Raytheon Technologies
Advancing Sustainable Aviation

How we're supporting the aviation industry's drive to decarbonize

Our approach to sustainable technology and innovation

The commercial aviation industry has a long history of producing more efficient aircraft with each successive generation, achieving 80% improvement since the first-generation commercial jet engines. Today, we are increasing the use of sustainable aviation fuel (SAF) throughout our product portfolio, developing sustainable technology and innovating greener products to help reduce greenhouse gas (GHG) emissions at a faster pace than ever before while supporting air traffic growth for a more connected future.

In October 2021, Raytheon Technologies, along with the commercial aviation industry, set an ambitious goal to achieve net-zero carbon emissions for commercial aviation by 2050, aligning global civil aviation with the Paris Agreement to pursue efforts to limit global temperature increase to 1.5°C above pre-industrial levels. Following this commitment, in October 2022, the International Civil Aviation Organization (ICAO) member states adopted a collective long-term global aspirational goal (LTAG) of net-zero carbon emissions by 2050 for international aviation.

Aviation is currently the only industry that has established a global resolution to address climate change. Achieving these aggressive goals will require strong collaboration from multiple stakeholders, including public-private partnerships, working with our suppliers, customers and energy companies, and continued investment in new technologies.

Leading our efforts is our chief technology officer (CTO), who works closely with the chief sustainability officers (CSOs) in our business units. These leaders work with engineering and advanced technology teams at our business units and the Raytheon Technologies Research Center. Together, they drive Research & Development (R&D) to develop products with world-class sustainability performance. In 2022, we spent a total of $7.1B in customer- and company-funded R&D.

We also established the Sustainable Technology & Innovation, Environmental, Social and Governance (ESG) working group to drive sustainable technology projects across the organization, develop and implement an environmental sustainability technology roadmap and support climate-related disclosures.

In addition to our R&D efforts, we invest in startups through our venture capital group, RTX Ventures, to accelerate the development of new technologies. In 2022, we announced agreements with VerdeGo Aero and H55 to accelerate hybrid-electric propulsion and battery technologies for advanced air mobility applications.

Our environmental sustainability technology roadmap

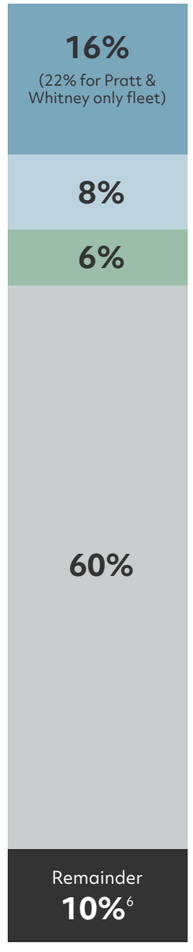
In 2021, we developed and launched our environmental sustainability technology roadmap, which outlines our path to supporting the civil aviation industry's 2050 net-zero commitment across our products and services. In 2022, we made strong progress in technology and innovation, leveraging the advantages of our scale, expertise and industry partnerships. Our roadmap to 2050 allows for the long-term nature of technology and infrastructure advancements in our sector. It also recognizes that actual changes in emissions only result once the technologies are matured, deployed into products, certified and delivered to customers. Our roadmap progress will be paced by the respective timelines for these activities. We plan to provide quantitative performance updates relative to these sustainability goals as we continue to progress.

As timelines for advancements vary, we are focused on improving engine efficiency, fielding 100% SAF-compatible, hybrid-electric propulsion systems in the near- to mid-term and supporting green hydrogen-powered propulsion systems in the long term.

		2035	2050
ENGINES AND AIRCRAFT SYSTEMS	**Continuous engine efficiency improvements and technology advancements**	Develop capability for hybrid-electric turboprop propulsion technology with potential fuel savings of **30%**.[1] Launch-ready, hybrid-electric GTF engine with up to **25%** potential fuel burn reduction over GTF baseline with SAF.[2]	Launch-ready, advanced-cycle, hydrogen-burning engines that improve efficiency by **up to 35%** over GTF baseline.[2]
	Aircraft system improvements	Optimize the design of aircraft components and equipment to minimize weight and maximize energy efficiency, reducing fuel burn by **3%** per flight.[1]	Optimize the design of aircraft components and equipment to minimize weight and maximize energy efficiency, reducing fuel burn by **8%** per flight.[1]
AIRLINE, AIRPORT AND AIR TRAFFIC OPERATIONS	**Aircraft trajectory and ground operations improvements**	Develop next-generation technologies for air traffic and ground optimization, leading to **5%** emission reductions on average per flight.[1]	Develop next-generation technologies for air traffic and ground optimization, leading to **8%** emission reductions on average per flight.[1]
Driven by Raytheon Technologies			
Supported by Raytheon Technologies			
VALUE CHAIN PARTNERS	**Sustainable aviation fuels (SAF), and other alternative aviation fuels (AAFs), airframer efficiency improvements and operations improvements from other industry stakeholders[3]**	Support energy industry value chain partners to achieve **30%** SAF availability.	Support energy industry value chain partners to achieve **85%** SAF/AAF availability.

Estimated fleet impact

Aggregate emissions reductions from the 2050 civil fleet with Raytheon Technologies aviation products, relative to an inventory baseline with 2015 technology levels[4,5]



[1] *Improvements measured over a baseline with 2015 technology levels.*
[2] *Improvements measured over a baseline with 2016 GTF technology levels.*
[3] *Airframers and other value chain partners enhance aircraft design to reduce drag and weight and improve overall vehicle fuel economy. This also includes technologies for air traffic optimization and infrastructure improvements from other value chain partners.*
[4] *Values represent Raytheon Technologies' forecasted estimates for civil fleet net CO_2 emissions, relative to a 2015 technology baseline, using GHG Protocol for Project Accounting methods for our fleet of engines and systems. We adopted a 2015 technology baseline consistent with ATAG Waypoint 2050, which is a vision of net-zero aviation widely adopted by the industry. Several new, significantly fuel-efficient aircraft, including Airbus A320neo and Boeing 737 MAX, were introduced after 2015 and have been, and continue to be, adopted by airlines to replace older aircraft and to grow their fleet to serve traffic demand.*
[5] *The forecasting method adds direct emissions from aircraft engines to indirect emissions from non-engine related equipment mass, aerodynamic drag and secondary power extraction. As detailed guidelines for fully analyzing emissions for the aviation industry do not yet exist, the methodology used in the future may evolve with industry standards.*
[6] *Potential solutions for reducing the remainder include enhancing the advancements noted above to further reduce emissions or employing market-based mechanisms.*

Accelerating the trajectory of aviation emissions reductions

In 2022, we made strong progress in multiple areas of our roadmap, including the entry into service of our latest advanced regional turboprop engine model PW127 XTM. We also initiated certification testing of the latest turbofan engine, GTF Advantage, where we continue to build upon the GTF engine's capabilities and reduce fuel consumption and emissions. Other ways we are working to bend the aviation emissions curve:

- We are developing **advanced-cycle engines** that recover water and waste heat to improve engine efficiency in the near term – Sustainable Water Injecting Turbofan Comprising Hybrid Electrics (SWITCH), and hydrogen-powered engines in the longer-term – Hydrogen Steam-Injected Inter-Cooled Turbine Engine (HySIITE). Hydrogen has an important role to play in enabling the aviation industry's pathway to net-zero emissions. While the development, distribution and use of these fuels present immense challenges, we are well positioned to make them compatible with future engines, ranging from regional turboprops to single-aisle class engines and beyond.
- We continue to innovate and mature **new aircraft systems**. These solutions span various technology threads, including hybrid-electric power distribution, hydrogen-compatible aircraft components and system design, thermal management, eco-friendly fire suppression systems, adaptive environmental control systems and advanced, lightweight materials.

- We are partnering with NASA to develop technologies that will continue to **reduce fuel consumption**, including advanced high-pressure turbine technologies, next-generation ceramic matrix composite materials (CMC), and demonstrating the compatibility of SAF with advanced combustors for small core engines.
- We are developing **aircraft avionics** to enable navigation systems to harness information for optimal aircraft trajectory planning, flight path optimization, flight planning, use of enhanced flight vision systems and weather radar for more efficient operations.
- We continue to improve the fuel economy of aircraft by optimizing **air traffic and flight operations**. This allows for flight trajectories to follow near-optimal routes at near-optimal altitudes and speeds during all phases of flight, which reduces delays, fuel consumption and emissions. We are also working to reduce fuel consumption at airports through improved taxi and ramp operations.
- We are fielding and upgrading state-of-the-art **air traffic management systems** as well as satellite-based precision navigation infrastructure as part of the FAA Next Generation Air Transportation System portfolio. This aims to deliver trajectory-based operations capabilities and more efficiency in the way controllers manage air traffic.
- We are providing and modernizing **datalink and enterprise network solutions** to support airlines and the Federal Aviation Administration (FAA). This includes weather information, weather sensors and integrated weather processing systems. Depending on the specific airspace environment, traffic conditions and the capabilities of the aircraft fleet, these operational improvements could reduce aircraft CO_2 emissions by up to 10%.

Under the EU's Clean Sky 2 research program, we developed a seven-meter-long cable raceway made of thermoplastics, the largest of its kind. The new generation of thermoplastic materials enables a more holistic and modular approach to aircraft design, resulting in a much lighter aircraft, which burns less fuel and has lower carbon emissions. Thermoplastic parts have the potential to provide up to a:

50%

weight reduction compared to metallic structures and 20% less than thermoset structures.[7]

80%

reduction in manufacturing cycle time compared to thermoset composites.[7]

100%

recyclability at the end of the part's life cycle.[7]

[7]Click here for more information

2022 PROGRESS

Continuous engine efficiency improvements and additional advancements

- **Engine efficiency:** Received more than 1,100 Pratt & Whitney GTF™ engine orders in 2022, which will reduce fuel consumption and carbon emissions by 16% to 20% over the previous generation of engines.
- **Engine efficiency:** Received certification for Pratt & Whitney 127XT-M™ turboprop engine, which offers 40% extended time on wing, 20% lower maintenance costs and 3% improvement in fuel efficiency.
- **Hybrid-electric:** Completed first successful engine run of our hybrid-electric propulsion technology demonstrator, a key milestone on the journey toward eventual installation and flight testing on a modified De Havilland Canada Dash 8-100 aircraft, targeted to begin in 2024.
- **Hybrid-electric:** Selected by the European Union Clean Aviation Joint Undertaking, which includes a consortium of aerospace technology companies to develop SWITCH technologies for integration into the GTF engine architecture. As the first single-aisle class engine demonstration to incorporate both hybrid-electric propulsion and Water Enhanced Turbofan (WET) technologies, it has a target to provide up to 25% improvement in fuel burn over current GTF and associated emissions.
- **Advanced cycles:** Launched our HySIITE project to achieve zero in-flight CO_2 emissions, while reducing nitrogen-oxide (NOx) emissions by up to 80% and reducing fuel consumption by 35% over the current GTF.

Aircraft system improvements

- Selected to participate in six additional projects under the European Union's Clean Aviation Joint Undertaking, collaborating with European airframers, engine makers, suppliers and academia to develop disruptive sustainable aviation technologies, including demonstrators for hybrid-electric powered aircraft and ultra-efficient short- and medium-range aircraft, thermal management and systems for novel wing designs.
- Clean Sky 2 Partnership: Achieved Technical Readiness Level (TRL) 5 on a high-performance gas expansion approach to develop the next-generation fire suppression system. It will use nitrogen, which is environmentally friendly and widely available as an alternative to halon. Under this partnership, we also achieved TRL 5 on an adaptive environmental control system that reduces the amount of fresh air required in cabin ventilation while maintaining cabin air quality and passenger comfort. This innovative technology is expected to save approximately 2% in aircraft fuel.
- We received a four-year grant from the French Civil Aviation Authority to develop next-generation actuation systems, which will offer a lighter and more compact advanced motorized gearbox and better thermal management compared to existing systems, resulting in improved engine efficiency.

Aircraft trajectory and ground operations improvements

- Selected by the FAA to provide technical refresh and dual-frequency operation upgrades to its Wide Area Augmentation System (WAAS), a space-based precision navigation system that is fundamental to efficient aircraft trajectory operations.
- Launched FlightHub™, which provides pilots with real-time route recommendations that enable a more efficient flight path and reduce fuel consumption and emissions.
- Achieved a technical standard order for our combined vision system for business aviation aircraft, providing clarity to pilots in all types of weather to confidently and securely navigate through low-visibility situations, saving fuel and reducing CO_2.

Driven by Raytheon Technologies

Value chain partners

- Completed four of the first Pratt & Whitney flight tests using 100% hydroprocessed esters and fatty acids synthetic paraffinic kerosene (HEFA-SPK) SAF without aromatics on Pratt & Whitney engines, including GTF™ engines in addition to other engines.

Supported by Raytheon Technologies

More information on our approach to sustainable aviation, including the technologies we are using to support the aviation industry's goal of net-zero emissions, can be found on our website.

Policy shaping partners

Sustainable aviation and net-zero emissions require multiple measures and can only be successful with cross-sector industry actions and support from policy makers. We collaborate with multiple stakeholders, including airframers, energy companies, customers, research institutions, standards development organizations and government agencies to jointly overcome challenges in achieving industry alignment on technologies, effective measurement processes, interoperability, infrastructure limitations and regulatory policies.

On a net-fuel life-cycle emissions basis, SAFs have the potential to reduce CO_2 emissions by an estimated 40-60%, with a maximum forecast of 80%[8] direct carbon capture, making them a key element of the roadmap to net-zero CO_2 emissions by 2050.

[8] *Air Transport Action Group (ATAG): Alternative fuels, particularly SAF, have been identified as excellent candidates for helping achieve the industry's climate targets. SAF-derived sources such as algae, jatropha or waste byproducts have been shown to reduce the carbon footprint of aviation fuel by up to 80% over their full life cycle.*

	PARTNER ORGANIZATION	OUR ROLE	OUR ACTIONS
INDUSTRY ASSOCIATIONS	**Aerospace Industries Association (AIA)**	Executive Committee member; Chair of the Environment and Sustainability Committee	Lead the Environment and Sustainability Committee and support the Sustainability Subcommittee to drive progress towards efficient aviation technology and operations.
	Air Transport Action Group (ATAG)	Board member	Support advancement of civil aviation sustainability and committed goals of flying net-zero CO_2 emissions by 2050.
	Airlines for Europe (A4E)	Member; member of Airspace & Sustainability Working Groups	Advocate for European policies supporting sustainability in the aerospace sector in alignment with other industry alliances.
	Commercial Aviation Alternative Fuels Initiative (CAAFI)	Founding member	Support advocacy for the acceleration of SAF development and uptake across all segments of the aviation industry.
	International Air Transport Association (IATA)	Strategic partner	Promote sustainable solutions that are critical to the future of the global aviation industry.
	European-American Chamber of Commerce	Member of Technology Committee; member and co-chair of the Transport Energy and Climate Committee	Support the roadmap of the European Commission toward carbon neutrality.
	International Aerospace Environmental Group (IAEG)	Founding member; Executive Committee; Board members	Collaborate on environmental solutions and policies revolving around a diverse range of topics including technologies, GHG management and supply chains for the aerospace industry. Develop industry guidance and best practices.
STANDARDS	**ASTM International**	Committee member	Work with ASTM partners on testing and qualification of new SAF feedstocks, pathways and blends, and developing SAF standards.
	SAE International	Contributors	Establishing standards for certification of hybrid-electric flight.
GOVERNMENT	**European Commission's Alliance for Zero-Emission Aviation (AZEA)**	Member	Support advocacy for European policies that will accelerate decarbonization of the aviation industry.
	FAA NextGen Advisory Committee	Member	Collaborate with airlines and industry partners to recommend air traffic management modernization programs and priorities to improve aircraft efficiencies in all phases of operations.
	International Civil Aviation Organization (ICAO) Committee on Aviation Environmental Protection (CAEP)	Working Group member	Participate in the development of new environmental standards, including the development of ICAO LTAG goals of net-zero CO_2 emissions for international aviation by 2050.
	National Academies' Aeronautics Research and Technology Roundtable (ARTR)	Board member	Collaborate to explore critical issues related to the U.S. aeronautics research agenda and options for public private partnerships that could support rapid, reliable knowledge transfer.

Innovating for the defense sector

Our defense customers are increasingly focused on minimizing potential impacts from climate change. In 2021, the U.S. committed to achieve net-zero emissions from federal procurement and across federal operations by 2050. We are supporting these efforts and are positioned to meet the critical mission capability needs of our defense customers related to range, payload and speed while addressing environmental impact through energy efficiency gains and reduced emissions.

Preparing for the future of electric combat vehicles

Our decades of experience in providing electric power generation and management solutions to the aerospace industry is helping the U.S. Department of Defense (DOD) power the electrical components in its military ground vehicles. A modernized Collins Aerospace 28VDC 1000-amp main electrical power generator is supporting the U.S. Army's Abrams main battle tank. The generator provides 60% more power and fits in the same space as the legacy system without requiring major changes to the vehicle or its electric systems architecture. With improved efficiency, it enables tanks to operate longer while also increasing their mobility and survivability.

Reducing size, weight and power requirements for radars with gallium nitride technology

Gallium nitride (GaN) is a semiconductor material that efficiently amplifies radio frequency (RF) signals to higher power levels. When used in defense products like radars, it greatly reduces the size, weight, power consumption and cost while enhancing performance. Our GaN material is used in a broad spectrum of military radars and defense systems from Patriot® to the GhostEye® and SPY-6 family of radars. An upgraded version of GaN, made at our semiconductor foundry in Andover, Massachusetts, has recently earned a Manufacturing Readiness Level (MRL) 9 assessment and is ready for full rate production. Our GaN process improvements have also received a 2022 Defense Manufacturing Technology Achievement Award from the DOD.

Modernizing electric systems for the B-52 Stratofortress bomber fleet

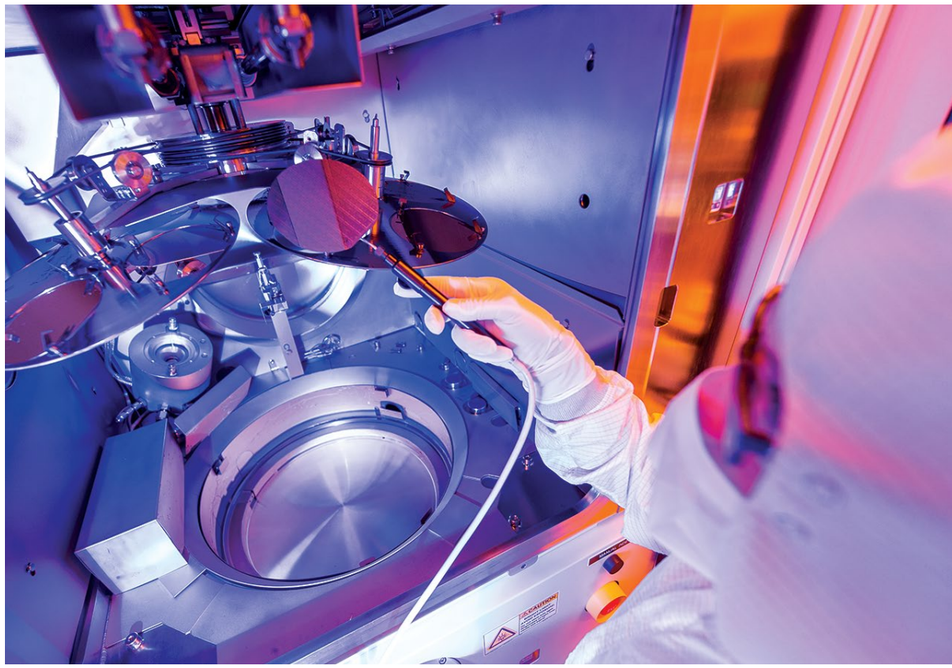
In January 2022, we were selected to modernize the B-52 bomber systems by integrating a new electric power generation system. By replacing the B-52's 70-year-old system, we will contribute to the U.S. Air Force's goal of improving fuel efficiency by 30% and decreasing CO_2 emissions while improving operational longevity.

High-efficiency engines for military aircraft

To achieve military customer requirements, Raytheon Technologies takes a full system approach to designing and building powerful and efficient jet engines. Whether transporting troops, assisting in humanitarian missions or deterring and engaging enemies, it is crucial that operational capability continues to be at the forefront of the technologies we deliver.

Our engineers have demonstrated capabilities to develop advanced fifth-generation fighter engines, such as the F135, which powers all variants of the F-35 Lightning II. They are also working to upgrade current engine systems to increase efficiency and add capabilities.

In 2022, Pratt & Whitney was awarded a $115 million contract for all variants of the F-35 engine enhancement effort, also referred to as an Engine Core Upgrade. This has the potential to accelerate fuel efficiency benefits for the global F-35 fleet of more than one thousand aircraft, as compared to a full re-engine program, saving taxpayers an estimated $40 billion in life-cycle costs and improving the operational capability of this combat-tested engine architecture.



Our ESG journey

We are committed to transparency and regular reporting on our performance in helping people and the planet, as well as how we embody our principles. For more details on our ESG strategy, including areas not discussed in this summary, please refer to our full 2022 ESG Report and Appendix at rtx.com/social-impact/our-esg-vision.

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