ASSEMBLY — 42ND SESSION

EXECUTIVE COMMITTEE

Agenda Item 16: Environmental Protection – International Aviation and Climate Change

STANDARDIZATION ROADMAP AND LTAG TECHNOLOGIES

(Presented by the International Coordinating Council of Aerospace Industries Associations (ICCAIA))

EXECUTIVE SUMMARY

This paper presents the views of ICCAIA on the Standardization Roadmap, as well as an update on the technologies so far submitted to the process in support of the long-term global aspirational goal (LTAG).

Strategic Goals:	This working paper relates to the High Priority Enabler on Innovation and the Strategic Goal *Aviation is Environmentally Sustainable*
Financial implications:	None.
References:	A42 Assembly WP/29, *Innovation in Aviation* AN-CONF/14 WPs 22, 23, 24, 25, 28 and 52 ICAO Assembly Resolution A40-27 – *Innovation in Aviation*

1. INTRODUCTION

1.1 ICAO Assembly Resolution A40-27 – *Innovation in Aviation* Operative Clauses 2 and 3 direct the Council to investigate evolving the processes of the Organization to keep pace with innovations that affect the sustainable development of civil aviation and develop high-level policies to address the findings.

1.2 In March of 2023, the Chair of the International Coordinating Council of Aerospace industries Associations (ICCAIA) presented a White Paper to the ICAO Council describing a potential solution to assist ICAO to anticipate readiness of upcoming, innovative technologies to enter the standards making process. It highlighted industry needs for regulatory certainty to secure investment in advanced technologies, and that one way to proactively anticipate the need for provisions would be to develop a 'regulatory roadmap' that mapped provisions required to the timeline of new technologies.

1.3 In the preceding years, the industry worked closely with ICAO to develop a technology roadmap supporting the LTAG (Long-Term Aspirational Goal for carbon reduction) Report. ICCAIA's White Paper suggested that the first phase of the 'regulatory roadmap' could be developed based on the LTAG Report's technology roadmap, since this was a document recognized by all stakeholders.

1.4 Subsequently, the Council Small Group on Innovation (SGI) examined the proposal in the ICCAIA White Paper and agreed that such a 'regulatory roadmap' would be a useful tool answering to the Assembly Resolution A40-27. The Air Navigation Commission was thus tasked by the Council to begin developing such a process using the identified LTAG technologies.

1.5 In developing this work further, and since ICAO develops Standards and Recommended Practices (SARPs) and not regulations, the ANC logically proposed changing the name to 'Standardization Roadmap'. Assembly WP/29 discusses the Standardization Roadmap in detail. This Information Paper provides ICCAIA's view of the Standardization Roadmap and its development process, and expresses support for the ongoing work to evaluate the LTAG technologies.

1.6 ICCAIA is supportive of the expansion of the Standardization Roadmap beyond LTAG technologies.

2. DISCUSSION

2.1 Achieving the long-term aspirational goal (LTAG) for international aviation of net-zero carbon emissions by 2050, adopted at the 41st ICAO Assembly, represents a significant challenge to the industry, requiring an unprecedented level of effort and investment. In particular, it requires evolutions to current technologies and operations as well as developing revolutionary engine and airframe technologies and concepts of operations.

2.2 Industry recognized the need for ICAO to be able to anticipate the development and market-entry of these technologies so that SARPs, and other such regulatory guidance, could be developed in good time. This would ensure that the regulatory framework for, particularly, revolutionary technologies would not act as a block or a delay for their availability. Additionally, timely SARPs also help the industry to gain funding for such technologies by providing regulatory certainty, thus reducing risk for investors and manufacturers alike.

2.3 Accordingly, at the 41st ICAO Assembly, Resolution A40-27 – *Innovation in Aviation* was adopted. This includes Operative Clauses as follows:

> *The Assembly*:
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> 2. *Directs* the Council to assess the need, as well as the resources required, to evolve the processes of the Organization, including its working methods with the industry in order to keep pace with innovations that affect the sustainable development of civil aviation;
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> 3. *Directs* the Council on the basis of the conclusions arising from the assessment to be undertaken pursuant to operative clause 2, to develop, high-level policies to address the findings of the aforementioned assessment and subsequently provide a framework that will help ensure the timely development of global policies and standards that support the continuing improvement of safety, efficiency, security, facilitation, economic and environmental performance;

2.4 The Council Small Group on Innovation (SGI) agreed that a 'regulatory roadmap' as proposed in an ICCAIA White Paper would be a useful tool answering to the Assembly Resolution A40-27. The Air Navigation Commission was thus tasked by the Council to begin developing such a process using the identified LTAG technologies.

2.5 Under the instruction of the Council and working closely with the industry, the ANC leveraged its Ad-hoc Working Group on Innovation to define the methodology for the Standardization Roadmap, including defining what became known as 'Gates'. Three 'Gates' enable review of innovations at various stages of maturity, and include a gap analysis at Gate 2 to identify likely provisions needed and linkages with or impacts on global plans.

2.6 During the development process, ICCAIA presented the ANC with a timeline of the identified LTAG technologies, extending from the present to 2050. The timeline identified both evolutionary technologies unlikely to require any adaptation of the existing Annexes, for example new aerodynamics, new engine technologies, use of Sustainable Aviation Fuels; and revolutionary concepts that may require adaptation of Annexes to secure safe operation, such as new propulsion concepts using battery or hydrogen for energy provision.

2.7 During the Fourteenth Air Navigation Conference (AN-CONF/14), ICCAIA and certain other industry associations provided a series of Information Papers that discussed the 'State of the Art' for a number of the identified LTAG technologies: *WP22 The State of the Art of Electric Propulsion Systems*; *WP23 The State of the Art of Hybrid Propulsion Systems*; *WP24 the Role of Hydrogen in Aviation*; *WP25 Considerations for Regulators on the Introduction of Sustainable Aviation Fuels (SAF) at Higher Blend Rates*; *WP28 Update on Wake Energy Retrieval*. These supported the overarching Working Paper prepared by the Air Transport Action Group (ATAG) *WP52 Industry Contribution to the ICAO Long-Term Aspirational Goal*.

2.8 Additionally, the industry provided support to the ANC for the inclusion of certain key criteria to be included in the evaluation methodology for each of the Gates. Not least, industry strongly supports the use of 'Technology Readiness Level', or TRL, as already used within the Committee on Aviation Environmental Protection (CAEP) in their technical work and throughout industry and government as a measurement of maturity. Industry maintains that the use of a common methodology is helpful both in the context of the LTAG, and for other technology developments.

2.9 ANC published a draft of the process for the Standardization Roadmap and its associated Gates in December of 2024, and the industry was asked to rapidly populate example evaluation sheets using a number of technologies identified within both the timeline and in the papers to the AN-CONF/14, enabling the ANC to 'stress-test' the process.

2.10 Work has already begun to further refine and provide additional detail for the initial entries made; ICCAIA expects to have submitted up to five entries with additional detail by the end of 2025.

2.11 As can be expected, a few shortcomings have been discovered and some improvements suggested. However, in principle the Standardization Roadmap methodology works. Going forward, it is incumbent on International Organizations and States to work with the companies developing the technologies to provide more extensive information and fill out the forms accordingly, noting that some technologies are already operational.

2.12 The preliminary conclusion is that the process works adequately and meets the intent of the task passed by Council but may need additional refinement once it has been tested with some detailed entries and over the course of some time.

3. CONCLUSIONS

3.1 While ICAO has set an ambitious goal with the LTAG, it is incumbent on the industry to invest in technology and operations to actually deliver that goal. Industry needs ICAO to help across all areas – airworthiness, certification, aerodrome standards and operations – to facilitate the timely delivery of standards that enable the safe use of alternative fuels, energies, configurations and operational concepts. Further information on some of the key technologies is provided in the Appendix.

3.2 Through the Standardization Roadmap, ICAO has heard the industry call-to-action and already launched collaborative works. Panels have also begun to understand the need to be prepared to facilitate the arrival of the new technologies.

3.3 The Standardization Roadmap works as intended, though will likely require some small refinements, proving the value of a collaborative process-development approach that is inclusive of industry.

3.4 ICCAIA supports continued work to test, populate and develop the Standardization Roadmap and applauds the Council, the Small Group on Innovation and the Air Navigation Commission for the excellent, collaborative, work thus far as laid out in Assembly WP/29.

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APPENDIX

LTAG TECHNOLOGIES PRESENTED AT AN-CONF/14

1. ELECTRIC AIRCRAFT

1.1 A number of 'General Aviation' technology demonstrator all-electric aeroplanes have been developed over the last two decades, including the Taurus Electro, the Airbus eFan and the Rolls-Royce ACCEL. Other companies have gone on to announce, or produce, serial production of all-electric aircraft, including Pipistrel and Diamond aircraft.

1.2 In general, these manufacturers have elected to use lithium-ion batteries for energy storage. These aircraft have demonstrated that, while all-electric flight is feasible, the applications up to now have been quite limited due to the difference in energy density (i.e. power developed per unit of weight) of batteries versus conventional fuel. Conventional Jet A1 fuel has an energy density of, typically, 12,000 Watt hours per kilogram. By contrast, a typical lithium-ion battery has an energy density of around 250 Watt hours per kilogram. Even with some battery manufacturers claiming that they can reach 450Wh/kg, the contrast is stark.

1.3 For civil aviation, the consequence of having such a high weight for the amount of energy stored is a severe restriction on the payload, the range or both. Consequently, the passenger-carrying, transport-category aeroplanes that are currently envisaged to utilise batteries for all-electric flight are small – between 6 and 19 passengers – and have a limited range, below 300 nautical miles.

1.4 Currently two transport-category all-electric aeroplanes are at various stages of operation and testing, with a 6-passenger, electrically powered DeHavilland Beaver conversion undergoing testing using an 850shp electric motor weighing 135kg; and the twin-engine, 9 passenger (+ 2 crew) eviation Alice also undergoing testing. A cargo version of the Alice for use as an express parcels aircraft is also envisaged.

1.5 A third aeroplane, the 19-seat Heart Aerospace ES-19 has recently been cancelled in favour of a hybrid-electric 30-seater. This switch to hybrid power emphasises the current difficulties associated to all-electric flight. As a consequence of the power-density and consequent payload-range limitations offered by current and foreseeable battery technology, the use of pure electricity for passenger category aeroplanes is limited. Although it is likely that some commuter type aircraft will come to the market over the next decade, it is unlikely that all-electric aircraft of the size and range capability of today's turboprop and regional jet airliners will appear for quite some time.

1.6 That said, the advent of Advanced Air Mobility (AAM) vehicles has caused a re-examination of the development of electric flight. All of the currently-flying AAM projects make use of battery-electric technology, though the mission profile of an AAM aircraft and a commuter aeroplane are significantly different. However, with multiple AAM projects underway, research into better and more efficient battery technology and even lighter motors has been renewed.

1.7 The reduction in CO2 (and other emissions) by electric aircraft is highly dependent on the source of the electricity used to charge the batteries of the aircraft. While there are no gaseous emissions at source, and relatively low noise, the risk is that the emissions are simply displaced to the point of energy generation. It is therefore important that airports either have access to, or generate their own, clean energy. Since many ground vehicles at airports are becoming electrically powered, and since hybrid aircraft are also likely to need a charging network, there are significant synergies to be made. Disposable and end-of-life environmental impacts of these batteries will also need to be considered.

1.8 Airports will also need to take account of the infrastructure needed to support these aeroplanes and their technologies. They will need to charge the batteries while the aircraft is at the gate, or change battery packs on the ramp, depending on the design. Power generation and distribution sufficient to recharge the batteries, either at the gate or at a remote location will be needed. A common standard for the connectors between the aircraft and the ground infrastructure is also needed to facilitate the transfer of aeroplanes between airports and regions. Ramp space to accommodate the additional battery servicing vehicles, including any increased safety distances, will also be required.

1.9 In case of an accident, emergency personnel will need to be equipped and trained to be aware of potential battery-fires and other battery-related emergencies (leakage in case of aircraft damage, for example).

1.10 Engine start up and shutdown procedures also have the potential to be different, and an engine run-up area for aircraft that have taxied using electrical power driving the wheels may be required, as may be a dedicated area for engine cool down at the end of flight.

1.11 Regarding certification and airworthiness, electric aircraft are also likely to have some different needs and requirements. For example, as energy is used, the aeroplane's mass remains constant, unlike a conventionally powered aircraft that burns fuel and becomes lighter during the mission. This leads to two critical differences compared to a conventional aeroplane. Firstly, the Landing Weight of the aeroplane is the same as the Take-off Weight as fuel is not consumed during the flight, leading to the landing gear and airframe structure being sized accordingly. Secondly, conventional liquid-fuelled aeroplanes climb to higher cruise altitudes with less dense air during the flight as they burn off fuel. This will not be the case for an electric aircraft, whose ceiling will not vary with distance as the weight of the vehicle remains constant throughout the mission. Consideration will also have to be given to the management of batteries whose energy storage capability may diminish with time.

1.12 Additionally, the reserves policy will need to be carefully considered. With conventional fuels, this is a simple calculation of additional fuel that needs to be uploaded to accommodate a diversion and hold. The calculation will necessarily be different for an all-electric aircraft and will need to address the need for reserve energy and an accurate flight planning in advance. This issue is exacerbated by the initial short range and potential lack of suitable alternate diversion airports.

2. HYBRID PROPULSION

2.1 As mentioned above, all-electric flight is likely to be subject to limitations caused by the energy density of currently-available and foreseen battery technologies. The weight of the batteries compared to the flight endurance that they can deliver means that electric aircraft are likely to remain relatively small with limited payload and range in the short term. Consequently airframe and engine manufacturers have been exploring technologies that can significantly reduce $CO2$ (and other) emissions while preserving payload/range capability of larger, regional aircraft.

2.2 The concept of hybrid power is not new. Railway locomotives have been using diesel engines to power electric traction motors for around a century, and the motor industry began introducing hybrid cars in increasing numbers since the early 2000s. Aircraft manufacturers believe that potential exists to transfer such technology to civil operations that are currently performed by turboprops and regional jets.

2.3 Although the concepts differ in detail, all use a conventional engine, which may be either a small gas turbine or a large reciprocating engine, in combination with an electrical power source such as batteries or a hydrogen fuel cell. Most require a turbogenerator that connects the two sources of power either directly to a propeller, or interconnects the two sources of power – although other concepts have been envisaged as described later.

2.4 For subsonic aeroplanes, the highest power is always needed during take-off and climb, with a relatively low power setting being used during the cruise. Current engine designs are sized to provide continued take-off power and climb in the case of one engine becoming inoperative. Different concepts are designed to overcome different challenges in different phases of flight. These can be largely grouped as follows:

- Power ‘boost’ during take-off and climb (electrical power used to increase take-off and climb thrust)

- Power reduction via partial conventional engine during cruise

2.5 In the first case, providing a power boost during take-off, electric motors are used to increase the available power only during take-off, allowing the conventional engines to be sized according to the cruise need and not ‘oversized’ for the take-off case. Manufacturers of such concepts claim that this can reduce mission fuel burn, and therefore CO2 emissions, by around 30%.

2.6 In the second case, the conventional engines remain sized for the take-off case as today, but during straight and level flight, or cruise-climb, one conventional engine is shut down. The remaining engine both provides thrust and is used to generate electricity via a turbogenerator, which in turn drives an electric motor producing thrust for the second engine.

2.7 A third, novel, approach for a single-engine aircraft is to use the engine to both drive the propeller and to provide electrical power for smaller propellers driven by electric motors distributed across the leading edge of the wing – the so-called ‘distributed fan’ concept. In this case, the distributed fans accelerate air across the top surface of the wing during take-off substantially increasing lift. This gives the advantage of being able to have a shorter wingspan, reducing drag during all flight phases.

2.8 Another common concept across all of the applications is the ability of the conventional engine to recharge batteries during flight. This would, in some cases, make the aircraft independent of ground-based charging infrastructure.

2.9 Some concepts have the added advantage that the energy stored in the batteries can also be used to power electric motors on the undercarriage, making taxi-out and taxi-in electrically powered. This has the advantage of reducing ground noise and ground emissions, although gas-turbine powered aircraft will still need sufficient time after engine start to warm up the engines prior to taking off and after landing to cool down the engines prior to shutting them down.

2.10 In all of these concepts, manufacturers have had to deal with a host of technological challenges not previously experienced in the field of aeronautics. Firstly, the need to consistently generate or store the energy for around 1MW of electrical power. Secondly distributing that power requires new wiring technology to transmit 500V-800V around the aircraft, with an adequate shielding. Smooth power transfer during flight and reliable turbogenerators are new requirements not faced before.

2.11 Airports will also need to take account of the infrastructure needed to support these aeroplanes and their technologies. Although most can recharge their own batteries, most will need to charge the batteries while the aircraft is at the gate or change battery packs on the ramp, depending on the design. Power generation and distribution sufficient to recharge the batteries, either at the gate or at a remote location will be needed. For those concepts that use hydrogen fuel cells in place of batteries, the storage, distribution and safe handling of hydrogen will be needed. Ramp space to accommodate the additional battery or hydrogen servicing vehicles, including any increased safety distances, will also be required.

2.12 Emergency personnel will need to be equipped and trained to handle battery-fires and other battery-related emergencies (leakage in case of aircraft damage, for example); similar training will be needed in the case of hydrogen fuel cell use.

2.13 Engine start up procedures are also likely to be different, and an engine run-up or warm-up/cool down area for aircraft that have taxied under their own electrical power may be required.

2.14 There may also be impacts on the take-off and climb phases of flight in the event of a loss of electrical power for those concepts that use electricity as a boost. Standards will need to be developed to ensure an approach at least consistent with those in force today, including for the turbogenerators and power distribution system reliability.

2.15 Consequently, as the competent international standard setting body for international aviation, the industry looks at ICAO for the timely development of Standards and Recommended Practices (SARPs) that allow for the safe introduction and operation of new hybrid-powered concepts.

3. HYDROGEN

3.1 Cleaner and alternative energies with lower lifecycle impact have been assessed as critical to the decarbonisation of the air transport sector by ICAO (ICAO LTAG report[1]). Hydrogen is seen as one promising vector in the basket of measures identified in the report and will require significant support of all aviation stakeholders in the ecosystem to make use of hydrogen a reality in the coming decades.

3.2 Today's Hydrogen economy consists of around 100Mt being consumed annually, but with over 99% originating from fossil sources[2]. Existing players, along with new potential consumers, are looking to pivot the sector towards full low-carbon hydrogen production. It will be essential, as with all energy types, to include the full lifecycle of emissions from hydrogen production and use in assessment of sustainability impact.

3.3 With respect to aviation, hydrogen has two potential uses:

As a feedstock input to produce Sustainable Aviation Fuels (SAF), or;

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[1] ICAO Report on the feasibility of a long-term aspirational goal (LTAG) for international civil aviation CO2 emission reductions: https://www.icao.int/environmental-protection/LTAG/Documents/REPORT%20ON%20THE%20FEASIBILITY%20OF%20A%20LONG-TERM%20ASPIRATIONAL%20GOAL_en.pdf

[2] IEA (2023), "World Energy Outlook 2023"

As a direct fuel, in either gaseous or liquid form, to either be reacted in fuel cells or combusted in hydrogen engines.

3.4 Regarding (i), SAF has already been identified as a very significant contributor to aviation's Net Zero target, and many stakeholders are fully engaged in enabling widespread use of SAF alongside ICAO. The main advantages, identified separately in IPxx, relate to the fact that the changes required to the air transport system are low compared to those for other energies. Power to Liquid (PtL), which is based on the synthesis of CO2 and green hydrogen from renewable sources, has the potential to deliver significant quantities of SAF in the future. However, significant investment in energy infrastructure will be required.

3.5 Regarding (ii), given the need to look at multiple solutions to meet emissions goals for the longer term projected growth, manufacturers are working on disruptive-technology hydrogen propulsion systems, whether they be designed purely for the use of hydrogen or be designed for 'dual fuel' SAF and hydrogen use.

3.6 As with other alternative energy propulsion systems, it is likely that hydrogen powered aeroplanes will be introduced in the regional sector first, after which increasingly larger and longer-range products could enter the market place (single aisle/narrowbody and later long range/widebody aeroplanes).

3.7 It is very likely that new policies, recommended practices, regulation and, potentially, incentives, would be needed.

3.8 The use of liquid and gaseous hydrogen in aviation introduces needs, challenges, risks and opportunities that are new to the field. Because of this, existing regulations and standards may not be applicable. As the aviation industry strives to overcome the technical challenges of hydrogen propulsion for aviation, a variety of technologies, systems and aeroplane architectures are being explored, with new projects emerging on a regular basis.

3.9 Regulatory frameworks will need to provide flexibility as technology evolves, while focusing on high level safety objectives. This is best achieved through the development and introduction of performance-based and technology-agnostic Standards and Recommended Practices (SARPs).

3.10 The industry is already developing recommended practices specific to hydrogen aeroplanes through the development of industry consensus standards undertaken within the framework of Standards Development Organisations (SDOs) such as SAE, EUROCAE, ASTM and ISO. To achieve this, the aviation industry is relying on a body of reference standards produced by other industries, some of which have been using hydrogen and hydrogen technologies for decades. This work may assist ICAO in its own standards making activities.

3.11 Additionally, some work is already being undertaken in ICAO. Notably a Job Card tasking the Aerodrome Operations Working Group with leading all activities required to support the introduction of aircraft powered by "alternative energies" such as hydrogen at Aerodromes has been launched. Areas of particular attention will be Rescue and Fire Fighting (RFF) at aerodromes, and aeroplane handling procedures for "alternative energies" as these may differ from those of currently existing fuel types.

3.12 As with most disruptive technologies, hydrogen will require significant investment in infrastructure and an entire ecosystem will need to be developed for the production and supply. Airport adaptation to accommodate hydrogen power is likely to be significant, with the need to either produce hydrogen locally, which itself requires a significant consumption of electricity; or alternatively to transport hydrogen. Storage facilities for hydrogen fuels will be needed. All of this hydrogen specific infrastructure will necessarily be in parallel to the existing infrastructure required for the storage and supply of kerosene/SAF.

3.13 Adjustments will also have to be made in the interface between airport infrastructure and the aircraft, with one main point of attention being during refuelling, maintenance or defueling as hydrogen's flammable nature will require special handling procedures. Considerations related to leak detection and monitoring, fire suppression systems suitable for hydrogen, safety training for personnel involved in handling and managing the hydrogen, personnel protective equipment or regulatory compliance will be needed.

3.14 The challenge in constructing and operating hydrogen infrastructure at airports will be significant, with the earliest hydrogen-powered (whether pure hydrogen or dual-fuel) aeroplanes likely to come to market in the next decade. Beyond this, it is anticipated that more aircraft powered by alternative energies will likely be introduced, starting around 2035. It will be important to converge on technical and regulatory aspects in a timely way to facilitate their introduction, which means a SARPs development between 2030 and 2035.

3.15 Some early synergies might be possible, however, as hydrogen fuel can also be used for powering ground equipment. Such a concept would lead to the airports becoming a 'hydrogen hub', and is one of the key founding blocks of the route to hydrogen deployment (both gaseous and liquid) for aviation decarbonisation. A stepped approach can be explored, first transitioning ground equipment and progressively introducing infrastructure until it is ready for the supply to aeroplanes.

— END —