Ohio State Forum on Transitioning to Low-Carbon Aviation
March 28, 2023
The Ohio State University Airport

On March 28, 2023, The Ohio State University hosted a group of industry, government, and academic thought leaders to explore the challenges of transitioning the aviation industry to a low-carbon future. Speakers highlighted the significant investments that will be required in terms of **aircraft design and propulsion**, the complexity of **infrastructure and ground systems** that will be needed to support new sources of power, and the **workforce development** necessary to service a new generation of air transportation.

This is the second sustainable aviation forum hosted by Ohio State. It reflects the tremendous expertise of researchers working across the university on sustainable aviation solutions from new propulsion systems to navigation systems for advanced air mobility to environmental equity considerations for infrastructure upgrades. This year's event was organized by faculty and staff from the Aerospace Research Center, the Center for Automotive Research, the Center for Aviation Studies, the College of Engineering, The Ohio State University Airport, and the Sustainability Institute. It was made possible by a grant from lead sponsor Honda.

Below is an executive summary of the proceeding. For additional information, please contact Josh Knights at knights.16@osu.edu.

Opening Remarks
Dorota Grejner-Brzezinska, *Vice President of Knowledge Enterprise, Ohio State*

- Ohio State is committed to public-private partnerships that innovate, create jobs, and contribute to economic development.
- It recently moved from #24 to #12 in university rankings based on research expenditures, which reached $1.38 billion in FY2022.
- The university welcomes opportunities to collaborate with the aviation industry to help it meet sweeping commitments in terms of sustainability.
- Aviation accounts for 2.5% of global greenhouse gas emissions, mostly from commercial travel, a number which will increase as other transportation sectors decarbonize.

- Since it is unlikely that passengers will forego the convenience of air travel in significant enough numbers to reduce the sector's emissions, research needs to focus on helping aviation become carbon neutral through solutions like sustainable aviation fuels.
- Biofuels in general face the challenge of scaling up to the levels needed to replace fossil fuels in the transportation industry. This change may also require special infrastructure as well as workforce training.
- Ohio State is eager to collaborate with industry to pursue federal funds available to pursue the research needed to solve these challenges.

Aviation's Commitment to Sustainability
Menelik (Mel) Solomon, *President, GE Honda Aero Engines*

- Aviation is an integral piece of the world economy. Worldwide, it supports 90 million jobs. As the global population increases and GDP continues to rise, demand for air travel will only continue to expand.
- The growth of aviation and the urgency of addressing climate change has elevated the importance of sustainable aviation solutions. For example, air transportation annually consumes 95 billion gallons of carbon-based fuel. In recognition of the need to act, the International Civil Aviation Association has adopted a goal of net-zero emissions by 2050.
- GE Honda Aero Engines has accepted the challenge and is in the process of implementing multiple carbon reduction measures. These include a demonstration test of operating an engine using 100% sustainable aviation fuel, developing a new gas turbine hybrid engine, and new open-fan engine design.
- Even with engines that can use sustainable aviation fuel, scaling up production is a limiting factor. Projections to get the industry to net-zero estimate that more than 60% of the improvement would need to come from sustainable aviation fuel, yet current growth models indicate that only 20% of the needed quantity will be produced by 2050.
- There is a pressing need for more public-private research partnerships such as the one Honda has with Ohio State to address these and other challenges.

Morning Keynote: Accelerating Aviation and Aerospace in Ohio
Adam Holmes, *Chair, Ohio House Committee on Aviation and Aerospace*

- The Aviation and Aerospace Committee is a relatively new committee in the Ohio House of Representatives. It is a standing committee with 11 members. Its mission is to unify and accelerate the development of the aviation and aerospace sector in Ohio.
- The committee can capitalize on the many aviation and aerospace assets in Ohio include Wright-Patterson Air Force Base, JobsOhio, NASA Glenn, companies like GE Aerospace and, of course, research institutions like Ohio State.
- The focus of the state government is on clearer policy and regulations that allow industry and academia to make advances sooner.
- Academia's role is preparing the workforce for the challenges of the future and to contribute to the development of new innovations through research.
- The lead for the direction of the aviation and aerospace sector must come from business, not government. The market system works best when government and academia support the development of business. In addition to providing leadership, business organizes the inputs needed through supply chains, trains and deploys the

employees needed to conduct the work, and invests capital in facilities and other infrastructure.
- The Aviation and Aerospace Committee has several operating concepts that align with this "support system" for the industry across the state. These include creating growth opportunities, increasing skills training, leveraging existing public networks, supporting public safety and national security, and raising general awareness about the industry.
- Ohio State will help contribute to the next generation of aviation leaders, some of whom will be agents of change and develop transformative business models.

Cleaner, Quieter and More Reliable: When Can We Have Low-Carbon Aviation?
Matilde D'Arpino, *Asst. Professor, Mechanical & Aerospace Engineering, Ohio State*
Arjan Hegeman, *General Manager of Advanced Technology, GE Aerospace*
Kui Ou, *Technical Director, Flight Sciences Department, Honda Aircraft Company*
James (JD) Terry, *Chief Engineer, Textron eAviation*

- Getting aviation to net-zero by 2050 will be extremely difficult. There is no "silver bullet" and all technologies will be needed.
- A major lever to reaching the industry's carbon commitments will be sustainable aviation fuel. GE Aerospace and Honda are both testing engines that could run on 100% sustainable aviation fuel. (Textron eAviation is developing fully electric small aircraft.)
- However, sustainable aviation fuel has many limitations starting with cost. It is likely to be much more expensive than traditional jet fuel. This is driven in part by its limited availability. At present, the feedstock and systems are not in place to scale up this fuel to anything approaching what would be needed by the industry.
- Hydrogen has also been discussed as a possible fuel. Yet, it has a long way to go to be practical. Methane is the most common feedstock currently used for hydrogen production and methane leakage is a potent source of greenhouse gases. In addition, hydrogen combustion creates high water content which generates contrails. One solution could be to use hydrogen to create a synthetic carbon fuel that could be burned in a jet engine.
- Textron is ramping up its investments in fully electric aircraft. Pipistrel has built small aircraft that operate on batteries that are fully integrated into the plane. Yet, current battery technology, often used in the automotive industry, is not sufficient for larger aviation. The company is going back to academia and government agencies like NASA to glean additional insights to electric propulsion.
- For most aircraft, fuel efficiency will be more important than ever before. Not only does a more fuel-efficient engine reduce the amount of carbon emissions, it requires less fuel which can help offset higher fuel prices, especially for sustainable aviation fuel.
- Aircraft design can also lead to better fuel consumption. Honda's over-the-wing engine mount was designed to reduce drag and resulted in great fuel efficiency. To truly capitalize on the next generation of engine, the aircraft and propulsion system have to be designed as an integrated system. This is not necessarily the mindset today.
- A final obstacle is the need to certify that a new design is safe. Safety is paramount to the industry. Companies need to innovate, build, and then test to the point that they can demonstrate that the design functions in a safe and reliable manner. This often takes years to accomplish, although advances in computing are helping to shorten the time involved.

Rethinking Our Infrastructure: What Does Aviation Decarbonization Require on the Ground?

Amber Woodburn-McNair, *Asst. Professor, Mechanical & Aerospace Engineering, Ohio State*
Rex Alexander, *President, Five-Alpha LLC*
Elaine Bryant, *EVP of Aerospace & Defense, Dayton Development Coalition and Managing Director, Military and Federal Sector, JobsOhio*
Rich Granger*, Managing Director, Workforce & Economic Development, DriveOhio/FlyOhio*

- Decarbonizing infrastructure is a "wicked" problem with many interdependent considerations. These include things like cost, available space, public safety, and environmental justice impacts.
- Take upgrading heliports for electric aircraft. Getting power for rapid charging to the top of a building can be challenging. Firefighting equipment would need to adapt since traditional methods like using foam does not work on electric fires. All these changes also create weight issues for a rooftop location. There are also space limitations, especially for a heliport in a developed area like on the top of an urban hospital.
- Military installations are looking at what it will take to get to net-zero in terms of carbon emissions but it is a steep hill to climb. The Air Force is the world's largest user of jet fuel and ramping up supply of sustainable aviation fuel (or other fuel sources) will require tremendous changes on bases.
- Government is looking for companies to lead in terms of the infrastructure changes that will be needed at most airports. There are more incentives available now to encourage companies to take steps toward implementation than ever before.
- The key to making infrastructure upgrades successful will be implementation through a coalition that represents the key sectors involved. Ohio has models that could be emulated. For instance, DriveOhio has supported a coalition to establish vertiports that involves JobsOhio, major metropolitan areas, health care companies, and others.
- Working through a coalition can also address multiple uses. Some companies are looking to install equipment to charge electric aircraft that also can be used to charge electric vehicles.
- While there are many considerations that must be worked out relative to the infrastructure needed to support aviation decarbonization, waiting too long comes at a price. The time scale for updating infrastructure, especially in dense urban areas, can be decades because of regulatory review and financing.
- A good place to start with low-carbon projects might be the regional airports across the state. These are often in areas that have space for expansion/upgrades although they will be highly sensitive to cost considerations.

Gateways to Blue Skies: Ohio State Students Envision the Airport of Tomorrow

Madi Herrmann, *Aerospace Engineering Major*
John Manuel, *Aerospace Engineering Major*
Niraj Patel, *Aerospace Engineering Major*

- An Ohio State student team took second place in NASA's "Gateway to Blue Skies," a national competition to envision the airports of tomorrow. The competition assumed a shift toward zero-emission aviation by 2050 and asked participants to design an airport that could support the next generation of low-carbon aircraft. The Ohio State team collaborated with the Las Vegas Airport on designing a new international airport.

- Competing teams were ranked in three key areas of focus: (a) aircraft accommodations; (b) sustainability; and (c) convenience and efficiency for passengers as well as aircraft crews.
- In terms of aircraft accommodations, the Ohio State team reviewed expected aircraft advancements by leading manufacturers Boeing and Airbus as well as private plane manufacturers like Textron producing electric planes. The students concluded that sustainable aviation fuel could work with existing fuel lines but that new accommodations would be needed to store and dispense liquid hydrogen fuel as well as charging stations for smaller private planes with electric propulsion.
- The Ohio State students took a deeper dive into the design of the airport itself to address overall sustainability. They evaluated building materials and made recommendations about using electrochromic windows as well as mass timber construction (the latter can reduce building carbon emissions by 20%). The team also estimated carbon emissions avoided through the installation of on-site renewable energy sources like vertical axis wind turbines, rooftop solar, and geothermal heating and cooling. Finally, the team proposed a design to collect deicing fluids and separate the glycol for reuse.
- Finally, the team studied traffic flow of both aircraft and people to suggest more optimal design of airport spaces. They suggested "gate pods" that would be separated by aircraft fuel type that would be accessed through bridges to the main terminal. There was also a perimeter bridge for connecting flights and to reduce congestion. In addition to these design enhancements, the team recommended the use of electric/autonomous ground support equipment. It requires less energy, has lower maintenance requirements and is easier to train employees to use.
- Ohio State already has a new team of students that will participate in this competition for 2023.

Afternoon Keynote: GE Aerospace and Workforce Readiness
Arjan Hegeman, *General Manager of Advanced Technology, GE Aerospace*

- GE Aerospace has embarked on a significant investment in R&D for its engines to help the company achieve net-zero carbon emissions by 2050. Globally, it spent $1.9 billion on R&D and hired more than 1,000 engineers in 2022.
- The company is charting a path over time to decarbonization. For now, it sees gains to be made by improving the energy-efficiency of its engines. In the near term, it views greater adoption of sustainable aviation fuel as a major contributor to reduce lifecycle carbon emissions. Longer term, the company is developing new technologies including hybrid electric engines, hydrogen fuel, and open-fan rotors.
- GE Aerospace has been actively assessing and qualifying sustainable aviation fuel for years. Today, all GE-made engines can operate on approved biofuel blends. The company has also conducted demonstration flights using 100% sustainable aviation fuel in an aircraft engine.
- Typically, the company invests in a single technology demonstrator per decade, yet it currently has three demonstrator projects in process.
- One demonstrator is focused on the co-development with NASA of a hybrid electric propulsion system. The project leverages the company's experience with motors, generators, power converters and power management systems.
- Another demonstrator is focused on generating greater fuel-efficiency through advanced engine designs, notably open fan architecture. The design has been around for years

but it has drawbacks related to performance and noise. GE Aerospace has built its own supercomputer cluster to help solve these problems and make the technology feasible.
- Finally, the company has a demonstrator in progress to develop hydrogen combustion and fuel systems for Airbus. Unlike sustainable aviation fuel which can run as a blend on current engines, hydrogen requires a different combustor.
- Each demonstrator is expected to spin off technology upgrades that can be phased into fleets over time. Readiness during this decade of these decarbonization technologies means upgrades can take place by the mid-2030s.

Reaching Workforce Takeoff: How Do We Prepare Works for Aviation of the Future?
Tim Rehner, *Dean and Director, The Ohio State University at Lima*
Mark Cleary, *Director of Research & Technology, Materials & Manufacturing, Boeing*
Deborah Scherer, *Senior Vice President of Global Trade & Investment, One Columbus*
Eboni Wimbush, *President & CEO, Airport Minority Advisory Council*

- Aviation and aerospace is not unique among industries in terms of its workforce development needs. It faces many of the same challenges as other sectors such as diversity, training, recruitment and retention.
- The aviation workforce of the future should look like our communities. Many companies are actively recruiting diverse pools of candidates. Diversity covers not only race and gender but things like educational experience. The industry needs more graduates of 2-year programs to meet technician needs and not just engineers from 4-year colleges.
- Industry is also looking for multi-disciplinary thinkers who have basic soft skills that enable them to work well on a team. “Pie-shaped” (well-rounded) engineers are in high demand. Some specific technical needs include data analytics as well as experience using augmented reality/virtual reality.
- Recruitment, especially of diverse candidates, is compicated. Companies need to evaluate how they develop and retain new hires and whether they are challenging (in a positive way) workers to motivate them. More interventions are needed before the college-level to get students interested in aviation and aerospace, especially among female populations. Some organizations are offering mentoring programs at the high school level. For instance, the Airport Minority Advisory Council’s foundation funds “Project LIFT” (Leaders Inspiring Future Talent) to expose students to educational and career paths in the aviation industry.
- There may also be recruitment potential among some non-traditional groups, like those who have exited the workforce for a time. Individuals from these groups can be helped to enter/re-enter the field through programs like apprenticeships.
- To stand out among potential hires, industry needs to be better at sharing its story. One of its greatest assets is its existing employees, who can volunteer with STEM and other school groups to introduce students to the field. Industry-sponsored capstone projects is a small investment that can yield a big payoff if meaningful connections are made with students and excitement builds about corporate opportunities.
- Preparing the workforce for changes that have not yet been implemented, especially around decarbonization, is difficult. Industry should lead in terms of identifying workforce training needs but there is an important role for public-private partnerships to create the programs to address those gaps. Universities obviously have a critical role to play in the delivery of required knowledge and programs.

Concluding Remarks
Joseph E. Zeis, *Senior Advisor for Aerospace & Defense, Office of Governor DeWine*

- Governor DeWine's vision for Ohio is to be a world-recognized leader in the aerospace and defense industry. The state is already home to nationally significant aerospace and defense installations, is an integral part of the sector's manufacturing and supply chain, and has a world-class workforce.
- Forums like this one, led by researcher leaders like Ohio State, help bring together the many stakeholders needed to move the sector forward in positive ways.
- Many of the most transformative technological advances in aviation and aerospace have been the result of Ohioans. Given this legacy and the state's current assets, Ohio is poised to lead the nation into the aerospace age of the 21st century.

Forum participants gather in the NetJets Observation Deck at The Ohio State University Airport