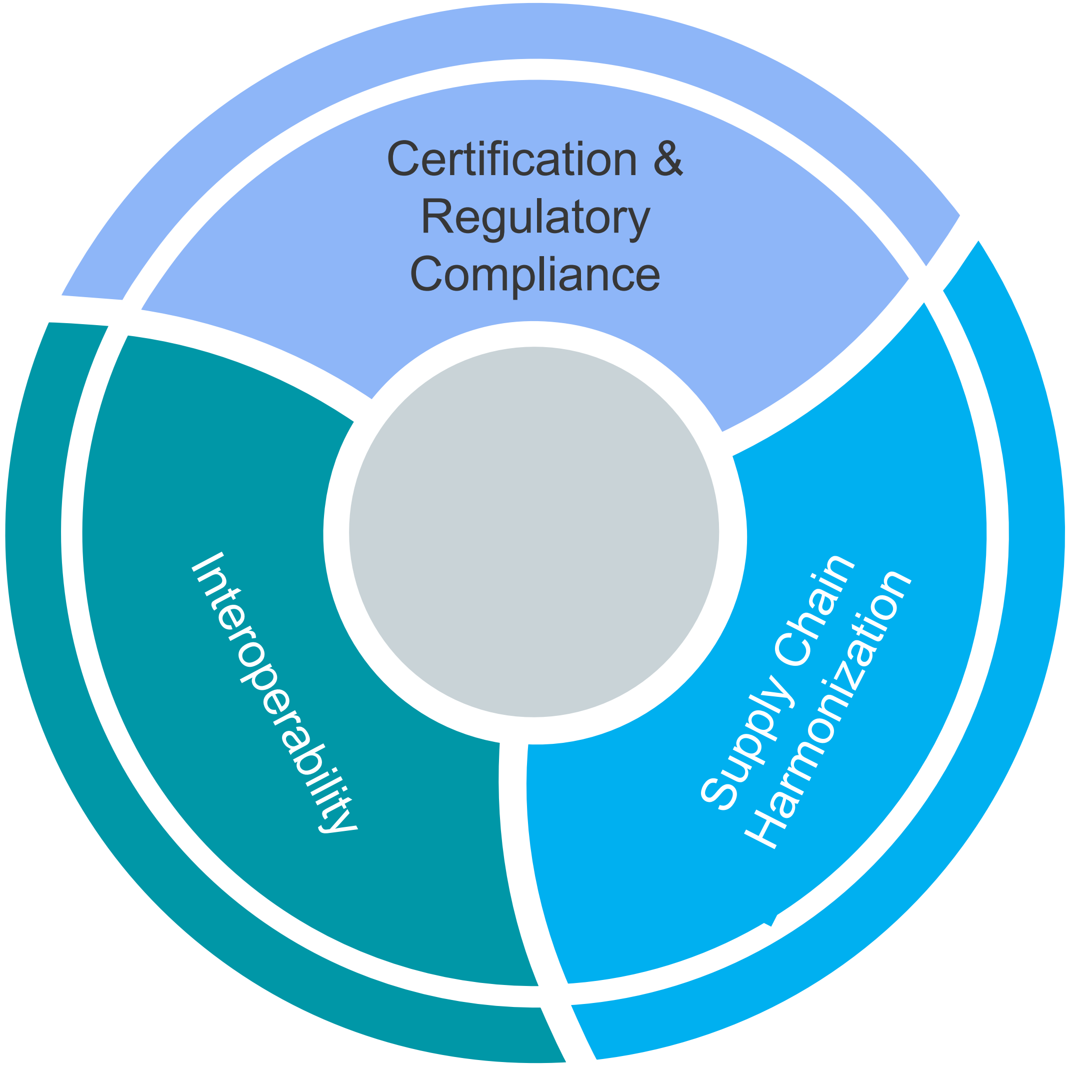
Alliance Zero Emission Aviation & SDO role perspective

H2 technologies

Introduction: Why is Standardization Important?

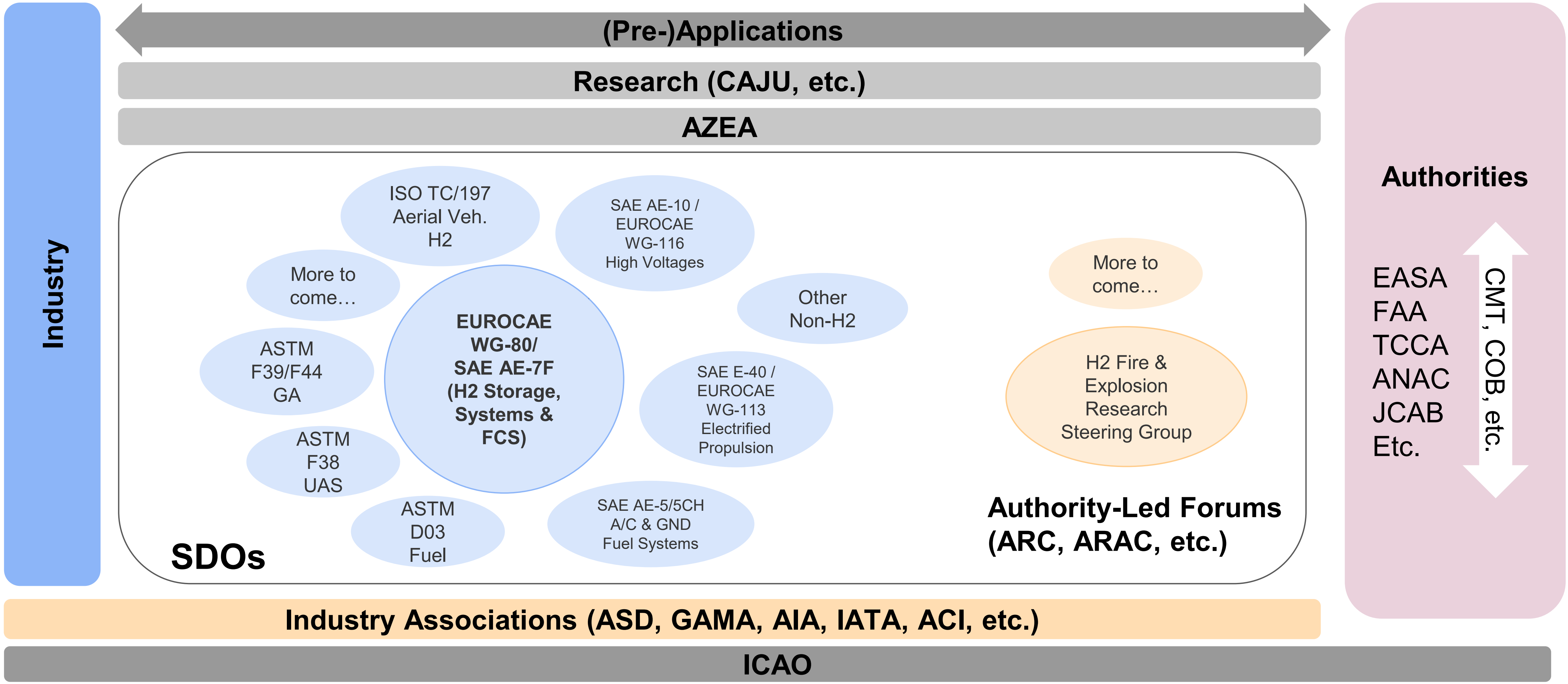


H2 Rulemaking & Standardization: 3-Level Approach

	Level 1 Rules	Level 2 MOC/AMC	Level 3 Industry Standards
First Step: **Gap Analysis & Recommendations**		**Authorities** + **Industry**	
Second Step: Establish **Priorities**		**Authorities** + **Industry**	
Third Step: **Develop / Adapt Material**	**Authorities**	**Authorities**	**Industry**

This is a joint and iterative process

Actors of the H2 Rulemaking & Standardization Challenge



Engaging the aviation ecosystem for the timely adaptation of the regulatory framework to support certification of H2 technologies

HYDROGEN CERTIFICATION WG

Governance

European Alliance for Zero Emissions General Assembly & Steering Committee

↓

WG-4 Regulation, Certification, Standardization

↓

SG-2 Certification

↓

SG-2B Hydrogen Aircraft Certification

Scope of work

More than 30 organisations, including academia, airframe OEMs, engine OEMs, fuel cells OEMs, system integrators, etc. **engaged in two fundamental debates:**

1. Sufficiency of the current EASA product certification structure – possible paths to certification
2. Sufficiency of current certification requirements for a CS-23 hydrogen-electric powered aircraft (gap analysis + functional hazard analysis)

HYDROGEN CERTIFICATION WG

White paper 1

Sufficiency of the current EASA product certification structure – possible strategies to certification

- **Legacy considerations** might not be appropriate anymore (aircraft vs. engine vs. propeller TC)
- **Classification criteria** for single/multi engine aircraft or complex/noncomplex motor-powered aircraft do not fit new H2 design concepts.
- Possibility to **retrofit older aircraft** through an STC is key to adapt in-service fleet to new ZE forms of propulsion; what will be the level of reinvestigation needed?
- **Certification boundaries** for systems have not yet been defined, therefore entering the regulatory system remains a high-risk business decision.

White paper 2

Sufficiency of current certification requirements for a CS-23 H2-electric powered aircraft (gap analysis + FHA)

- **Performance-based requirement level provisions for CS-23 are largely sufficient.** Main gap is the shortcoming of AMCs/GMs/Standards for integration (Subpart D, E and F).
- Special condition (SC) E-19 excludes H2 applications. **New or amended generic SCs are needed** to cover requirements when using fuel cells as main propulsion.
- Other specifications for maintenance certifying data or emissions **might need adaptation**. Also other domains beyond certification such as operations.
- **High-level safety objectives in CS-23 are set in 23.2510 and fit for purpose**, with means of compliance yet to be developed.

HYDROGEN CERTIFICATION WG

White paper 1

Sufficiency of the current EASA product certification structure – possible strategies to certification

Issue 1 - 100% completed

White paper 2

Sufficiency of current certification requirements for a CS-23 H2-electric powered aircraft (gap analysis + FHA)

Issue 1 - 90% completed

Focus remains in the category of CS-23 due to other ongoing activities specific to CS-25 products in the context of Clean Aviation.

The group will soon review the work mandate and priorities for 2025

AZEA WG-4 SG-3 “STANDARDS”

Identify standards required to support the certification of hydrogen and electric aircraft.

STANDARDS MAPPING

Alliance for Zero-Emission Aviation
Working Group 4

Current Standardization Landscape

10th May 2023
Brussels, Belgium

PUBLISHED
June 2023

GAP ANALYSIS

- Review of the standardization mapping
- Identification of areas where new standards are needed to ensure compliance and safety.
- Resource for SDOs and industry to identify areas as opportunities for collaboration and harmonization of activities

STANDARDIZATION
GAP ANALYSIS
12 November 2024
AZEA WG-4 SG-3

Final Version Approved
14/11/2024

ROADMAP AND RECOMMENDATIONS

STANDARDIZATION GAP ANALYSIS

SDO collaboration | **Authorities involvement**

Hybrid-electric

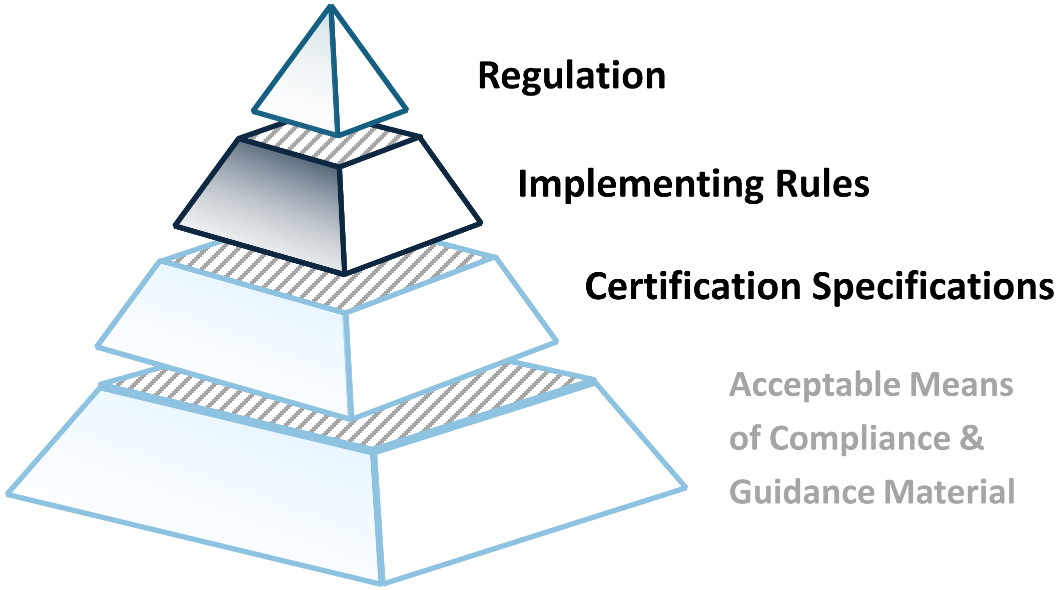
- Performance metrics under various operational conditions, integration with existing aircraft systems, and establishing protocols for maintenance and safety.
- It is expected that aircraft integration requirements and standard MOC will be developed iteratively, addressing one category after the other;

Hydrogen

- For hydrogen propulsion, the primary gaps lie in storage and distribution infrastructure, fuel cell technology integration, and ensuring the safe handling and refueling processes.
- Resources shall be used to work on standardization activities at the system level which is expected to be common to most aircraft categories and applications.

SDO role perspective

EUROCAE & SAE International



Performance-based Regulation

- Reference to industry standards
- Best practices/Acceptable requirements

Interoperability – Harmonization

- Global Aviation and Industry

SAE Standards

Hydrogen in Aviation

Member

Engage
14,000+
SMEs

Collaborate
640+
Committees

Ballot/Revision
Ballot
Ballot
Technical Information Report
Technical Recommended Practices
SAE Standard

Build & Maintain
9,900+
Standards

Deliver
200,000+
Documents

EASA - 76 references to SAE standards

MoUs with EUROCAE and ASD-STAN

Offices in London & Amsterdam

SAE Mobilus
StandardsWorks
OnQue

Sustainability

Hydrogen in Aviation

IAEG®
INTERNATIONAL AEROSPACE ENVIRONMENTAL GROUP®

Energy Source

Non-hazardous materials

Lightweight Materials

Airports & Operations

Alternative Aviation Fuels Steering Group

Hydrogen in Aviation

SAE INTERNATIONAL

Why the Need for Standards?

To build capability through standardization – they provide thought leadership and understanding of innovation, using a consensus to support more mature new technology deployment.

Alternative Aviation Fuels (AAF) and **Hydrogen** are the alternative fuels considered within the scope of the Alternative Aviation Fuels Steering Group.

EU Members

CIRA Italian Aerospace Research Centre
Rolls Royce
BAE SYSTEMS
SAFRAN
AIRBUS
LEONARDO
Lufthansa Technik
EASA European Union Aviation Safety Agency

Alternative Aviation Fuels Steering Group

Hydrogen in Aviation

Task Groups

1. Fuel Production
2. Airport Infrastructure
3. Propulsion Systems
4. Emissions
5. Testing
6. Aircraft Systems

Deliverables

- Roadmap for defining Alternative Aviation Fuels standards
- A “matrix” (or equivalent tool) that tracks coordination, alignment, and identified gaps
- Recommendations for standards necessary to advance Sustainable Alternative Fuels developments to be shared with SAE Technical Standards Committees

Standardizing Hydrogen

Hydrogen in Aviation

AE-5CH Hydrogen Airport Task Group

This is a joint activity with WG-80.

The AE-5CH has the responsibility for hydrogen as a fuel at the airport.

The objective is to develop standardization for hydrogen in aerospace and other aspects at the airport such as fueling, transport and storage.

Harmonization with existing SAE Standards efforts and Codes (such as NFPA, etc.) will be a priority.

AE-7F Hydrogen & Fuel Cells

This is a joint activity with WG-80.

Addresses all facets of aerospace electrical power systems–design, testing, measurement, procedures, and in-service experience.

It develops standards and specifications relative to the generation, conversion, load management, and utilization of electric power in aerospace vehicles.

AE-5CH / WG-80 Hydrogen Airport Task Group

Hydrogen in Aviation

Just Published!

The World's First Aviation Hydrogen Refueling Standard

AIR8466 Hydrogen Fueling of Aircraft, in both Gaseous and Liquid Form

SAE AIR 8466 is to establish a baseline for hydrogen fueling station specifications and process limits for both gaseous and liquid hydrogen fueling of aircraft at the airport from small aircraft to widebody.

This document was developed in partnership with the Vertical Flight Society.

Works In-Progress

AIR8999 High Flow Liquid Hydrogen Fueling Couplings for Aerospace and Heavy Transport Applications

AE-7F / WG-80 - Hydrogen and Fuel Cells Committee

Hydrogen in Aviation

Published

- AS7141 Hydrogen Fuel Cells for Propulsion
- AS6679 Liquid Hydrogen Storage for Aviation
- AS7373 Gaseous Hydrogen Storage for General Aviation

Works In-Progress

- AIR6464 Aircraft Fuel Cell Safety Guidelines
- AS6858 Installation of Fuel Cell Systems on Large Civil Aircraft
- AIR7765 Considerations for Hydrogen Fuel Cells in Airborne Applications


AEROSPACE STANDARDS

SAE TECHNICAL COMMITTEE

AE-7F Hydrogen & Fuel Cells Committee

CALL FOR INTEREST

Why use hydrogen in Aviation?

- Supported by government recommendations and mandates for reductions in CO2 emissions, industry and research initiatives are focusing on the use of Hydrogen as a credible energy source in aviation. Hydrogen has a high energy density, a low operational cost and short refueling times; it may also be produced locally at airports to support zero-emission targets through the life cycle.

Where is hydrogen being used in the aviation ecosystem?

- As clean fuel for highly efficient gas turbine engines
- In Fuel Cells replacing APU, Galleys, RAT
- Airport ground vehicles, ground power units, battery charging units, etc.

Future: De-carbonization of aviation by 2035

- Develop "means of compliance" for Civil Aviation Authorities (CAA's) of hydrogen and fuel cell systems for airplane propulsion

EXAMPLES OF SAE AE-7F STANDARDS

AIR6464/ED-219
Aircraft Fuel Cell Safety Guidelines - Issued in 2013

AS6858/ED-245
Installation of Fuel Cell Systems on Large Civil Aircraft - Issued in 2017

AIR7765/ER-020
Considerations for Hydrogen Fuel Cells in Airborne Applications - Issued in 2019

AS6679/EDXXX
Liquid Hydrogen Storage for Aviation - Work in Progress started in 2019

AS7373/EDXXX
Gaseous Hydrogen Storage for General Aviation - Work in Progress started in 2021

SAE AE-7F

Electrifying Aviation

Hydrogen in Aviation

The Link Between Hydrogen Fuel Cells and Powering Electric Aviation

Empowering Electrification: SAE Committees + Standards

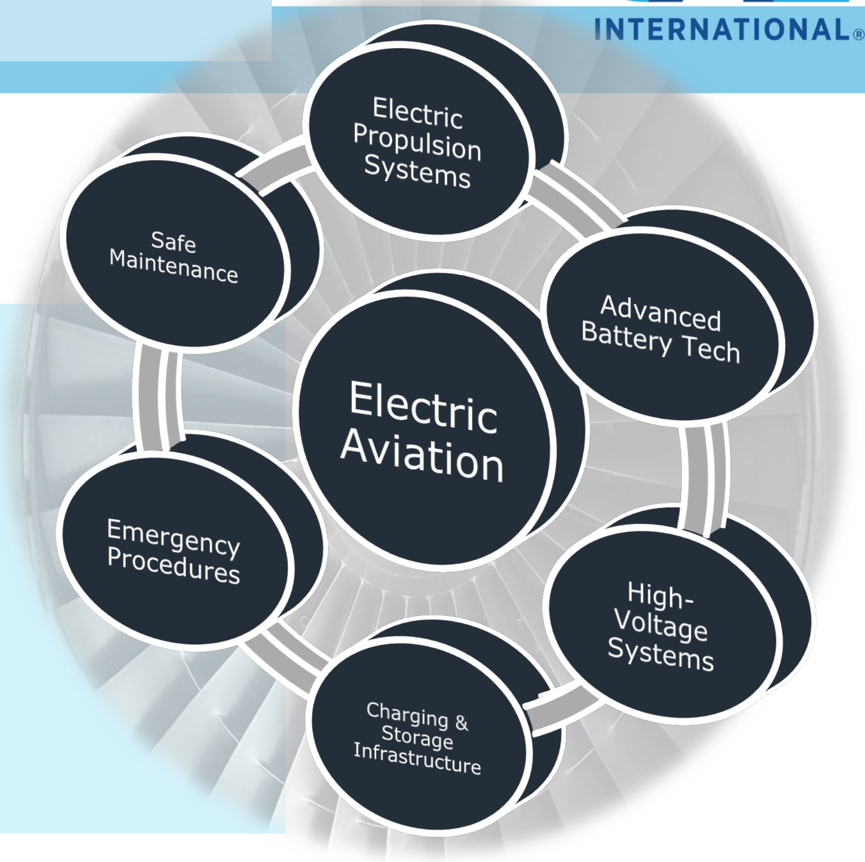
E-40 Electrified Propulsion

AE-10 High Voltage

EG-1 Aerospace Propulsion Systems Support Equipment

A-6 Aerospace Actuation, Control and Fluid Power Systems

AE-11 Aging Models for Electrical Insulation in High Energy Systems



AIR8678 Architecture Examples for Electrified Propulsion Aircraft

ARP8677 Safety Considerations for Electrified Propulsion

ARP8689 Endurance Tests for Aircraft Electric Engine

ARP8676 Nomenclature & Definitions for Electrified Propulsion Aircraft

EUROCAE Standards

Address aviation stakeholder needs by developing high-quality standards:

- Built upon state-of-the-art expertise
- Fit for purpose
- Adopted internationally
- Support operations, development and regulations
- Address emerging global aviation challenges

EUROCAE – Environmental Sustainability Standards

EUROCAE

Supporting aviation's transition to environmental, social, and economic sustainability

Energy sources, advanced airframes, and optimized operations.	Innovations reducing CO2, non-CO2 impacts, and aircraft noise	R&D support under SESAR, Clean Aviation and Horizon Europe

Partnering with RTCA, SAE, and others for worldwide harmonization

Deliver high-quality impactful standards for a greener, sustainable aviation sector

EUROCAE – Environmental Sustainability Standards

New technologies for propulsion of aircraft

- WG-113 Hybrid Propulsion Systems
- WG-116 Power distribution – High Voltage
- WG-80/AE-7F Hydrogen Fuel Cells

Wake energy retrieval

- Wake Energy Retrieval operations - SESAR 3 project GEESE

Green Airport

- Autonomous Taxi - SESAR initiative STX (Sustainable TaXiing)
- WG-80 SG-1/AE-5CH Airport Energy Infrastructure
- Quality of air

EUROCAE – Environmental Sustainability Standards

New technologies for propulsion of aircraft

- **WG-113 Hybrid Propulsion Systems**

Develop standards against SC-EHPS requirements MOC within the Aviation Safety Regulations (EASA IR/AMC/GM).

ER-025	List of standardization needs for Hybrid Electric Propulsion
ED-321	Guidance material for endurance substantiation of Electric - Hybrid Propulsion Systems EHPS
ED-xxx	Guidance material for durability substantiation of Electric - Hybrid Propulsion Systems EHPS – joint with SAE E-40

EUROCAE – Environmental Sustainability Standards

New technologies for propulsion of aircraft

- **WG-116 High Voltage Systems**

Develop standards to support the certification new design for electrical and hybrid aircraft, where electrical voltages will be much higher than the current standards

ED-332	Interface Characteristics and Power Quality of Aircraft High Voltage Propulsive Electrical Systems
ED-320	Guidance Document Aging mechanisms of electrical insulation materials in a high energy system
ED-xxx	Guidance for High Voltage Risk Mitigation at EWIS and Human Safety Level
ED-xxx	Test guidelines for electrical insulation materials and components for a high voltage system

WG-80 / AE-7F - History & current status

Preliminary guidance & requirements

2013
ED-219 / AIR6464 ⇒ **Introductory safety guidelines** for **fuel cell power systems design**, for use on Part 25 applications

2017
ED-245 / AS6858 ⇒ more detailed requirements for the installation of **FC non critical systems** (Medevac, galley, emer power)

2019
ER-020 / AIR7765 - **introduction of H2 aspects** and use in various applications, for decision makers

Context evolutions

Concrete projects with H2 as a fuel for aviation
- regional up to middle range aircraft
- fuel cells for a critical system

New technos, new pheno, new risks, to integrate ⇒ **Key features of system architectures & A/C design impacted**

Usual **industrial precautions not directly transposable** to aeronautics

New aeronautical entrants

Detailed guidance & specific standards for MoC needed

New documents

Initial ambitions: specifications for design, safety, qualification, maintenance, certification

Updated target: *recommendations* for design as a 1st step. Enrichment with other topics as next steps of an iterative approach

2019+
LH2 storage critical for higher range A/C ⇒ AS6679 / DP003 "LH2 Storage for Aviation"

2021+
General aviation paving the way, using GH2 storage ⇒ AS7373 / DP005 "Gaseous Hydrogen Storage for General Aviation"

2023+
Use of **FC based PPS** in several projects ⇒ AS7141 / DP006 "Hydrogen Fuel Cells for Propulsion"

2024
Joint AE-5CH & AE-7F - ER-034 / AIR8466 - "Guidelines for Airport **H2 fueling stations**"

WG-80 / AE-7F - Ambitions

Challenges encountered

Aeronautical industry experience ⇒ lack of mature or applicable inputs on technos and H2 pheno

Knowledge maturity and applicability: academic expertise vs applicability in an industrial & aircraft context

Reach **consensus** on recommandations

Historical context:

- Huge interest & quick team growth
- Various level of involvement
- Heterogeneous population

⇒ **group richness + organisation & wow challenges**

++ Participation improvement currently; consolidation needed

Way forward

Target modest but focussed outputs:

- Issue 1st precise design recommendations = **baseline to** start guiding & impacting the ecosystem
- Prioritise **targeted precise topics**, to elaborate small but powerful standards in the near future

Coordinate with other initiatives (Clean Aviation, AZEA, …) for consistency & efficiency

Joint work with AA to get feedback for standardisation, and bring **concrete support** to the 3 steps of rulemaking

Provide the appropriate and consensus based tools (standards)
to support relevant compliance demonstration to the future H2 aircraft regulations

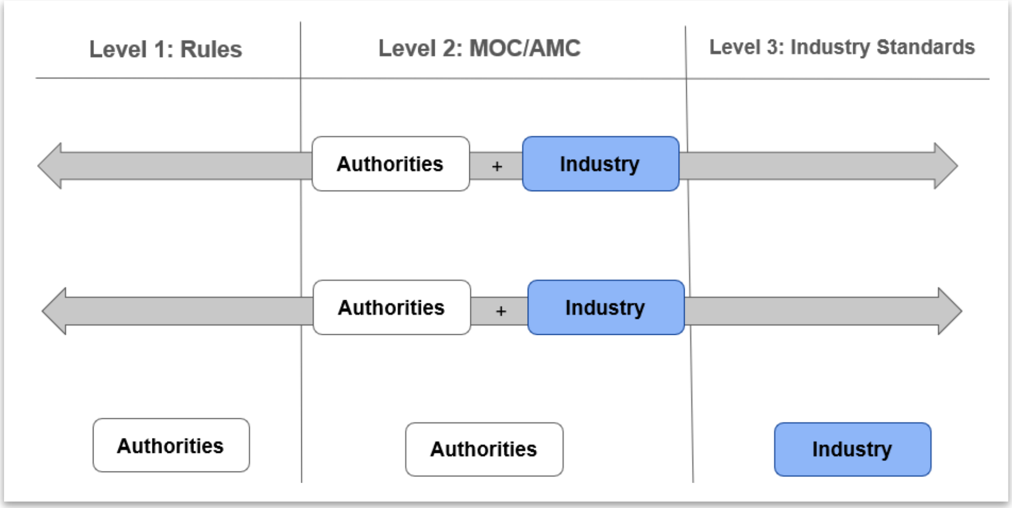
Summary & recommendations

Most new regulations expected to be performance based ⇒ agreed **MoC** are crucial
Standards are key enablers for certification, but also for interoperability and business efficiency
The **arsenal is in place**; 1st material is being produced

EASA (and industries) active involvement is required
EASA guidance on prioritisation (based on their transverse view) is critical for standardisation & certification roadmaps
EASA guidance on which **forum** it is favoured for **rulemaking** work (potentially topic by topic)
Despite the “chicken and egg” dilemma, **concrete proposals from EASA** would support industrial applications

Appropriate support to innovation also means **EASA resources** are commensurate to the need

Joint work with standardisation groups brings synergies and provide support for above needs



THANK YOU