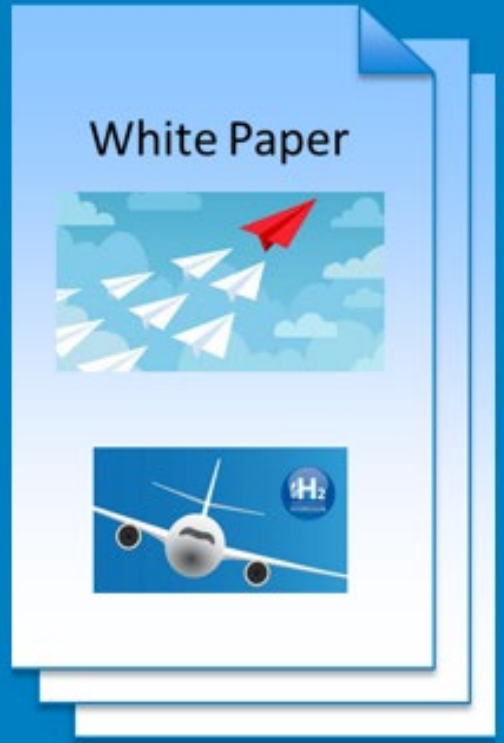
EASA
European Union Aviation Safety Agency

Federal Aviation Administration

UK Civil Aviation Authority



International White Paper

A joint presentation by EASA, FAA, and CAA UK

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Helen Leadbetter (CAA UK), Technical Strategy Lead - Zero Emissions Flight

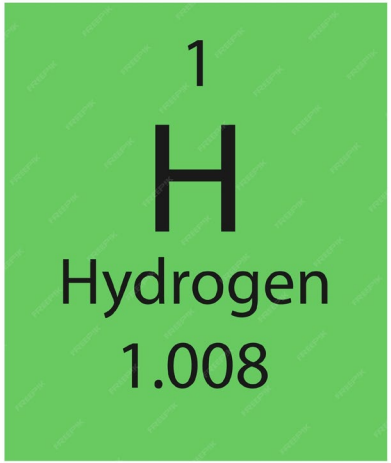
Cologne, 17th December, 2024

Your safety is our mission.

An Agency of the European Union

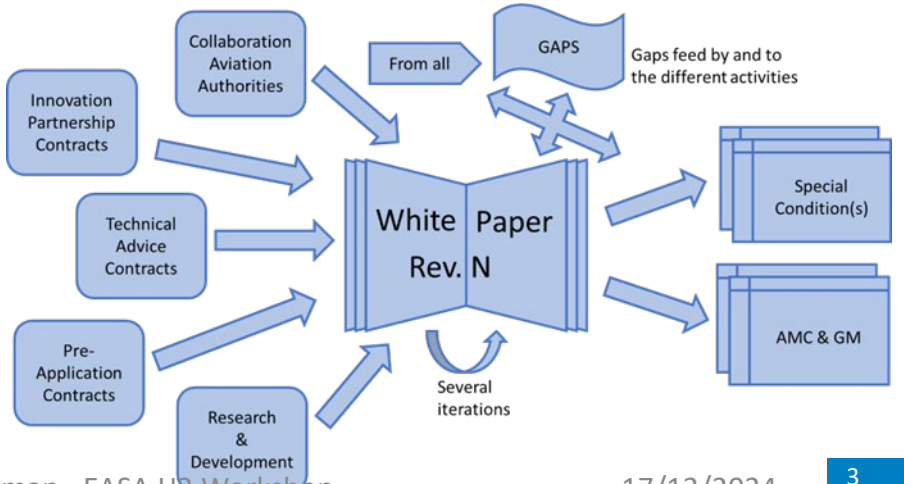
Outline of this presentation

- → Why a white paper?
- → Current prevalent Hydrogen Technologies architectures
- → Challenges ...



Purpose of this International White Paper

- → Part of the H2 Roadmap (EASA, …)
- → Sets boundary on technology we foresee for airworthiness certification
- → Explore impact on airworthiness of these technologies
- → Proposing path to address these impacts in the current regulatory landscape

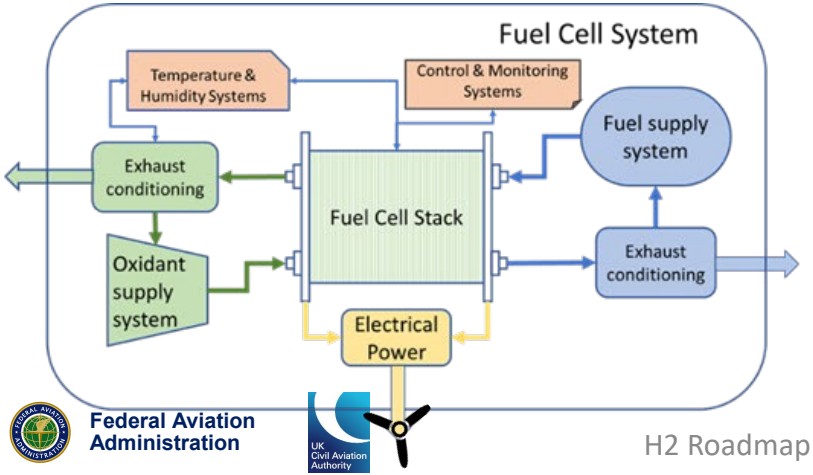


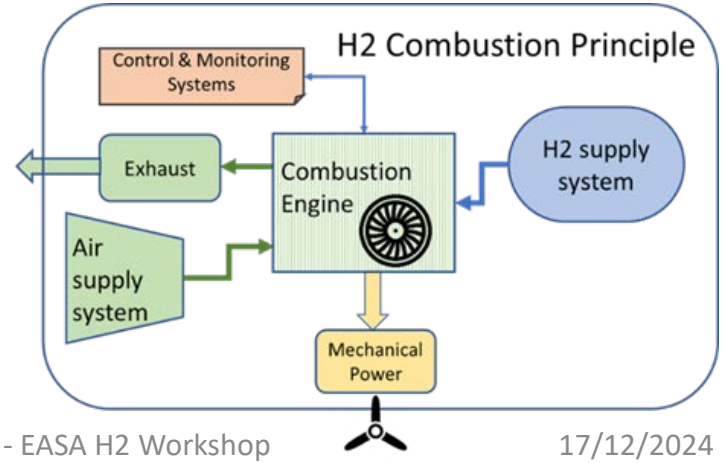
Two main applications

The two main routes to use hydrogen in current propulsion solutions are (both use air for oxygen supply):

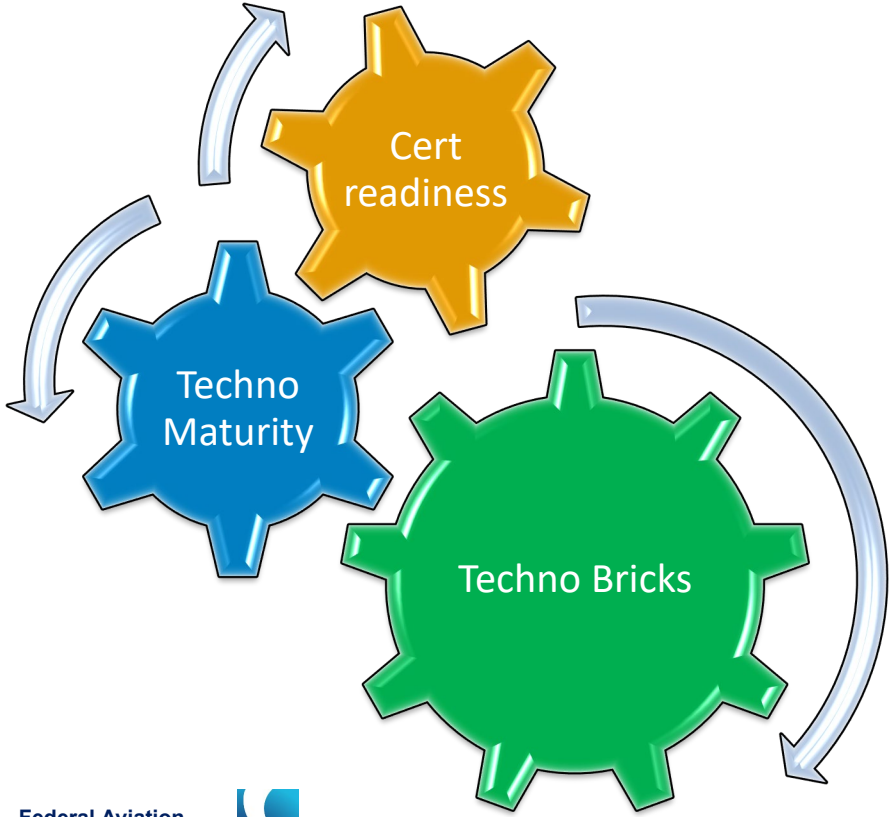
→ hydrogen as a reactant in a fuel cell stack

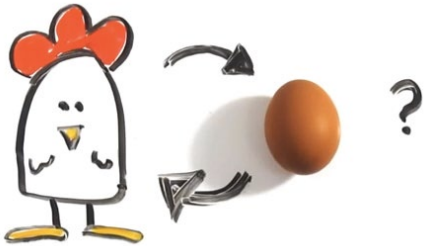
→ hydrogen as a combustion fuel in an engine





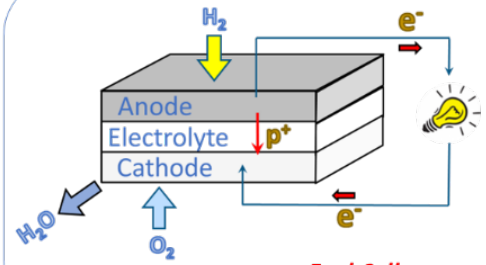
Elements in the equation to safety

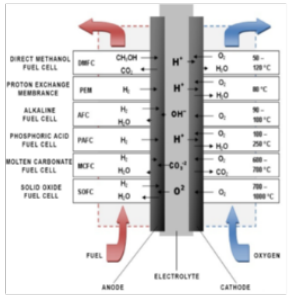




Technology bricks

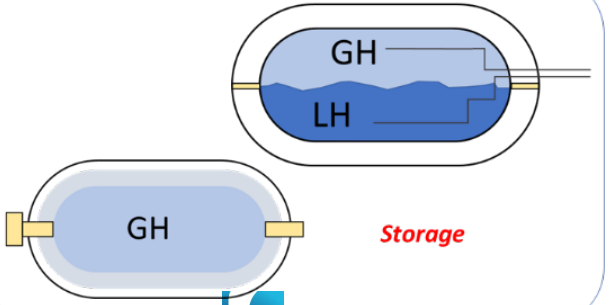
Larger chunks specific or common to these applications



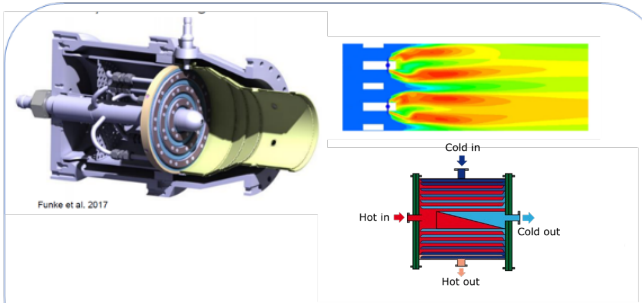


Fuel Cells

Distribution: GH or LH

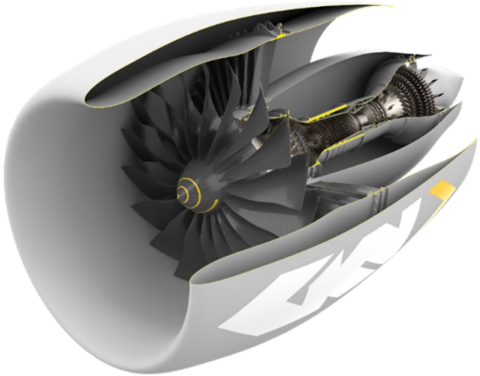


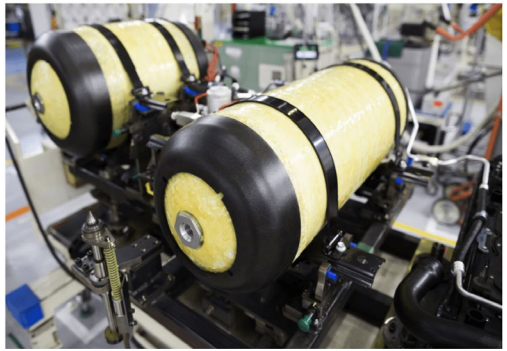
Storage



Combustion Engine

Overall maturity… ?





Some examples, TRL, CRL, where are we?

Hydrogen tanks before being installed to a Toyota Motor Corp. Mirai fuel-cell vehicle (FCV) in Japan on Oct. 13, 2016. Photographer: Tomohiro Ohsumi/Bloomberg

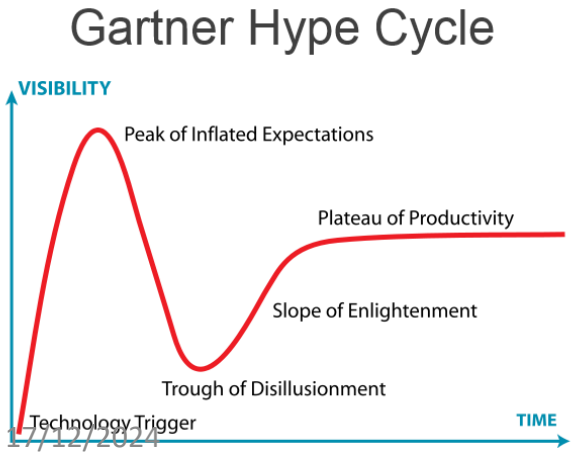
Airworthiness Considerations

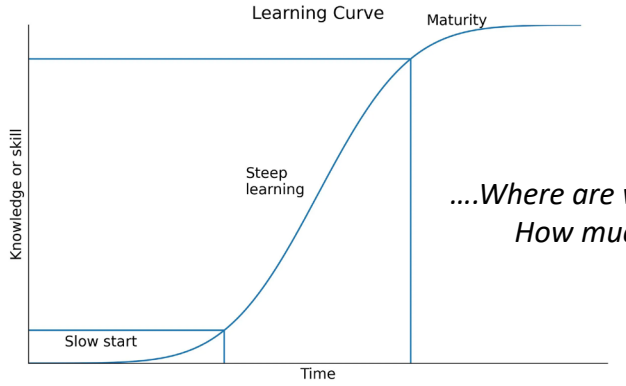
- → Effects of Hydrogen in the Aircraft (e.g. accumulation of H2, material damage, etc.)
- → Survivable Emergency Landing – crashworthiness
- → Hydrogen leaks
- → Fire & Explosion Protection
- → Interaction of Systems and Structures
- → LH2 tank fatigue and damage tolerance including maintenance and ICA aspects.

It should be noted that this list is not meant to be exhaustive.

Research effort is paramount

- There are many research areas where H2 threat impact would need further understanding and characterisation plus gather data to support definition of regulations and guidance.
- Fragmented ecosystem
  - Different platforms doing different things but challenging for having holistic cohesiveness.
  - The development of these bricks must be planned, financed and demonstrated either through other European or national research programmes or through the industry itself.
- **We need to work together and join forces : when, how, in which setting?**





….Where are we on these curves….?
How much time we have?

Hydrogen Propulsion & Related Research Areas

Combustion

- What are design requirements for safe operation of H2 fuelled turbine combustor stage?
- What are combustion chamber design changes necessary for H2?
- How to establish H2 flammability limits and flame speed as function of pressure and temperature i.e. as function of altitude?
- What is the impact of hydrogen embrittlement and H2 leakage on compressor & turbine?
- Any other questions pertinent to safe combustion of H2 as aviation fuel?

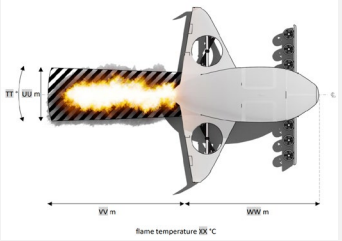
Materials & Design

- How to qualify new materials for safe H2 aviation?
- How does the purity level affect Environmental H2 Embrittlement?
- What is the appropriate design/materials for fuel tanks?
- What effect on boil off and consequent pressure results from LH2 slosh during fuelling?
- Are there any other questions pertinent to the impact of H2 as an aviation fuel on design and materials?

Fire & Explosion

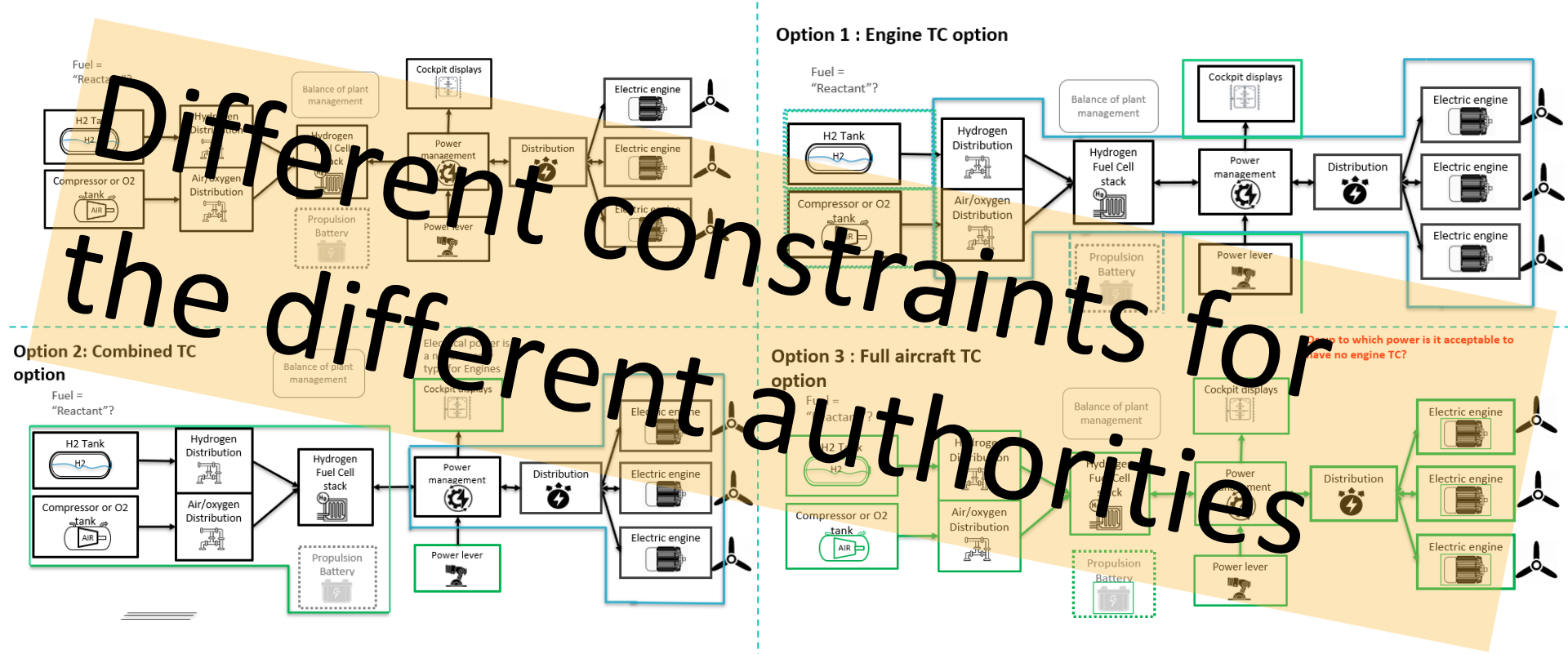
- H2 Fuel Tank Safety
- H2 Fire – Getting a Standard
- H2 leaks – gaseous & liquid
- Concepts of DFZ, FFLZ … Fuel Cell zone…
- Post-Crash Fire

Research Topic Title	Research Topic Description
Air ingress acceptability criteria	H2 tank and cryogenic storage components pressure collapse phenomena to define requirements that mitigate the risk of air ingress into H2 systems. Refuelling with contaminants or trapped air at connection during refuelling might be condition when air ingress may occur. Research on air ingress acceptability criterial in which conditions?
Accumulation of liquid oxygen (fire hazard)	During cryogenic or extremely cold Liquid H2/Gaseous H2 release (leittisen; venting; thermal insulation failure…) risk around pipes to condensate leading to potential accumulation of liquid air (cryogenic hazard, explosion hazard in the event of rapid vaporization). Any acceptable amount? Need to tolerate a certain amount?
Hazardous quantity of leakage	Determination of hazardous quantities of leakage. The quantity might differ for a GH2 or a LH2 application.
H2 fire/leak detection	Hydrogen leak detection and localisation. Hydrogen fire detection. Technology capable to detect and withstand H2 fire requires research need (including qualification and protocol adaptation). Deliverable should be a performance requirement that provide safe operation. Hydrogen fire threat timeline (to determine appropriate definition of "quick acting".
Explosion Proof	Research new methodology for Explosion Proof equipment requirement when considering H2 instead of kerosene. DO 160 should be adapted to other fuels like H2. Define acceptable ignition energy threshold below which one would comply with the minimisation effort.
Surface Temperature limit	Research about new surface temperature limits when



Examples

Possible Approaches: Work in Progress



Different constraints for the different authorities

Engine TC

Aircraft TC

HFC-HPS: Certification strategies comparison

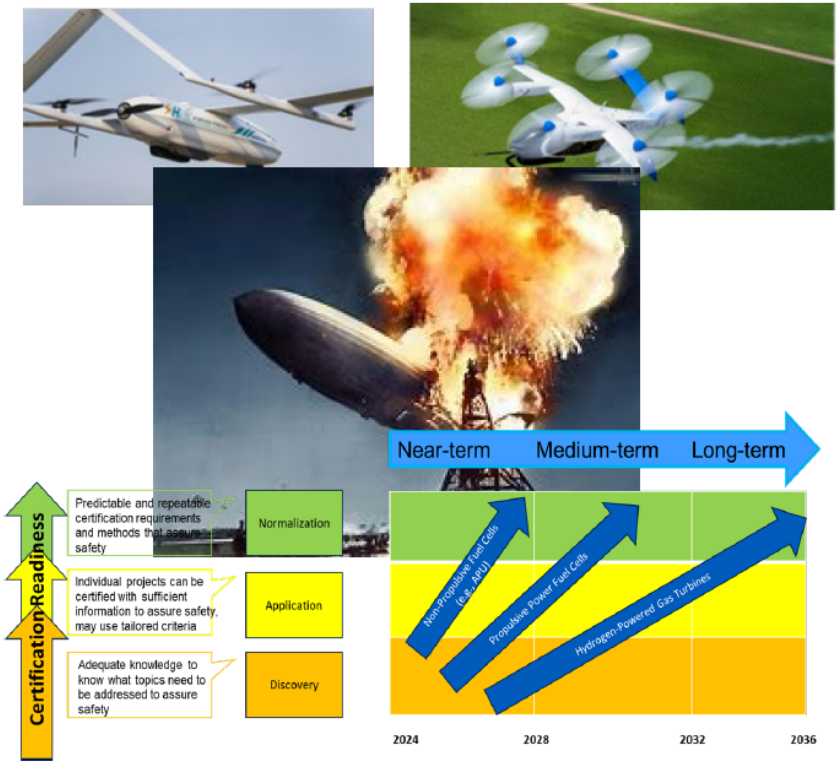
	Advantages	Challenges
Option 1: Engine TC HFC systems, E-engine systems, H2 distribution system. Tank Excluded.	• Input/output similar to traditional engine definition (fuel replaced by H2/O2, output is power to a propeller) • High interaction and interdependencies between systems • "best" option for Pods architecture (tank excluded)	• Novel disciplines & competencies as part of engine / DOA problematic • New requirements specific to HFC, and to A/C (25.1309?) • May not be compatible with distributed propulsion architecture • Intellectual properties : FC suppliers can be reluctant to share all their design with the Engine TC holder
Option 3: Separated TC Tank, H2 distr, HFC aircraft TC. E-engine systems and power management: Engine TC.	• Technical disciplines and competencies of DOA holders remains highly similar → same sharing of activities as today • Less regulatory mixing of technical competencies • More compatible with distributed architectures	• High interaction level between systems may represent a risk • Electrical power is a new type of Energy to be defined as an engine input • Intellectual properties : FC suppliers can be reluctant to share all their design with the Airframe TC holder
Option 2: Aircraft TC HFC systems, E-engine systems Tank, H2 distribution system	• Perhaps easier for smaller aircraft manufacturers? • makes it easier to manage changes (non affected areas…) or implement new technologies	• Novel disciplines & competencies covering the engine // DOA problematic • New competencies related to Fuel Cell system • Intellectual properties : FC suppliers can be reluctant to share all their design with the Airframe TC holder
Additional option: ETSO HFC systems	• Stop commercial FC manufacturer / protection of intellectual property : a concern for several FC suppliers • If an separate CS is created for FC specificities : more flexibility	• Strong links and airworthiness responsibilities between ETSO organization, and the TC Holder • Need for more maturity from Industries / SDOs → Need to be driven by industries
TANKS : Certification as part of an engine (ex: 'Pods'?)	• Proposed for some Pods architectures	• Sensitive part (risk of explosion) and novel technologies related to H2 tanks • Too many disciplines that would be novel for engine manufacturer competencies (Crashworthiness / structures..) • Would require extensive wok on SCs to be added

Several approaches are under discussion in authorities, different constraints

Elements in the equation to safety

Takeaways

- Hydrogen in aviation is here already and likely to stay
- We must treat it with respect
- Safety roadmap, technology R&D are initial steps; much work remains, not least in coordination



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