Advancing aviation technology towards industry decarbonisation

By Scott Goobie, Rudy Dudebout, Gregory Steinmetz, Eric Upton, Bruce Parry, Leo Knappen, Miguel F. Garcia Claro, Mark Huising, William Lee, and Arnaud Bonnet (ICCAIA and IBAC)

Introduction

The International Coordinating Council of Aerospace Industries Associations (ICCAIA) and the International Business Aviation Council (IBAC) members are committed to advancements in all fields including aerodynamics, propulsion, aircraft systems and structures technologies, aircraft manufacturing technologies[1] and all types of potential energies (sustainable aviation fuels, electricity and hydrogen). Aircraft technologies are focused on increased efficiency and carbon emissions reductions as a way to reduce aviation's climate impact over the long term. In the short term, Sustainable Aviation Fuels (SAF) have a greater role in decarbonisation than other mitigation measures as these "drop in" fuels will reduce carbon emissions from thousands of aircraft already flying. In 2021, the Air Transport Action Group (ATAG) released the second edition of its *Waypoint 2050* report[1]. This report highlighted the commitment of its members to net zero carbon emissions operations by 2050. Business aviation, represented by IBAC, General Aviation Manufacturers Association (GAMA)[2] , National Business Aviation Administration (NBAA)[3] and their global members, likewise committed to decarbonisation by 2050 via the Business Aviation Commitment on Climate Change (BACCC)[4]. In addition to demonstrating industry's broad commitment to net zero carbon by 2050, both documents provide a credible roadmap towards reaching this target. Both reports follow a structure similar to that provided here, with high level technology categories, SAF, and alternate energy sources showing the improvement possible by 2050. The shape of aviation's decarbonisation curve is shown in Figure 1.

With aircraft service lives measured in decades, and SAF blends applicable to the entire fleet, increasing the use of SAF is our priority. The urgency to introduce advanced carbon-reduction technologies to new aircraft and engines is simultaneously high.

In 2019, ICCAIA and ICAO (International Civil Aviation Organization) shared a technology perspective[5] for 2014 to 2019 by showcasing technology advancements on newly introduced and updated commercial aircraft. These aircraft are currently in service and providing substantial reductions in fuel burn relative to the previous generation of airliners. Expanded use of these aircraft continues to reduce the rate of emissions per revenue passenger kilometer (RPK). In the Business Aircraft and Regional Aircraft markets, a host of new technologies were also introduced in this period on new, more efficient aircraft. In addition, expansion of SAF

1 ATAG Waypoint 2050: Aviation: Benefits Beyond Borders (aviationbenefits.org) https://aviationbenefits.org/environmental-efficiency/climate-action/waypoint-2050/
2 https://gama.aero/
3 https://nbaa.org/
4 https://www.gama.aero/wp-content/uploads/GAMA-IBAC-Joint-Position-on-Business-Aviation-Tackling-Climate-Change-1.pdf
5 ICAO 2019 Environmental Report, Chapter Four, Climate Change Mitigation: Technology and Operations, Advancing Technology Opportunities to Further Reduce CO2 Emissions, ICCAIA, pages 116 to 121, https://www.icao.int/environmental-protection/pages/envrep2019.aspx

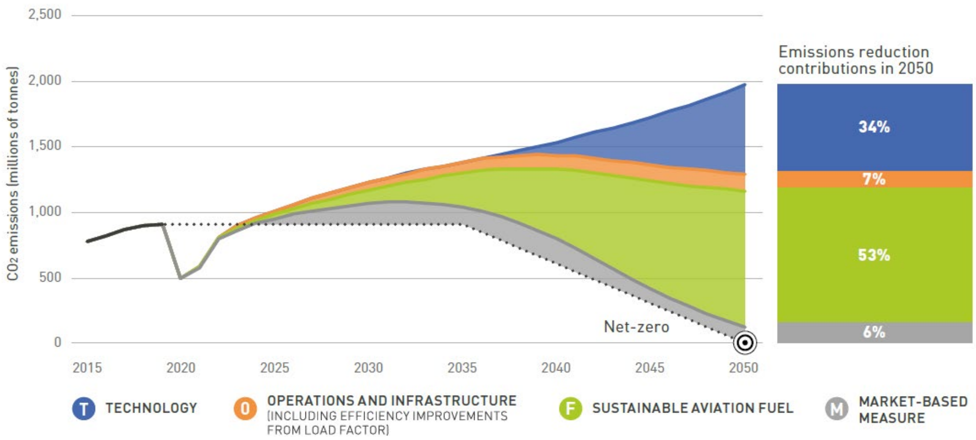

FIGURE 1: Decarbonisation of aviation by 2050

use and market-based programs like the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA[6]) and Book and Claim[7] programs for maximizing efficiency of SAF distribution are already helping accelerate progress to net zero emissions.

We continue to benefit from national and international research programs, with cooperation between industry, governments and academia essential to rapidly mature advanced carbon reduction technologies and new generations of aircraft[8]. We have seen, for example, prototyping with smaller aircraft used in the development and testing of technology demonstrators with hydrogen fuel cells[9], hydrogen propulsion[10] , advanced battery technology[11] , more electric or electric hybrid propulsion[12], and aircraft systems technologies[13] . Engineers in these collaborative environments will leverage cooperation to advance development, testing, and demonstration of readiness of new technologies to speed the years-long development process for new airplanes without sacrificing safety or reliability.

Aircraft Configuration (new concepts) – Full Vehicle

The "traditional" (pre-2010 generation) and "advanced" (current generation) tube and wing aircraft will begin to be superseded in the 2035 to 2050 timeframe by "advanced concept" aircraft. These concepts will produce a step change reduction in fuel burn, based on the vehicle aerodynamic configuration, improvements from advanced flight controls using stability augmentation to reduce drag, achieve structural optimisation, and enhance propulsion system integration.

Various new aircraft types and configurations from Urban Air Mobility[14] to light jets and turboprops to large civil single aisle and twin aisle aircraft are expected to make wide and varied use of a range of more specific technologies, explored below. Figure 2 shows an example of an advanced configuration business aircraft.

6 CORSIA – Carbon Offsetting and Reduction Scheme for International Aviation, https://www.icao.int/environmental-protection/CORSIA/Pages/default.aspx
7 Book and Claim – https://doi.org/10.1016/j.enpol.2019.111014
8 Efficiency research across the globe, https://www.iea.org/reports/net-zero-by-2050
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FIGURE 2: Potential future business aircraft configuration (Bombardier)

FIGURE 3: Airline based testing of skin riblet drag reduction (Deutsche Lufthansa, Oliver Roesler)

Aerodynamics (Specific Aero Technology applied to Local Aircraft Geometry)

In addition to full vehicle configuration reshaping, there are many local (i.e. wing, fuselage, stabiliser) geometry improvements expected in the next 15 years. These include improved wingtip devices, laminar flow control, morphing wing shapes and skin surface riblets[15] (See Figure 3).

Systems (More Electric + more efficient)

Many significant systems-level improvements are emerging in the next generation of advanced concept aircraft. Systems opportunities include low power wing anti ice; improved battery energy efficiency and energy density maturity for systems energy; single pilot operations[16]; advanced fly-by-wire; hydrogen fuel cells for systems; and "fly-by-wireless" and "fly-by-light", partially tied to miniaturisation of avionics.

Structures (Load Reduction, Structural Efficiency, Topological Optimisers)

Airframes of advanced concept aircraft are benefiting from optimal structural topologies. The efficiency of structures capable of withstanding extreme loads is ever increasing, reducing the overall weight and influence of the airframe on aircraft emissions[17]. Newer and better load alleviation technologies are emerging, and so are beneficial weight reductions inherent in improved manufacturing processes. The enhanced ability to apply these technologies and improved production processes across a wider range of aircraft sizes also broadens their benefit to the overall fleet.

Materials (Lightweight Materials and Alloys)

Lightweight materials and alloys have continuously improved in the ratio of weight to load carrying capacity over past generations of aircraft, and this trend is expected to continue and diversify for development of future. The use of new alloys requires processes that are closely linked to the load alleviation technology mentioned above. Structures addressing the types of loads and necessary characteristics of materials will be produced as "designed composite materials" in place of past reliance on available "raw" materials[18].

15 https://aviationweek.com/aerospace/program-management/lufthansa-cargo-equip-777-freighters-fuel-efficient-surface-technology
16 Single Pilot Operations, https://hsi.arc.nasa.gov/flightcognition/research/spo.html
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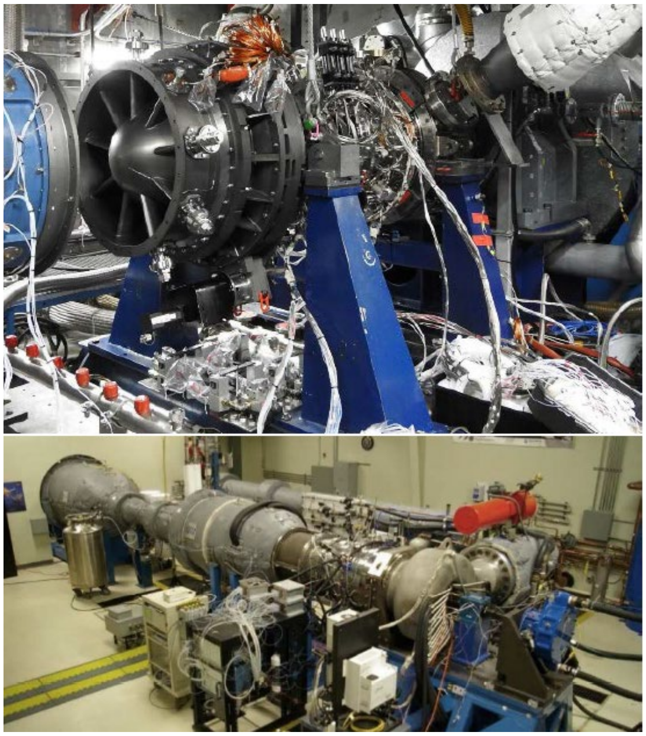

FIGURE 4: a. FAA CLEEN Phase II compressor, b. Turbine Core Technology Rig

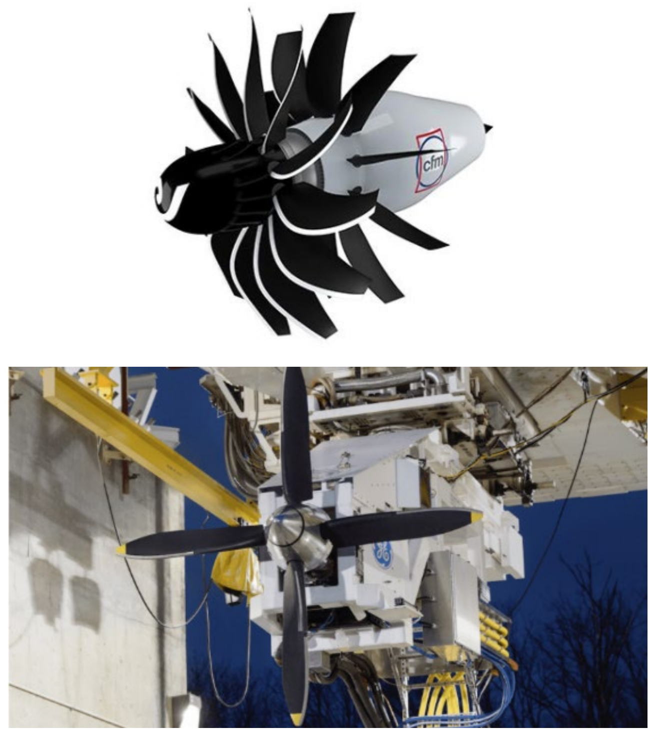

FIGURE 5: a. FAA CLEEN Phase III Open Fan b. Electric Propulsion concepts

Engines (including BLI[19], Hybrid Electric, Increased Efficiency of Gas Turbines)

Gas turbine engines are the primary propulsion system for aviation today. Three technology paths can reduce gas turbine engine fuel consumption (and CO_2 emissions): increase thermal efficiency by increasing the compressor Overall Pressure Ratio (with consequent increasing engine temperatures); increase propulsive efficiency by increasing the engine Bypass Ratio (BPR); and reduce installed engine weight and drag. In the short term, ensuring aircraft fuel systems and engines can safely use SAF is essential. Other approaches, including using hydrogen as a fuel, or augmenting/substituting the gas turbine with electric, hybrid-electric or fuel cells, are being developed for mid- to long-term application, especially for shorter-range aircraft.

Major research programs continue to provide important contributions to develop, mature and demonstrate promising propulsion technologies along the engine efficiency, alternate fuels, and alternate power source paths: Within the US, the national research program CLEEN[20] (Continuous Lower Energy, Emissions, and Noise) is an FAA-led public-private effort to accelerate development and deployment of promising certifiable technologies towards reducing fuel burn by up to 40%. CLEEN research has demonstrated potential for significant fuel burn reductions through the development & application of advanced materials, sealing, and improved engine architectures (see Figure 4).

The recently launched CLEEN Phase-III focus areas include fuel burn reduction via fan module technology, combustor and HPT technology, open fan technology, and highly integrated hybrid-electric systems (see Figure 5). Another focus area is SAF development – both qualification/ASTM standards maturation and increasing blend ratios to up to 100%.

Europe's Clean Sky 2 joint technology initiative aims to develop and demonstrate breakthrough technologies for civil aircraft that could reduce CO_2 emissions by 20%

19 BLI, Boundary Layer Ingestion, https://ntrs.nasa.gov/citations/20130010733
20 CLEEN, https://www.faa.gov/about/office_org/headquarters_offices/apl/research/aircraft_technology/cleen

FIGURE 6: a. & b. Clean Sky 2 Demonstration engines showing advanced Low Pressure (LP) and High Pressure / core technology

FIGURE 7: a. Future Hybrid Electric Aircraft Demonstration (courtesy Airbus), b. Future Hydrogen Aircraft Demonstration (courtesy Airbus), c. Transonic Truss-Braced Wing (TTBW) concept (courtesy Boeing)

(2025) to 30% (2035). Focus areas have included contra rotative open rotor (CROR) demonstration, design/test of a turbofan LP spool and nacelle technologies demonstrator, and testing of very high bypass geared engine technology for widebody aircraft (Figure 6).

The new Clean Aviation2 framework will further mature key engine concepts linked to three main pillars. The first pillar is focused on ultra-efficient aircraft and concepts such as truss-braced wings, boundary layer ingestion[21] and the open fan engine. The second pillar is dedicated to electric and hybrid-electric engines covering a wide range of power and energy levels. The third pillar addresses hydrogen powered aircraft with a focus on compatibility of engines and fuel systems (Figure 7).

Finally, the EU Horizon 2020[22] program is funding disruptive concept studies such as ULTIMATE (propulsion concepts including topping/combined/recuperative cycles), IMOTHEP (distributed electric propulsion), and ENABLEH2 (addressing H_2 challenges such as combustion & fuel system design).

21 BLI, Boundary Layer Ingestion, https://ntrs.nasa.gov/citations/20130010733
22 EU HORIZON 2020, https://ec.europa.eu/info/research-and-innovation/projects/project-databases_en

Alternative Fuels (Their Impact on Aircraft Design Configuration, i.e., AC size and shape)

Technologically advanced alternative fuels (i.e. Stored Electricity, Hydrogen, etc.) are certain to be introduced to achieve the ultimate net zero targets. These technologies will influence the aircraft shape, size, and safety provisions. The use of alternative fuels for propulsion in place of Jet fuel with highly advanced gas turbines and electrically produced thrust will drive research, development and the ultimate design of many of the advanced aircraft referenced above. These alternative fuels offer game-changing environmental benefits.

The associated regulations and highly integrated functional requirements linked to these technologies will heavily influence future design concepts. Important guidance for this effort is provided in the latest revision of SAE document ARP 4754[23] (Guidelines for Development of Civil Aircraft and Systems) and ARP 4761[24] (Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment). Accompanying measures for these technologies will be co-developed by ICAO, by national and international regulators (EASA, FAA, etc.), global research partners, airframers, engine suppliers and aircraft systems suppliers in harmony with the timely progression of the new energy technologies themselves.

Summary

The aviation industry is changing rapidly. ICCAIA and IBAC have described areas that support our commitments to net zero carbon emissions by 2050, via (1) SAF, (2) emerging technologies, (3) infrastructure and operational improvements and (4) carbon credits for the net zero forecast shown in Figure 1. These improvements are already having an impact on fleet carbon emissions, with some all-electric private aircraft already certified and in service, and the benefits will grow continually.

Much of the aviation community has committed to net zero carbon operations by 2050 via uptake of SAF and e-fuels or direct use of alternative energies in concert with efficiency improvements driven by new technologies. Witnessing aviation products and services achieve emissions reduction targets provides confidence in the long-term success of all market segments of the aviation industry.

Authors: This article was written and reviewed by the following ICCAIA and IBAC members: Scott Goobie (Bombardier); Rudy Dudebout (Honeywell); Gregory Steinmetz (GE); Eric Upton (Gulfstream); Bruce Parry (European Business Aviation Association); Leo Knappen, Miguel F. Garcia Claro, Mark Huising and William Lee (Bombardier); and Arnaud Bonnet (Embraer).

The International Coordinating Committee of Aerospace Industries Associations (**ICCAIA)** brings together international aerospace industry associations to create a global community of over three thousand companies engaged in the design, development, manufacture and in-service support of aeronautical and space products and technologies, including ground-based systems and services. ICCAIA aims to foster growth of the world's aerospace manufacturing industry by supporting the development of effective standards for safe, secure, sustainable and efficient air transport, growing international civil aviation capacity and providing technical expertise.

The International Business Aviation Council **(IBAC)** provides expert advocacy and intelligence on behalf of the global business aviation community. IBAC advocates at the global level on behalf of the worldwide business aviation community to keep business flying around the world, accelerating economic growth, development, and environmental sustainability across all regions.

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