELY HANDS-FREE
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INTRINSICALLY SAFE
HMT-1Z1 model for potentially explosive environments in oil & gas, etc. FMC1/D1 & ATEX Zone 1

DISPLAY
High-resolution micro-display recreates the equivalent view of a 7-inch tablet held 20-inches away from your eyes.

More Than "Just" Drones: Opportunities for Innovation and Businesses

A drone operated by the Roswell Flight Test Crew carries a FLIR thermal imaging camera to assist first responders during a structural firefighting exercise, providing the incident commander with an aerial perspective on the scene.

Drones are becoming a mainstay in our society. We see them in tech and toy stores, catalogs of cool things, and have even noticed them in more print media, movies and commercials. Why the big deal about drones? What are they anyway?

First, the word "drone" is a common moniker that has gained widespread acceptance. In reality, the term "Unmanned Aircraft System," or simply "UAS" is more precise. A UAS is more than the aircraft or rotary wing platform. It includes all the components that make the device work: the airframe, its mechanical components, the controller used by the pilot, the communication system that allows the airframe to be controlled by the pilot and so on. Every piece that makes the device "work" is part of the unmanned system. And it's in all those "pieces" that companies can innovate and compete in this growing market.

> ***"In addition to cost savings over manned aircraft and risk avoidance for dangerous or difficult missions, the commercialization of UAS mandates training, education and service industries like insurers, law firms and data analytics companies to complement the system and component providers."***

As evidenced in how often we're seeing or hearing about them, the UAS market is exploding — and with that explosion are opportunities for innovation and new businesses. The FAA has registered more than 600,000 UAS in the past 18 months and expects 3.5 million registrations by the end of 2017. These will range

from a simple, fist-sized rotary wing UAS, to a sophisticated commercial UAS designed with significant autonomy and capability to carry complex payloads. This opens opportunities in material technologies such as: composites for light weight and longer endurance; communication links capable of working in dense urban environments or at long ranges; sensors to perform data collection; green, reliable propulsion systems; engineering breakthroughs to fly safer and faster without colliding with fixed and movable objects; and software to manage flight profiles that ultimately become reliable enough for "Uber-like" air taxi passenger service. The dynamic evolution of these technologies will help fuel a broad spectrum of UAS missions ranging from cinematography and real estate imaging to precision agriculture, emergency response, food and medicine deliveries, resource management, industrial and infrastructure inspections, and much more.

The economics for UAS are compelling. In addition to cost savings over manned aircraft and risk avoidance for dangerous or difficult missions, the commercialization of UAS mandates training, education and service industries like insurers, law firms and data analytics companies to complement the system and component providers. Statistics reflect the UAS commercialization momentum. Venture capitalists invested nearly $750M in the industry last year and that amount is accelerating. Just since August of 2016 when FAA rules were finally issued for UAS weighing less than 55 pounds at takeoff, over 45,000 UAS pilot (Remote Control Operator) Certificates for commercial operators have been issued. Market analysis indicates 90,000 UAS pilots will be required by 2020 to meet mission demands. Locally, the Association for Unmanned Vehicle Systems International (AUVSI) estimates that with the continued integration of UAS into the national airspace system, Washington has the potential to generate 10,000 jobs and over $10B in revenue in the next decade, part of a predicted $100B to $125B global market.

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Tom Hagen is a retired Navy carrier aviator, retired Boeing Phantom Works unmanned systems manager, President of Enterprise Initiatives Consulting and the Cascade Chapter of AUVSI in the Pacific Northwest.

The AgBOT drone, developed by Aerial Technology International of Clackamas, OR, checks the health of a northwest vineyard using a multi-spectral sensor to perform a Normalized Difference Vegetative Index (NDVI) analysis.

SEATTLE-TACOMA INTERNATIONAL AIRPORT

Port of Seattle

Seattle-Tacoma International Airport

Partners in leading the industry to aviation biofuels

The Port of Seattle is committed to being the greenest, most energy-efficient port in North America. We invest in sustainability to improve quality of life in our region, to ensure a long-term future for our businesses, and to protect our beautiful natural environment - even while managing growth that has made us the ninth busiest airport in the nation.

OUR GOAL

Power every flight fueled at Sea-Tac with sustainable aviation biofuel and become carbon neutral by 2050.

We're working with our partners, like Alaska Airlines and Boeing, to develop a commercial-scale aviation biofuel program.

We live in a community that inspires us to think bigger about sustainability. The Port of Seattle is committed to thinking differently about how airports can limit our climate impact while continuing to support economic growth.

Find out more about our leading role: www.portseattle.org/environmental

Follow us on social media and sign up for our email newsletter Connections to learn more about opportunities with the Port of Seattle: www.portseattle.org/subscribe

Advanced manufacturing processes have helped build more than 40 777s to date

Mechanic & Machine

Boeing's Advanced Manufacturing Improves 777 Assembly

Mechanic Mike Jennings has two new words in his job title — robot operator.

He helps oversee one of the robots used in the new Fuselage Automated Upright Build, or FAUB, system that helps manufacture 777s — more than 40 to date — in Everett, WA.

Stationed at a computer that shows robot diagnostics and images from a small camera built into the multifunction tool at the end of a robot arm, Jennings monitors its movements and makes notes. He and fellow team members maintain the system and tweak it if needed.

Dung Bui (left) and Jason Hicks, 777 mechanics, guide equipment on automated guided vehicles, or AGVs, inside the Everett, WA, factory housing new processes to build 777 fuselages. AGVs move components — including work stands, fuselages and robotic arms — inside the factory.

Bo Galinec, 777 mechanic, uses a control pad to direct robotic arms drilling inside a fuselage in the Everett, WA, factory.

Photos compliments of Gail Hanusa

"I'm learning a new aspect of manufacturing, and that's really cool," Jennings said. "I like being part of this cutting-edge technology that's helping improve how we build airplanes."

FAUB couples automation with manual work to assemble the forward and aft sections of the 777 fuselage. After teams load and set the panels, robot pairs move in unison along the barrel, "drilling and filling" thousands of fasteners that connect the sections. It's a job Jennings used to do by hand — repetitive work that he said was tough on his back, neck, shoulders and arms.

FAUB eliminates that stress on the mechanics. It also improves quality and will speed up and add flexibility to the build process, said Samantha Jarema of FAUB Production & Integration.

"Most everything in here is on wheels," said Jarema, referring to the machinery in the new FAUB factory built at the east end of the Everett site. "We can build any portion of the forward or aft section in any of our six main production positions."

Mechanics are able to move the robots and massive parts around on automated guided vehicles (AGVs). That mobility and flexibility will allow FAUB to manufacture all 777 models, including the upcoming 777X, said Ben Nimmergut, 777 production engineering chief engineer.

He said the system is not at its full production potential but is making gains each day. "In any new production system like this, there's going to be challenges," Nimmergut said. "We're learning and growing from those challenges. It's expected and it's OK."


A6 & A7


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Alaska

Port of Seattle: Biofuels Use Grows

The Port of Seattle is leading the move toward aviation biofuels, nurturing a fledgling industry to get it off the ground. As the operators of Seattle-Tacoma International Airport, we're working with energy and research partners to systematically evaluate all aspects of developing a commercial-scale program from scratch.

Sustainable aviation biofuel reduces carbon dioxide emissions by 50 to 80 percent compared to fossil fuel. This is because a biofuel feedstock, or source material, absorbs carbon dioxide (CO2) during its growth cycle (e.g. photosynthesis). Using biofuel also reduces sulfur emissions, soot and particulates.

Aviation biofuels can simply be dropped into the current fuel supply. No new engines, no new aircraft, and no separate fuel delivery systems are needed at airports. Currently, aviation biofuel is not produced in Washington and must be imported by truck, rail, or barge, and then blended with fossil jet fuel before it can be integrated into our airport's fueling systems.

Aviation biofuel infrastructure integration will make Sea-Tac Airport an attractive option for airlines committing to biofuel use and will assist in attracting biofuel producers to the region as part of a longer-term market development strategy. Charting a path to commercial-scale production of biofuels in our region, we aim to play a significant role in the creation of a biofuel market through support of fuel integration and infrastructure, assistance with the incremental cost of fuel, and helping incentivize biofuel production.

In partnership with Boeing and Alaska Airlines, we released a first-of-its-kind study in 2017 that identifies the best infrastructure options for delivering aviation biofuel to Sea-Tac Airport.

The infrastructure study evaluated 30 sites around Washington state that could potentially support the receipt, blending, storage, and delivery infrastructure required to supply the airport with up to 50 million gallons per year of sustainable aviation biofuel. Potential sites were evaluated both for the ability to accommodate near-term (12-18 months) supplies of five million gallons per year and long-term (2-10 years) supplies of more than 50 million gallons per year.

Currently, fossil jet fuel is produced at three refineries approximately 90 miles north of Sea-Tac, and delivered to airport facilities in the south via the Olympic Pipeline. The study evaluated many locations along the Olympic Pipeline where biofuels could be blended and injected into the delivery system. It also evaluated the infrastructure needed for small and large biofuel delivery volumes. The study concluded that we should focus on short-term investments at smaller-scale facilities that are flexible and could support other aviation fuel supply uses due to the lack of long-term supply source for aviation biofuels. Facilities that rely on offloading fuel via rail and marine modes are only cost-effective for large volumes of biofuel over the long term due to high infrastructure costs.

The Olympic Pipeline Company and the petroleum refineries and distributors have shown strong interest in upgrading their facilities to handle aviation biofuel and moving the blended product in their pipelines. As the biofuel supply expands, the Port, its partners, and the fuel supply and transport organizations could work cooperatively toward the ultimate goal of integrating aviation biofuel into the fuel hydrant delivery system at Sea-Tac Airport.

A small biofuel receiving and blending facility at the Sea-Tac Airport Fuel Farm is the most cost-effective solution in the short term. In terms of aviation biofuel infrastructure, Washington's northern-area refineries are the most cost-effective options for large volumes of aviation biofuel over the long term due to their access to marine, rail, truck, and the Olympic Pipeline. The Phillips 66/Olympic Pipeline Company sites in Renton, WA also showed potential to accommodate receipt and blending facilities for moderate-to-large biofuel volumes over the long term.

Another study to be released in 2017 will identify the best ways to finance such a system. The full aviation biofuels infrastructure study can be found at www.portseattle.org/environmental.

Elizabeth Leavitt is the Senior Director of Environment and Sustainability for the Port of Seattle, where she also served as the Director of Aviation Planning and Environmental Programs.

AFA MEMBER SPOTLIGHT

Pioneers in Touchscreen Display Technology for the Cockpit

Esterline Corporation, founded in 1967, is a shining example of an organization powered by innovation.

Headquartered in Bellevue, WA, Esterline operates manufacturing facilities in Belgium, Canada, China, Dominican Republic, France, Germany, India, Japan, Mexico, Morocco, Singapore and the United Kingdom.

As a specialized manufacturing company with nearly 13,000 employees serving the aerospace and defense markets, approximately 80 percent of Esterline's total revenues are generated from these markets. The remaining 20 percent is from the application of these technologies in adjacent markets. Esterline management views the company's businesses in three segments related to its set of core competencies: Avionics & Controls, Sensors & Systems and Advanced Materials.

Korry, an Esterline brand, offers an example of how these technological advances are changing the horizon in aerospace. The Korry Utility Control System (UCS) Touchscreen Display Technology is the first touchscreen control solution for overhead panels in civilian and military aviation. It offers a 75 percent reduction in separate display and switching components as well as higher reliability, and is currently flying on Gulfstream G500 and G600 long-range business jets. It not only increases ease of use for the crew, but it also simplifies the long-term management of the pilot interface, with control-panel functions easily changed by updating software rather than hardware.

The concept in developing the UCS display was to integrate many separate displays and switching components into one interactive surface while increasing flexibility and reliability. Its architecture combines hardware and software so aircraft manufacturers can configure one piece of hardware to meet varying individual aircraft requirements and adapt functions to changing

needs over time. This consolidation of functions into one screen, however, did present a number of challenges.

For example, think of using the touchscreen on your smartphone or tablet outside on a sunny day. The display must be bright enough to allow the pilots to view the controls. Too much glare reflecting off the screen or fingerprints on its surface can make the display hard to see. Esterline addressed these challenges by developing a sunlight-readable high-bright, high-contrast display in combination with a new anti-fingerprint coating that repels skin oils.

The human factors involved in entering commands also presented issues. Mistyping on controls for an aircraft can have a greater impact than mistyping a text message. Ensuring an action is correct and intended by the flight crew involves the use of tactile feedback through Esterline developed features. Esterline's implementation requires the operator to select an action by applying the right amount of pressure to the screen with a gloved or bare finger or a stylus. For additional security, a touch-hold-release user interface reduces the chance of inadvertent activation.

Features of the Korry UCS touchscreen display technology include:

- **Flexibility:** control-panel functions can be changed by updating software instead of changing hardware.
- **Triple redundancy:** three displays, each with two channels, allow for one channel to be down without interfering with normal aircraft operation.
- **Anti-fingerprint surface:** novel surface technologies allow skin oil to stay on the operator's skin instead of the display surface.
- **High-bright/high-contrast display:** all information is readable in direct sunlight even at wide angles.
- **Reliability:** reduction of separate switches by more than 75 percent minimizes the potential for failure; the glass screen is designed for life-of-the-aircraft durability.
- **Multiple touchscreen display sizes:** ranging from 3ATI to 15.4 inches.
- **Open architecture:** customers can implement their own look and feel for the control interface.
- **Ergonomics:** control activation is secure in varying conditions, including turbulence, and with different types of contact.
- **Design values:** the technology can be packaged in a sleek, low-profile format ideal for new-generation aircraft.

After pioneering its UCS touchscreen display technology for the business jet market, Esterline is now making it available in a format easily adapted to a wider range of aircraft.

Recycled Carbon Fiber Composites in Permeable Pavement

A Game Changer for the Environment

The same light-weight carbon fiber that will improve the efficiency of Boeing aircraft may also clean the polluted rain water that dirties Puget Sound and rivers in our region.

Washington State University is collaborating with Boeing and the Washington Stormwater Center to research the use of recycled carbon fiber composites to strengthen permeable pavement, a porous paving material that can mitigate pollution from stormwater runoff.

This research, supported by Boeing with a $212,000 grant to the Stormwater Center, relies on donated carbon fiber composite material from aircraft production operations. The grant supports research programs at the WSU Puyallup Research and Extension Center and on the Pullman campus through the university's Composite Materials and Engineering Center (CMEC).

Stormwater – or polluted rainwater, as John Stark, environmental toxicologist, Director of the Stormwater Center, and WSU professor and administrator likes to call it – is a particularly challenging byproduct of urban life.

Rain beats down onto conventional roads and parking lots picking up contaminants as it is channeled into local creeks, rivers, lakes, the Puget Sound, and the Pacific Ocean. Approximately 85 percent of the water pollution in the United States is caused by this kind of runoff, according to the US Environmental Protection Agency.

Recycled Carbon Fiber Permeable Pavement

"Water is one of our most precious resources, and we need to treat it as such," says Ursula English, vice president of Boeing Environment, Health, and Safety. "Creating the opportunity to expand the use of permeable pavement is good for the environment and the communities in which we live and work."

According to the EPA, permeable pavement allows the polluted stormwater to percolate and infiltrate through the surface into the soil below, where the water is naturally filtered and pollutants removed. Since 2010, Stark and his colleagues have been relying on grant money from the Washington Department of Ecology and the City of Puyallup to study the positive impacts of permeable pavement.

"The water trickles through the pavement to a gravel base below. Over time, the water seeps into the ground where many impurities are filtered out," says Stark. "We've been closely monitoring data. It's 100 percent effective at filtrating water and stopping runoff."

Though permeable pavement is effective in parking lots and side roads, it's generally not strong enough for heavily travelled highways or high-use surfaces that have heavy equipment running back and forth on the pavement. The new collaborative research will test whether recycled carbon fiber composite material can strengthen permeable pavement and expand its potential use.

"If we find this material safely strengthens permeable pavement, resulting in an increase in its use, this could be a game changer in terms of reducing the impact of pollutants in stormwater on the environment," says Stark. "Preliminary results look promising in terms of increasing the strength of the pavement and reducing the toxicity of the pollutants."

Stark and his colleagues are working with engineers at the WSU CMEC and at Boeing on the next phase of the research. They will be evaluating the durability of the modified pavements on experimental stretches of asphalt exposed to vehicle traffic. Researchers will examine whether the addition of carbon fibers increases pollution filtering and how long the filtering process lasts with wear and tear on the permeable pavement material.

John Stark is an ecotoxicologist specializing in ecological risk assessment of threatened and endangered species. He was recently named Director of the Washington Stormwater Center, located at WSU Puyallup Research and Extension Center.

PACIFIC
HYPERLOOP

Los Angeles-based Hyperloop One recently held a competition in Washington, DC, to find the first few candidates — out of a slate of 11 that had been whittled down from an initial field of 2600 — for a high-speed Hyperloop transit system in the United States. Pacific Northwest Hyperloop was one of the candidates proposing a solution that could change America's transportation infrastructure. If successful, that could mean a boon to Washington state's aerospace supply chain.

Diversification of Washington's Aerospace Supply Chain May be an Added Benefit of Hyperloop Transportation Technology

Travel from Seattle to Portland in just fifteen minutes?

Pacific Hyperloop is working to make it a reality. The Seattle-based group is a semi-finalist in the Hyperloop One Global Challenge, a competition that sought applicants from around the globe to make the case for Hyperloop in their region. Pacific Hyperloop is in the early planning and development stage for a Seattle-to-Portland route and is supported by Janicki Industries and the Seattle Department of Transportation. The Pacific Northwest's aerospace industry carries a key competitive edge relative to all globally proposed routes. Pacific Hyperloop is leveraging the PNW aerospace industry's unique position to secure a first-to-market advantage in the $180 billion Hyperloop POD global market.

The Technology

Hyperloop is a transformative transportation technology reaching speeds up to 760 mph; nearly the speed of sound. It combines existing magnetic propulsion technology and pneumatic tubes to eliminate friction and air resistance, turning hours of travel time into minutes. Los Angeles based Hyperloop One is developing the infrastructure and vehicle technology. In 2016, it successfully completed a public demonstration of the magnetic propulsion reaching a top speed of 116 mph in 1.1 seconds. As of April 2017, Hyperloop One has completed build-up of the test facility "Devloop" in Nevada. This test facility will demonstrate the combined system of magnetic propulsion inside a low-air pressure tube track.

Hyperloop for the PNW Region

Pacific Hyperloop is conducting a preliminary feasibility study of the route from Seattle to Portland, then continuing to Vancouver, BC, and eventually connecting to a continental Hyperloop network. The company is pushing for the Pacific Northwest to be the first region in the United States to implement Hyperloop. The PNW region is competitive by offering two key advantages over other US regional proposals: the region has demonstrated forecast-beating population growth and recession-proof GDP growth, and; the safety record and manufacturing capability of the aerospace supplier base exceeds those of other areas. Hyperloop passenger and cargo vehicles will be travelling at mach 0.95 speeds. Aerospace manufacturing has the proven expertise to instill confidence in passenger safety in the new industry. Pacific Hyperloop has energized the community and is bringing together all the public and private stakeholders to position the PNW region competitively.

> **"The PNW region is competitive... (because) the safety record and manufacturing capability of the aerospace supplier base exceeds those of other areas."**

A Minimum $180 Billion Market Opportunity

Manufacturing synergies are inevitable for Hyperloop and the aerospace industry, says Pacific Hyperloop Founder, Ahmed Elayouty, "Safety is key to Hyperloop's success. Manufacturing of Hyperloop passenger vehicles, or pods, will require aerospace-grade tolerances and quality control to replicate such a safety record. Moreover, Hyperloop pods are essentially wingless airplane fuselage. Passengers will be sitting inside a pressurized cabin travelling in a low-air environment and we see significant overlap with the aerospace industry."

The PNW aerospace sector is best positioned to secure the first-mover advantage. Value of Hyperloop PODs for Seattle to Portland route is estimated at $4 billion to

$6 billion. As Hyperloop routes are constructed globally, over the next 20 years, a conservative estimate of $180 billion will be spent on Hyperloop PODs.

Janicki Industries recognizes this unique generational opportunity and is partnering with Hyperloop One and Pacific Hyperloop to advance the PNW region competitively as the first region to connect via Hyperloop.

Closing the case for the economic gain, job creation and community benefits requires collaboration with all innovators in the aerospace sector. Pacific Hyperloop is engaged with interested parties to form a joint venture in accelerating regional Hyperloop implementation. The PNW region must secure the first-mover advantage to continue the global leadership as the net exporter of transportation technology.

Charlie Swan is a Co-Founder and the Business Development Manager of Pacific Hyperloop, and is a student in the Department of Economics at the University of Washington. pacific-Hyperloop.com

Manufacturing Innovations

Continued from page 8

It is an exciting time in the industry but also disruptive to skilled labor, supply chains, design and engineering groups, and procurement. Our educational institutions need to be at the forefront of producing the technical talent for the new manufacturing environment, leading the research projects that will produce the knowledge base for future manufacturing innovation and certification, and retraining those individuals who will be displaced.

The authors are grateful for support from the UW CCAM (Collaborative Center for Advanced Manufacturing).

Drones

Continued from page 14

Why Washington? Sure, there is plenty of competition from outside the US, especially from Chinese companies, one of whom, DJI, has a 70 percent market share in the "pro-sumer" UAS market space where commercial operators use a consumer UAS in their business. Additionally, "custom drone" designs or major parts thereof, can be rapidly produced with 3D printers and piece parts are readily available from global and US sources, often leading companies to assemble or manufacture UAS components in house.

However, the sheer growth of this market merits the attention of Washington companies manufacturing everything from connectors to composites, contracting imaging services, autonomous software, sensors, avionics, payloads, launch and recovery hardware and that meet the all-important data analysis and management needs the industry generates.

To no one's surprise, Boeing subsidiary, Insitu, is focusing more on commercial UAS market opportunities. Amazon's well known UAS delivery efforts and Microsoft's own work and investments in airspace software activities reflect great interest in the UAS realm as well. And there are a whole host of smaller, innovative companies that conceive, develop, test, manufacture or otherwise provide products and services for the UAS market today. Concurrently, our major universities, community colleges and even K-12 schools are engaged in UAS or robotics education efforts, including those for the ground and maritime environments.

As Russell Wilson of the Seattle Seahawks would say, "Why not us?" The seeds of innovation are right here in Washington, in our companies, clusters, trade associations and our educational institutions. Now is the time to take advantage of those seeds to help the state become a preeminent leader in the UAS segment of the aerospace industry.

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