Technology / Requirements / MoC / Standards: “chicken & egg dilemna”

Export Control Not Technical

COMMERCIAL AIRCRAFT

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Agenda

- Context
- H2 aircraft Certification - New Risks
- H2 aircraft Certification - The Challenges
- H2 aircraft Certification - Safety Objectives
- Technology / Requirements / MoC / Standards: “chicken & egg dilemna”

Context - The Legacy

What is granted: regulations & standards

- ➔ providing a high level of safety
- ➔ progressively built from decades of experience on conventional products
- ➔ sometimes addressing a global threat by a cumulation of partial (and prescriptive) requirements stacked up over the years (e.g. cabin fire)

What are the “habits”

- ➔ OEM applies for the certification of a new *conventional* product
- ➔ Authorities
  - ◆ review the proposed design & confirm the adequacy of the existing requirements
  - ◆ adapt them for “unusual design features”, i.e. come back to the *intent* of the prescriptive requirement and modify it to cover the new feature.

H2 Aircraft Certification - New Risks

H2 is not a liquid and "passive" fuel at ambient temperature, which invalidates a large part of the very basic assumptions used by current aeronautical regulations:

- ➔ H2 leak "capability" is far greater than Kerosene
- ➔ H2 leak consequences may be far different than Kerosene (ignition / deflagration / detonation…) but are not yet mastered, at least in Aeronautical Industry - hence a big question mark on the related Hazards
- ➔ LH2 brings its own challenges (liquid phase management, leak cryo risk …)

In addition, H2 related technologies (Fuel Cells, H2 systems elements) bring their own additional risks, for which aeronautical industry can't take profit of other industries' experience.

All this in a context of new High Voltage risks (for Fuel Cell solutions), although High Voltage is not a complete unknown.

H2 Aircraft Certification - The Challenges

- ➔ **No** experience (in aeronautical industry since the 1930s) on the H2 technology, while the safety level of air transport has tremendously improved
- ➔ **No or Low** competences at the start of the journey (Aeronautical Industry *and* Authorities)
- ➔ H2 Technology sometimes too disruptive to “adapt” existing requirements, leading to come back at the global threat scenario level and redefine first what should be the “intent” of the regulation.
- ➔ The chicken & egg dilemma: design needs regulations and regulations are usually built around a design.

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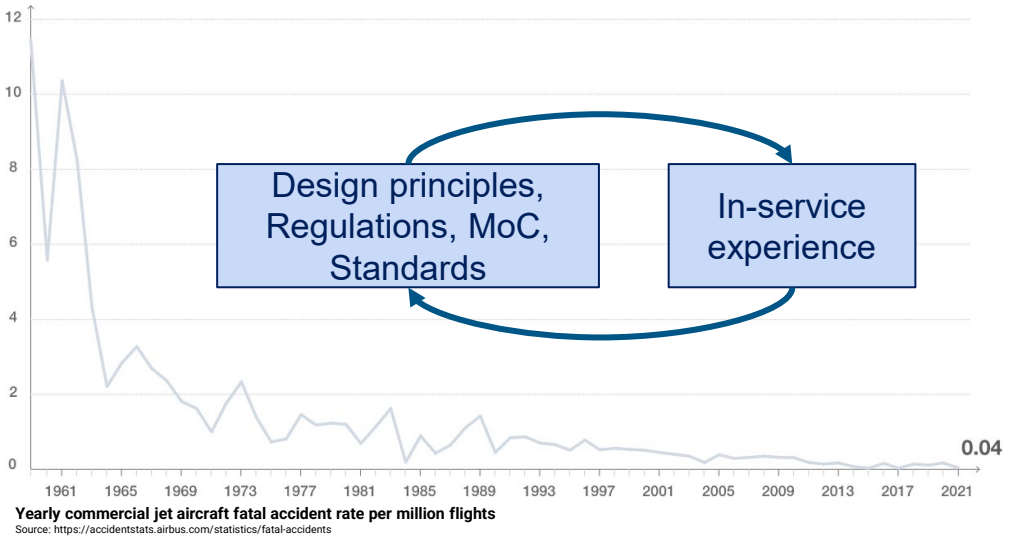
H2 Aircraft Certification - Safety Objectives (for Part 25 products)



Yearly commercial jet aircraft fatal accident rate per million flights

Source: https://accidentstats.airbus.com/statistics/fatal-accidents

H2 aircraft at least as safe as today's fleet ⇒ How?

Reduce and compensate uncertainties

Equivalent level of safety, for novelties

Compliance to current regulations still applicable

Identification of the uncertainties type and range ("*known unknowns*"): **decrease** by **extensive maturation**, **coverage** by design

Examples: thermal effects

"Unknown unknowns" **risk minimisation** by **extensive maturation** (tests "beyond standards")

Examples: degradation speed, sensitivity characterisation, …

Challenge: Extensive coverage to build the needed experience

New regulation and/or MoC, based on the **intent** of the existing kerosene fleet regulations and/or MoC impacted by the novelties

Example: 25.981 & inversion minimisation / prevention for flammable mixture / ignition source

Internal processes, standards, ways of working enrichment

Examples:
- New particular risks (cryogenic thermal risk)
- Compare severities of failure scenarios for similar A/C effects (flammable fluid leak, loss of thrust, …), between kerosene and hydrogen A/C

Challenge: "inspiration" given by current regulations or solutions shall be used with care, and not preclude step back, global approach and fine tuned "conscious" coverage of the novelties and associated risksc

Current **applicable** regulations and/or MoC (compliance dossier may be different)

Examples: CS25.1309, CS25.721(b)(c): minor crash landing conditions, engine detachment, …

This "layered" approach is key to maintain fleet safety, and to ensure full trust of A/W authorities in A/C manufacturers, and of the public in our products

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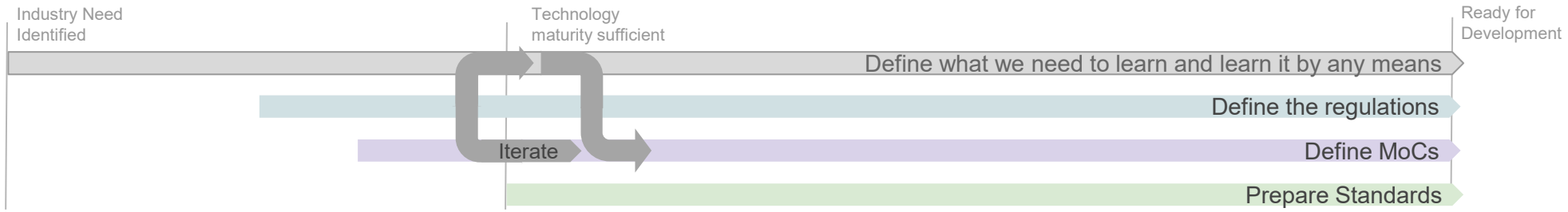
“Chicken & egg dilemma”

- Design activities need to understand what the regulations will be and how to comply with them
- H2 technology is so disruptive that a thorough update of the regulations and related Methods of Compliance is needed. This is a difficult exercise, even more in the cases where no concrete design concept is available to support the discussion.
- Design, regulations & methods of compliance can hardly be defined without a good understanding of the hazards, meaning here a good understanding of H2 phenomenology impact.

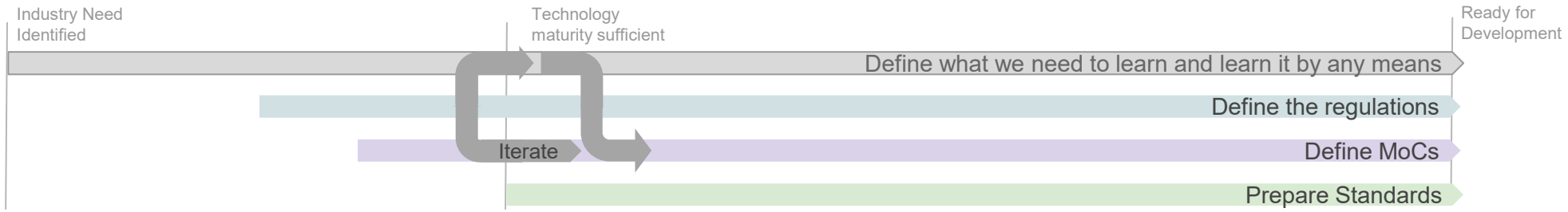
“Chicken & egg dilemma” - way forward



Priority 1: *need to define what we (Industry & Authorities) need to learn…and learn by any means*

- Return on experience from other industries
- Launch of generic projects (e.g. Clean Aviation, Azea) or OEM projects allowing to run a first regulation gap analysis and identify the knowledge gaps to be filled
- Fill these knowledge gaps through
  - Research activities coordinated by Authorities (e.g. H2 Fire & Explosion Research Steering Group, UK CAA Regulatory Sandbox for Hydrogen)
  - OEMs R&T activities – to be shared with Authorities
    - ➔ “Small Airplanes” projects and demonstrators should help gather experience quicker

“Chicken & egg dilemma” - way forward (con’td)



Priority 2: *need to update the regulations*

- ➢ Define « performance based » regulations - addressing global hazard scenarii when too different from conventional products

Priority 3: *define adapted Methods of Compliance for each design solution*

- ➢ MOCs will adapt to the knowledge available, so may evolve over time.

Priority 4: *iterate*

- ➢ Refine design, regulations, methods of compliance as our knowledge increases

Parallel Priority: prepare a set of standards to support Methods of Compliance determination

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