2020

Committee on Aviation Environmental Protection (CAEP) – Topic 2

Director – Vincent Correia

HYBRID ELECTRIC AND ELECTRIC PROPULSION FOR AIRCRAFT

1. Context

ICAO, as the entire aviation community, is committed to reduce the impact of air transport on climate change. Notwithstanding the fact that the adoption of CORSIA, following Resolution A39-3 of the General Assembly, constituted a major achievement, other actions need to be taken at the international and national levels, in order to find innovative technological and/or operational solutions for the future.

ICAO is supporting the further development of new means of propulsion. In its Resolution A40-17[1], Appendix B, adopted in October 2019, ICAO's General Assembly expressed the need for the development of Standards, Recommended Practices and/or Guidance Material relating to the quality of the environment and acknowledged that "new innovative technologies and energy sources for aviation being under development in a fast pace, including hybrid and electric aircraft." Hybrid Electric Propulsion (HEP) and Electric Propulsion (EP) indeed offer promising perspectives[2], as they would significantly reduce, or eliminate, aircraft emissions of greenhouse gases[3]. They would furthermore allow near-silent operations at a time when noise around airports is heavily scrutinized and criticized. HEP and EP would, also, help ensuring the stability of the air transport industry in a general context of increased fossil fuels prices. Hence, ICAO's General Assembly requested the Council to "closely follow-up innovative technologies and new energy sources for aviation to prepare for the timely environmental certification of such technologies, as appropriate"[4]. The certification of the new propellers and, in general of the aircraft to which they are attached, is key to ensure the safety of aviation in the future, while not hampering technological innovation.

The progressive shift towards hybrid-electric propulsion is already a reality in general aviation, which can open the way for commercial aviation in the years to come. Indeed:

> *"For large civil transports, most planners and analysts forecast a lengthy time frame (decades) before hybrid electric propulsion (HEP) or electric propulsion (EP) solutions could become technically feasible. In any event, given the current interest in HEP and EP technologies, ranging from small aircraft to large*

---

[1] Resolution A40-17, Consolidated statement of continuing ICAO policies and practices related to environmental protection - General provisions, noise and local air quality

[2] See C. L. Bowman, J. L. Felder, T. V. Marien, "Turbo- and Hybrid-Electrified Aircraft Propulsion Concepts for Commercial Transport", https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20180005437.pdf.

[3] ICAO Environmental Report 2019, p. 124.

[4] Resolution A40-17, Appendix B, para. 9.

> *aircraft, it is not surprising that many companies and organizations are executing robust research and advanced development programs in this area"*[5].

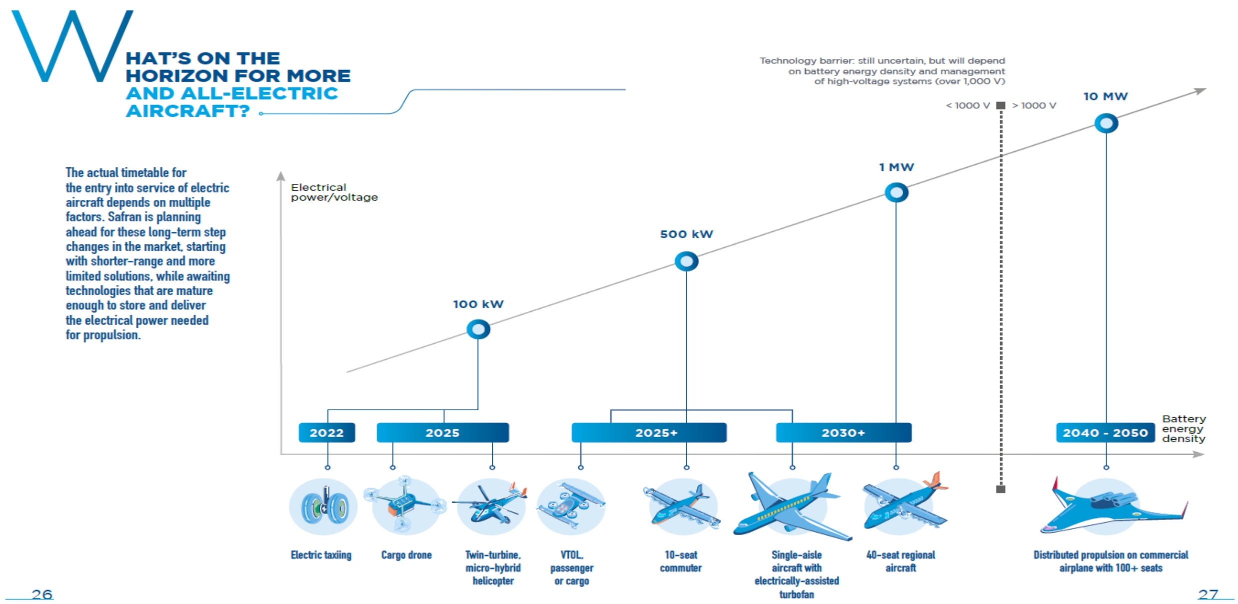
Given the actual technological constraints on batteries and energy management, electric propulsion is still limited to unmanned aircraft[6] and short-haul flights, but can nevertheless contribute significantly to the mitigation of climate change, for instance when it comes to regional/feeder flights[7]. EP is also at the heart of new projects of small aircraft, or so-called "air-taxis", but the industry is already planning ahead. Aircraft and engine manufacturers are investing a lot of time and efforts in order to overcome the actual shortcomings of HEP and EP and introduce electric propulsion gradually.

According to SAFRAN:

> *"Some aircraft will use* ***micro hybridization****: a combination of current combustion engines with small, smart electric motors, like the start-stop systems now common in automobiles. A similar system has been developed by Safran for the Airbus Helicopters Racer high-speed rotary-wing demonstrator. This technology allows the pilot to shut down one of the two engines during the cruise phases. Then, whenever necessary — when landing, for example, or if the pilot needs to gain airspeed or perform an emergency maneuver — the engine is restarted at full power by an electric motor.*
>
> ***Full hybridization*** *will involve developing more powerful systems combining combustion engines and electric generators that will directly provide lift and forward thrust for the aircraft, as well as power its non-propulsive functions.*
>
> *The final destination will be* ***all-electric propulsion****, where conventional combustion engines will be completely superseded by a purely electric power source."*[8]

---

[5] T. B. IRVINE, "The Shift to Electric Propulsion", *Aerospace America*, September 2017, p. 7.
[6] See J. SLIWINSKI, A. GARDI, M. MARINO, R. SABATINI, "Hybrid-electric propulsion integration in unmanned aircraft", *Energy*, 2017, vol. 140, pp. 1407-1416.
[7] See A. HADHAZY, "Fly the electric skies", *Aerospace America*, July-August 2017, p. 24-31.
[8] SAFRAN and Aviation's Electric Future, https://www.safran-group.com/file/download/dp_safran_bourget_2019_safran_and_aviations_electric_future_en.pdf, p. 18.



Source: SAFRAN and Aviation's Electric Future, pp. 26-27

ICAO is accompanying and monitoring several projects under its "Electric and Hybrid Aircraft Platform for Innovation (E-HAPI)"[9], including NASA's X-57 Maxwell full electric aircraft, Boeing's SUGAR volt HEP aircraft or the E-Fan X project jointly carried out by Airbus, Siemens and Rolls Royce. According to Airbus, the E-Fan X HEP aircraft will begin test-flights by the end of 2020. It is estimated that large commercial aircraft using HEP will enter into service after 2030. Other projects, such as Boeing Aurora eVTOL and City Airbus had their first flights in 2019[10]. Some all-electric aircraft, such as the Pipistrel Alpha Electro (a 2-seat trainer), have already been certified. However, as admitted by ICAO:

> *Currently there are no specific ICAO environmental standards in Annex 16 to cover such aircraft types. ICAO is monitoring the developments around these new entrants, and the need for SARPs and guidance.*[11]

Furthermore, no provisions on HEP or EP aircraft can be found in Annex 8 to the Chicago Convention, which governs the airworthiness of aircraft.

2. Technological barriers and promises

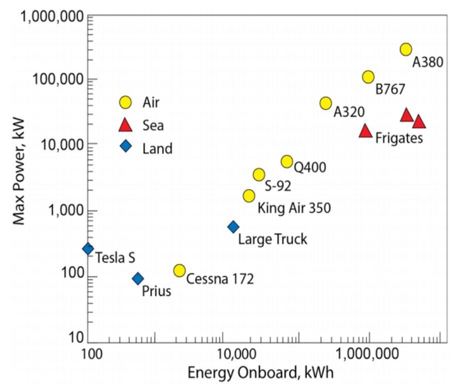
For time being, several technological barriers are hampering the widespread use of EP for commercial aviation: such "technical barriers to electric propulsion development include the management of high-voltage systems, high energy density storage solutions, and thermal issues."[12] On the one hand, the technology to power small aircraft used in general aviation or air-taxis already

---

[9] See https://www.icao.int/environmental-protection/Pages/electric-aircraft.aspx
[10] ICAO Environmental Report 2019, p. 124.
[11] ICAO Environmental Report 2019, p. 125.
[12] T. B. IRVINE, "The Shift to Electric Propulsion", *Aerospace America*, September 2017, p. 7.

exists, but limits the range of the aircraft. On the other hand, regional and large commercial aircraft still can not be propelled using EP, because of their weight. According to some studies:

> *"while a small light plane may have power requirements similar to those of an automobile, 100–150 kW, current airliners require takeoff power from 20,000 to 300,000 kW and begin flights with 200,000 to 3,000,000 kWh of energy onboard to execute maximum capability missions"*[13]



Source: A. H. Epstein, S. M. O'Flarity, "Considerations for Reducing Aviation's CO2 with Aircraft Electric Propulsion", Journal of Propulsion and Power, 2019, vol. 35, n° 3, pp. 573

Hence, the efficiency of the propellers and the autonomy of the batteries still need to be drastically improved before making the dream of full electric commercial flights a reality, since "No known battery technology is capable of powering such aircraft at the ranges now flown"[14]. Several other elements must also be taken into account: the environmental impact of the production and disposal of batteries and the costs linked to the increased need of electricity, in case of a total transition towards EP aircraft.

The industry is nevertheless confident in the promises of the new technologies:

> *"More-electric architectures are more robust and require less maintenance. Smart electronic management makes them potentially more compatible with new digital technologies, allowing data to be collected and analyzed for greater automation, optimized flight and better failure prediction and management."*[15]

On the short term, HEP seems to be the most promising solution, even if there are some uncertainties regarding the results in terms of fuel saving for large commercial aircraft. It is

---

[13] A. H. EPSTEIN, S. M. O'Flarity, "Considerations for Reducing Aviation's CO2 with Aircraft Electric Propulsion", *Journal of Propulsion and Power*, 2019, vol. 35, n° 3, pp. 572-582.
[14] A. H. EPSTEIN, S. M. O'FLARITY, "Considerations for Reducing Aviation's CO2 with Aircraft Electric Propulsion", *Journal of Propulsion and Power*, 2019, vol. 35, n° 3, p. 581.
[15] SAFRAN and Aviation's Electric Future, www.safran-group.com/file/download/dp_safran_bourget_2019_safran_and_aviations_electric_future_en.pdf, p. 19.

generally understood as a "stepping stone towards purely electric vehicles; while battery technology catches up with the energy density of liquid fuels"[16]

The crucial questions to be addressed at ICAO Level

While monitoring the development of EP and HEP aircraft, ICAO has to pay due attention to several considerations:

- The introduction of new technologies may not induce safety hazards;
- EP and HEP large commercial aircraft should be able to operate as traditional aircraft;
- The introduction of electric propulsion should not create additional indirect environmental costs;
- The source of the electricity should be taken into account, in order to avoid "carbon leakage";
- The certification methodology should be thoroughly assessed to prevent any unexpected safety issue, in close cooperation with manufacturers;
- The certification methodology should be adapted, to foresee future evolutions and avoid hampering technological development.
- The principle of Common but Differentiated Responsibilities must be balanced with the necessary uniformity of aviation rules and standards, while making sure that no Country is left behind.

3. Non-exhaustive list of potential questions to be addressed by the delegates:

Should ICAO further promote the use of EP and HEP given the existing technological uncertainties?

How could ICAO further assist the industry in the development of EP and HEP?

Can a "risk-based approach" be adopted regarding the certification of EP and HEP aircraft, in order to foster technological innovation?

Should ICAO's Council adapt the certification Standards and Recommended Practices or wait for the technology to be more mature?

What general actions could ICAO undertake on the short term to foster the development of EP and HEP?

4. Selected bibliography

Convention on International Civil Aviation, 7 December 1944, 15 UNTS 295, ICAO Doc 7300/9.

[16] C. Friedrich, P. A. Robertson, "Hybrid-electric propulsion for automotive and aviation applications", *CEAS Aeronautical Journal*, 2015, n° 6, pp. 279-290, p. 289.

ICAO, Regulatory and Organizational Framework to address Aviation Emissions, 2017, at: https://www.icao.int/environmental-protection/Documents/ICAO%20UNDP%20GEF%20RegulatoryGuidance.pdf

G. T. BLUMENTHAL, *Aviation and Climate Change*, Hauppauge, Nova Science Publishers, 2010, 242 pp.

C. L. BOWMAN, J. L. FELDER, T. V. MARIEN, "Turbo- and Hybrid-Electrified Aircraft Propulsion Concepts for Commercial Transport", https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20180005437.pdf.

A. H. EPSTEIN, S. M. O'FLARITY, "Considerations for Reducing Aviation's CO2 with Aircraft Electric Propulsion", *Journal of Propulsion and Power*, 2019, vol. 35, n° 3, pp. 572-582.

C. FRIEDRICH, P. A. ROBERTSON, "Hybrid-electric propulsion for automotive and aviation applications", *CEAS Aeronautical Journal*, 2015, n° 6, pp. 279-290, p. 289.

A. HADHAZY, "Fly the electric skies", *Aerospace America*, July-August 2017, p. 24-31.

T. B. IRVINE, "The Shift to Electric Propulsion", *Aerospace America*, September 2017, p. 7.

J. SLIWINSKI, A. GARDI, M. MARINO, R. SABATINI, "Hybrid-electric propulsion integration in unmanned aircraft", *Energy*, 2017, vol. 140, pp. 1407-1416