GE Aerospace

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Chair Cantwell, Senator Cruz and members of the Committee, on behalf of GE Aerospace, our 24,000 employees in the U.S., and 45,000 employees worldwide, thank you for the opportunity to testify today on the topic of next generation aviation technologies and the future of flight. My name is Arjan Hegeman, and I lead advanced technologies for GE Aerospace.

GE Aerospace, based in Cincinnati, Ohio, with operations in 25 states, is one of the world's largest manufacturers of jet engines, components, and systems for commercial and military aircraft. We also have a global service network to support these offerings.

It's a privilege to join you and the other organizations invited to share our testimony today, during what's truly one of the most exciting periods of my 25-year career as an aerospace engineer. We welcome the opportunity to join other stakeholders in the aviation industry – Universal Hydrogen, ZeroAvia, the FAA and NASA – to show how we're shaping the future of flight.

Today, GE Aerospace and its joint venture companies have nearly 41,000 commercial engines at work powering three out of every four aircraft departures globally and a diverse portfolio of more than 26,000 military engines. As a result, nearly 3 billion people flew with our technology under wing in 2022. We take that responsibility seriously, living our purpose to invent the future of flight, lift people up, and bring them home safely.

GE Aerospace is a top aircraft engine producer due in large part to the strength and ingenuity of our U.S. employee base and infrastructure. Earlier this month, we announced plans to invest more than $335 million in existing U.S. manufacturing facilities this year, purchasing cutting-edge equipment and making upgrades to position the company and our U.S. workforce of more than 24,000 people for a strong future. For example, in Lynn, Massachusetts, we'll invest $31 million toward test facility and tooling upgrades to support engine production and development. In anticipation of continued manufacturing growth in Auburn, Alabama, we'll invest $16 million towards facility upgrades to support increased use of additive manufacturing technology.

In addition to these investments in our operations, we are also investing in the development of new technologies to define the future of flight. We have embarked on one of the most extensive technology demonstration plans in our 100-plus year history, spending $1.9 billion[1] on aviation research and development in 2022.

In 2022, government members of the International Civil Aviation Organization (ICAO) adopted targets to reach net zero carbon emissions for international flights by 2050, following a similar commitment made by the aviation industry. This is an ambitious goal, requiring broad cooperation and significant investment across all sectors of the industry. New innovative aircraft engine systems will need to be developed that burn significantly less fuel to help meet emission reduction goals, supporting America's drive toward energy independence.

In my role, I work with engineers designing, testing, and maturing technologies for the next generation of aircraft engines to enable an even more efficient and safe commercial aviation fleet. This is a pivotal moment for the aviation industry, as we're already at work today developing the technologies that will power the aircraft of tomorrow.

As you consider the FAA Reauthorization Act of 2023, I would urge you to recognize the important role the agency plays in industry oversight, as well as in the development of aviation technologies that improve efficiency, reduce noise and emissions, and enhance safety for the public.

GE Aerospace's roadmap for the future of flight

At GE Aerospace, we are taking bold action to define and develop technologies for the next generation of engines. GE Aerospace and our partners have incrementally improved fuel efficiency with each successive new commercial aircraft engine design. The GEnx engine, introduced in 2011, is up to 15 percent more efficient than its CF6 engine predecessor. The LEAP engine[2], introduced in 2016, is 15 percent more efficient than the CFM56 engines it replaces. Our most recently certified engine, the GE9X, has been designed to be up to 10% more efficient than the GE90-115B, with emissions of nitrogen oxides (NOx) 55% below current regulatory requirements, due to a low-emissions combustor designed through the FAA's Continuous Lower Energy, Emissions and Noise (CLEEN) program.

Plans now aim to achieve something GE Aerospace hasn't ever done before with a revolutionary new engine design – pushing for 20 percent greater fuel efficiency in one generation.

To address this challenge, GE Aerospace, along with Safran Aircraft Engines, announced the CFM RISE[3] (Revolutionary Innovation for Sustainable Engines) technology demonstration program in June 2021. The CFM RISE program encompasses a range of new, disruptive technologies for future engines that could enter service by the mid-2030s.

Central to the program is advancing open fan engine architecture, a novel engine design that removes the nacelle around the front fan to optimize propulsive efficiency and reduce weight and drag. This proposed open fan architecture is a key enabler to achieving significantly

[1] GE, customer and partner funded

[2] LEAP engines are a product of CFM International, a 50-50 joint company between GE and Safran Aircraft Engines.

[3] RISE is a registered trademark of CFM International, a 50-50 joint company between GE and Safran Aircraft Engines.

improved fuel efficiency while delivering the same speed and cabin experience as current single-aisle aircraft. NASA and FAA programs are supporting RISE program technologies, such as NASA's Hybrid Thermally Efficient Core (HyTEC) project, through which GE Aerospace is advancing combustion technology further for a new compact engine core.

CFM's RISE program will also use hybrid electric capability to optimize engine efficiency while enabling electrification of many aircraft systems. Through the Electrified Powertrain Flight Demonstration (EPFD) project, NASA and GE Aerospace are developing an integrated hybrid electric powertrain to demonstrate flight readiness for single-aisle aircraft. The EPFD program builds on recent GE Aerospace and NASA efforts at NASA's Electric Aircraft Testbed (NEAT) facility that was the world's first test of a megawatt-class, multi-kilovolt hybrid electric system in conditions simulating altitudes up to 45,000 feet. We expect to conduct ground and flight tests of the hybrid electric engine system by the mid-2020s using a modified Saab 340B testbed and GE's CT7 turboprop engines. Boeing and its subsidiary Aurora Flight Sciences are providing GE Aerospace with airplane modification, system integration and flight-testing services.

Additionally, CFM is collaborating with Airbus on a hydrogen demonstration program as part of the CFM RISE program. CFM will modify a GE Passport engine for testing by designing a new cryogenic fuel delivery system, hydrogen combustor and fuel controls. This is no easy feat, requiring a significant change to the propulsion system to be capable of safely burning liquid hydrogen, which doesn't generate carbon emissions during the combustion process. Efforts to design a new hydrogen combustor engine will draw from GE's more than 8 million hours of operating experience with hydrogen combustion with land-based gas turbines.

The RISE program embodies CFM's mission to push the limits of innovation to develop, demonstrate, and bring to market breakthrough technologies that will advance the industry.

Alternative fuels — key to reduced aviation emissions

Revolutionary technologies and alternative fuels both have critical roles to play in meeting the aviation industry's net-zero ambitions.

The biggest opportunity to make progress toward net zero by 2050 is Sustainable Aviation Fuel (SAF), an alternative jet fuel with a lower carbon footprint. All GE Aerospace engines can operate on approved SAF blends today, which can be made from plant-based material, fats, oils and greases, alcohols, waste streams, captured carbon, and other alternative feedstocks. When blended, SAF has the same chemical composition as the jet fuel most commonly used today. The key difference is that instead of being made from fossil-based sources, SAF is made from partially or completely renewable sources. The use of renewable feedstocks and processes reduces net carbon emissions over the entire lifecycle of SAF compared to fossil-based fuels by up to 80%.

GE Aerospace has been actively involved in assessing and qualifying SAF since 2007 and works closely with producers, regulators, and operators to help ensure SAF can be widely adopted for use. One of the major roles GE plays is in evaluating and qualifying new types of jet fuels for engine operation, including various types of SAF.

While approved SAF is compatible with existing aviation equipment and infrastructure today as a drop-in solution, supply is extremely limited. Currently, SAF production is less than 1% of global jet fuel demand.

To address the current scarcity of SAF, the U.S. Department of Energy, U.S. Department of Transportation, the U.S. Department of Agriculture, and other government agencies introduced the SAF Grand Challenge in 2021 to develop a comprehensive strategy for scaling up new technologies for SAF production on a commercial scale. GE Aerospace supports this vision to reduce the cost, enhance the sustainability, and expand production and use of SAF. It represents an opportunity to demonstrate global leadership while promoting energy independence.

Another candidate jet fuel that has received increasing interest globally is hydrogen. Whereas approved SAF can be used in jet engines today, hydrogen as an aviation fuel requires the development of new aircraft engines to be compatible, which we are exploring.

The role of agencies in aviation technology development

NASA and the FAA play crucial roles in accelerating development of new technology through research investments.

NASA has deep domain expertise and excellent facility resources, making the agency the ideal technology collaborator. For more than a century, NASA and its predecessor organization – the National Advisory Council for Aeronautics – has been the global leader in aviation research. As outlined in the Aeronautics Mission Directorate Strategic Implementation Plan, NASA is continuing its aeronautics leadership through the sponsorship of four key programs: the Advanced Air Vehicle Program (AAVP); the Airspace Operations and Safety Program (AOSP); the Integrated Aviation Systems Program (IASP); and the Transformative Aeronautics Concepts Program (TACP). These programs have led to major investments for the development of new hybrid electric jet engines and more compact engine components that can withstand higher operating temperatures to reduce fuel burn. Similarly, NASA's Sustainable Flight Demonstrator (SFD) program represents an investment into new aircraft designs needed to achieve the aggressive performance goals for future products. As the SFD program advances, integration of new engine architectures will become more important to reach efficiency objectives.

As this shows, the NASA aeronautics investment portfolio reflects a continuation of successful government/industry partnership to maintain and advance competitiveness of U.S. aviation products.

The Continuous Lower Energy, Emissions and Noise (CLEEN) Program is the FAA's principal environmental effort to accelerate the maturation of new aircraft and engine technologies. Through the CLEEN Program, the aviation industry partners with the FAA via a cost-sharing approach to expedite integration of more environmentally beneficial technologies into commercial aviation. Technologies developed under the CLEEN Program effectively transform the commercial fleet, replacing legacy aircraft with new products that produce less noise and fewer emissions, while using less fuel. These technologies support the overall environmental performance goals of the FAA's Next Generation Air Transportation System (NextGen) to help protect the environment in a way that allows the aviation industry to grow.

GE Aerospace's history of collaboration with FAA and NASA

GE Aerospace's partnership with NASA has transformed the landscape of aircraft propulsion over the last 50 years. Collaborative programs like the NASA Quiet Clean Short Haul Experimental Engine (QCSEE) in the 1970s contributed to the design of the GE CF6-80C

engine, which is still in commercial service today. Similarly, following successful demonstration of an F101 core powerplant under the QCSEE program, GE Aerospace obtained an export license to incorporate it into the CFM56 engine, which went on to be the best-selling commercial aircraft engine in history, powering both the Boeing 737 and Airbus A320 narrowbody aircraft. In response to the energy crisis of the 1970s, another combined NASA and GE effort gave rise to the GE Unducted Fan Demonstrator, UDF™, and the subsequent open fan engine concept that is informing CFM's RISE program today.

Although unducted fan development was previously canceled when oil prices declined, joint GE Aerospace and NASA development of composite technology was introduced into service in 1995 with the GE90 engine, powering the Boeing 777, featuring the industry's first fan blades made from composite materials that are lighter weight and more durable than their metallic counterparts. GE and NASA continued composite fan technology collaboration, demonstrating a new design on the NASA Advanced Ducted Propulsion (ADP) rig, which entered service in 2011 on the GEnx engine. The GEnx engine powers the Boeing 787 and 747-8 aircraft.

With the current focus on energy independence and environmental sustainability, GE Aerospace and NASA are collaborating on multiple fronts to develop new technologies to enable a future product, targeting 20% better fuel efficiency than today's most advanced engines. These programs include: EPFD (hybrid electric), HyTEC (engine core), and other small projects.

GE Aerospace's partnership with the FAA has been similarly successful. Through Phases I and II of the CLEEN program, the FAA has partnered with GE Aerospace to introduce technologies into the current generation of products, including the CFM LEAP family of engines, powering narrowbody aircraft, which represents the largest segment of the commercial fleet. LEAP engines burn 15% less fuel and are 10 to 12 decibels quieter than CFM56, the prior state-of the art. The CLEEN program also helped develop technology for our latest commercial engine, the GE9X, which will power the newest U.S. widebody offering, the Boeing 777X. The GE9X is up to 10% more fuel efficient than the GE90 engine, the prior generational equivalent, with NOx emissions 55% below regulatory requirements.

Currently, CLEEN III program funding supports research and development efforts for several of the most promising technologies to achieve CFM RISE program goals for a major step-change reduction in carbon emissions for future, next-generation single-aisle aircraft engines. Through CLEEN, GE Aerospace is advancing open fan engine architecture, electrification, noise-lowering technologies, and more, as well as continuing ongoing research into alternative jet fuels. Looking to the future, CLEEN IV is on the horizon, to accelerate additional technologies into the fleet, in coordination with industry and NASA.

Further, the FAA's Fueling Aviation's Sustainable Transition (FAST) grant program, also known as the AERO Act and created in the Inflation Reduction Act of 2022, supports efforts to accelerate aviation innovation and technological advancements. This program complements ongoing efforts to accelerate the uptake, distribution, and use of SAF while simultaneously spurring investments in innovation and technological advancements. GE Aerospace thanks the committee for its role in creating this program, especially Senator Raphael Warnock (D-GA), Senator Maria Cantwell (D-WA), Senator Gary Peters (D-MI), and Senator Alex Padilla (D-CA) who led in the creation of the AERO Act.

NASA and FAA investments fuel aviation competitiveness

The U.S. aviation industry faces fierce competition from Europe and emerging challenges from China. During the pandemic, European governments increased investments in more sustainable aviation including Germany, France, and the UK. These funds join existing EU-wide programs focused on next generation technology development such as Horizon Europe, which supports the European Partnership for Clean Aviation. Meanwhile, China is advancing its aerospace airframe and propulsion capabilities by investing tens of billions of dollars in homegrown champions under its Made in China 2025 plan and other initiatives.

That is why strategic, structural government investment in aviation technology infrastructure is critical to protect U.S. national security and economic interests amid foreign competition, reduce long-term aerospace emissions, and maintain the U.S. aviation industry's position as a global leader as it continues to recover from the COVID-19 pandemic. To meet aviation industry carbon commitments and global regulatory requirements, a next generation aircraft fuel burn reduction goal of more than 20% is needed, requiring a shift in propulsion and aircraft technologies. This requires accelerated research and development of advanced propulsor, thermal management, and hybrid electric technologies, as well as advanced integration of propulsion systems with optimized aircraft designs.

Additionally, new concepts like hydrogen fuel cells and hydrogen combustion present both new opportunities and new challenges that will require investment to ensure U.S. leadership in these emerging technologies. Scaling these new revolutionary technologies will also likely require new manufacturing methods and skillsets. Industry partnering with NASA through the programs outlined in the ARMD strategic plan and with the FAA through the CLEEN program are proven paths with a successful track record of accelerating development and transitioning new technology into the aviation fleet.

Advancements tied to certification and regulatory progress

In addition to playing a critical role in accelerating the development and demonstration of key technologies, these partnerships also provide a pathway for developing certification standards required for the successful implementation of new technologies into future aviation products. Realizing the benefits of our advancements are dependent on the regulatory agencies being able to certify our new technologies in a timely manner so that they can be adopted throughout U.S. fleets and accepted by other civil aviation authorities around the world. Delays in certifying these technologies will have a ripple effect and slow our industry's technology implementation, energy independence, and sustainability initiatives.

For the FAA to keep pace with innovation in the development of new products and technologies, it must issue new and updated regulations, policies, and guidance necessary to support certification and continued airworthiness during operation. The FAA lacks sufficient resources to simultaneously address the volume of guidance, policy and regulatory support requested by industry, resulting in a backlog of in-process regulations, policy, and guidance.

The FAA has a strong commitment to safely integrating new technologies as part of its mission to provide the safest, most efficient aviation system in the world. The close coordination of government and industry during the technology development and demonstration phases ensures the FAA builds the technical depth required to create appropriate regulations, policy, and guidance for new technologies. And as these technologies are matured, the Safety Management System (SMS) approach championed by the FAA – which GE Aerospace

voluntarily adopted in 2017 – further ensures that technology development efforts targeting significant reductions in emissions continue to keep safety of flight at the forefront.

GE Aerospace is encouraged by this Committee's focused attention on reauthorizing the FAA. It is important that the agency is reauthorized in a timely manner because, as this committee well knows, the FAA must approve all products before they reach the marketplace. Through the FAA reauthorization, Congress provides critical direction and funding stability to the agency. Recent certification and regulatory reforms exemplify the importance of the reauthorization process. It provides Congress the opportunity to review how those reforms are working and adjust as necessary. Importantly, if the certification and regulatory processes do not run smoothly, new and innovative products, which often enhance safety and increase efficiency, cannot access the marketplace or benefit the National Airspace System and its users.

Workforce readiness

GE Aerospace would not be a world-leading jet engine manufacturer without its workforce of 45,000 people around the world and more than 24,000 team members in the U.S. As we seek to invent the future of flight and support our fleet of engines in operation today, talent development and retention is key. The ability to attract new, skilled talent is also vital.

To help inspire future generations to join the aviation industry, GE Aerospace introduced in 2021 Next Engineers, a global college- and career- readiness program to increase the diversity of young people in engineering. The program, offered in the U.S. in Cincinnati, Ohio, and Greenville, South Carolina, provides students ages 13 to 18 with first-hand experiences in engineering concepts and careers, and ultimately awards partial scholarships to pursue higher education in engineering.

College graduates with a passion for technology can apply for GE Aerospace's Edison Engineering Development Program. Through the two-year, entry-level program, young professionals gain valuable experience across the engineering spectrum, including engineering hardware design, controls, validation testing, materials, power electronics, software, and more. Additionally, program participants can accelerate professional and technical development through GE Aerospace's Advance Courses in Engineering and a variety of business-critical engineering assignments. Upon completion, Edison program graduates have the technical and business foundation to help invent the future of flight.

The aviation industry can't achieve its ambitious goals for the future of flight and create jobs in local communities without a collective effort to address workforce shortages. Industry groups are advocating for expanded workforce development programs for aviation manufacturing, creating a transition process for military members to join civil aviation, and creating a national center for the advancement of aviation. GE Aerospace supports proposals like these that promote aviation careers and provide resources to help develop a skilled U.S. aviation and aerospace workforce through scholarships, apprenticeships, aviation curriculum development, and other outreach efforts.

Conclusion

On behalf of GE Aerospace, I want to thank Chair Maria Cantwell and Senator Ted Cruz for convening this hearing and allowing us to testify on next generation aviation technologies. We are grateful that the Committee has prioritized this issue during your work to reauthorize the

FAA and appreciate that you are working, on a bipartisan basis, with aviation stakeholders to provide the resources and programs to advance aviation's future. Maintaining global leadership in aviation offers multiple benefits to the American public including high-paying jobs, enhanced national security, and meeting the sustainability challenges we face. Thanks to all committee members who participated today.