The first step towards decarbonized air mobility in South Africa: a hydrogen powered unmanned aerial vehicle

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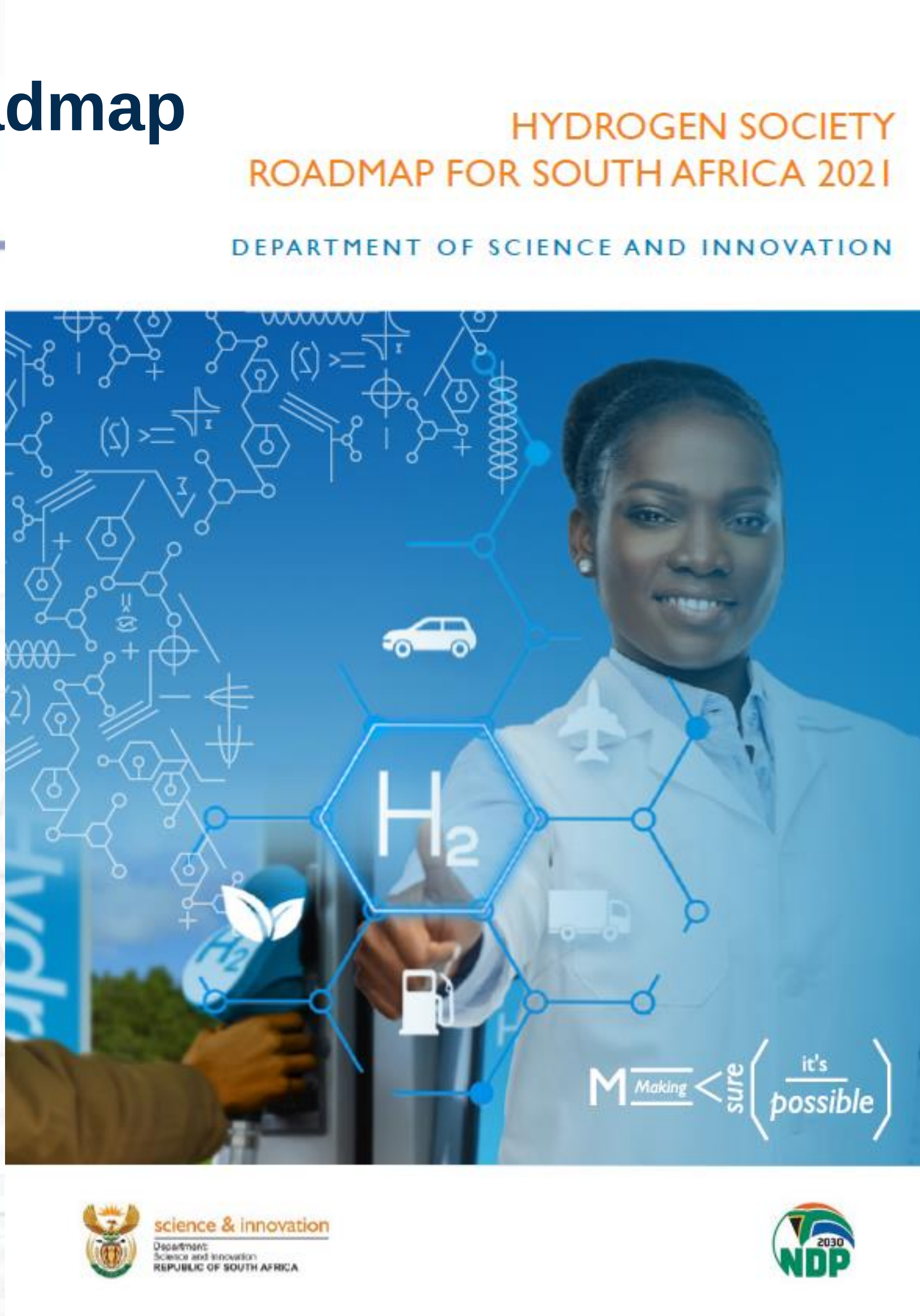
Outline

- Air mobility in the Hydrogen Society Roadmap
- Why hydrogen for decarbonizing aviation?
- Why start with an UAV – the hydrogen air mobility roadmap
- Project objectives
- The market
- The concept
- Hydrogen propulsion unit
- The development plan
- Key stakeholder management

Air Mobility in the Hydrogen Society Roadmap

- Hydrogen Society Roadmap (HSRM) - strategic plan to implement vision of “an inclusive, sustainable and competitive hydrogen economy by 2050”
- The HSRM has six key outcomes, including:
  - Decarbonisation of transport sectors
  - Creation of a Centre of Excellence in Manufacturing for hydrogen products and fuel cell components
- HySA Mobility Cluster at CSIR focuses on the “Decarbonisation of transport sectors”
- Initial focus areas:
  - Air mobility
  - Mining mobility
  - Heavy duty transport mobility



Air Mobility in the Hydrogen Society Roadmap

- Air mobility objectives
  - Localise technical expertise in local H2 propulsion systems for airborne applications
  - Develop expertise in optimizing aircraft for H2 propulsion
  - Act as catalyst to migrate H2 expertise into South African aviation sector & confront/address operational, safety & regulatory issues as they arise
  - Exposure & capacity building for H2 in SA skies
    - Demonstrations and conferences

Zero-Carbon Emission Aircraft Concepts, report FZO-AIN-REP-0007, Aerospace Technology Institute – FlyZero, March 2022

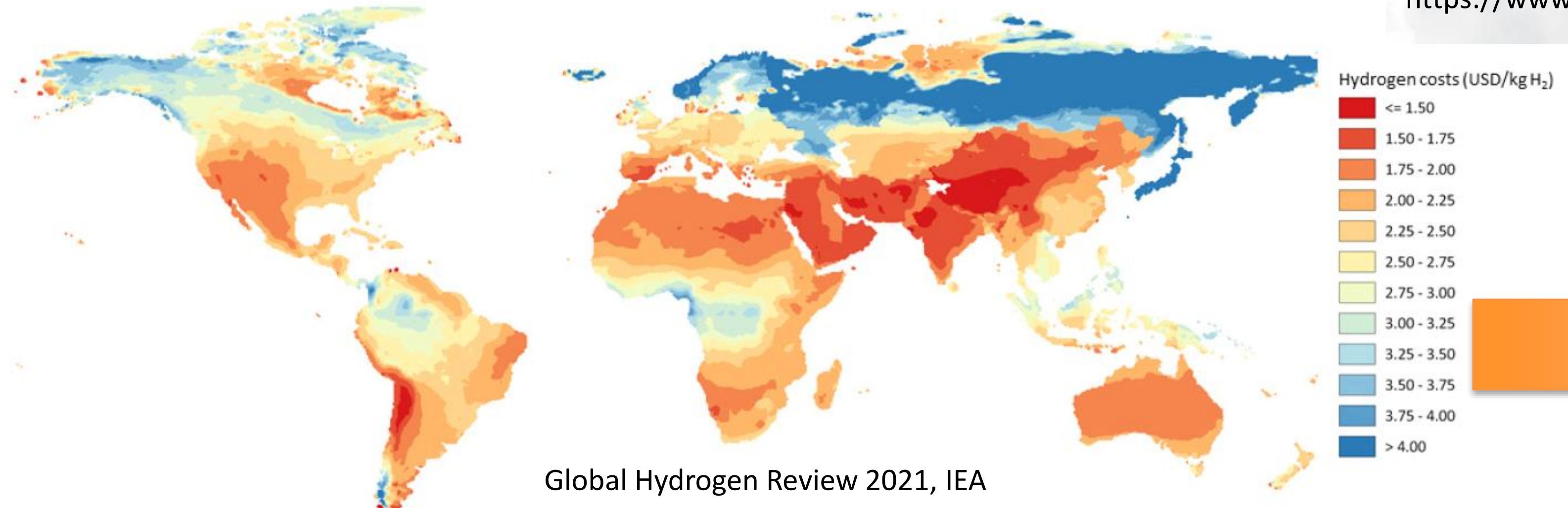
Why hydrogen for decarbonizing aviation?

- Growing imperative to decarbonize aviation
  - Pressure to move to “net zero” (12% of transport CO_2 emissions)
  - Aviation is driven by mass & density: energy to weight/volume ratios
    - Moving away from high specific energy fossil fuels is immense challenge
  - Many paths forward, likely to split into family of mission dependent solutions
    - Jet A-1: 43 MJ/kg; 820 kg/m^3
    - Lithium-ion batteries @battery pack level: <0.7 MJ/kg, 2400 kg/m^3
    - Compressed gas H_2 @350 bar: 120 MJ/kg; 26 kg/m^3
    - Cryogenic H_2: 120 MJ/kg; 71 kg/m^3
  - More effort required to select appropriate propulsion architectures

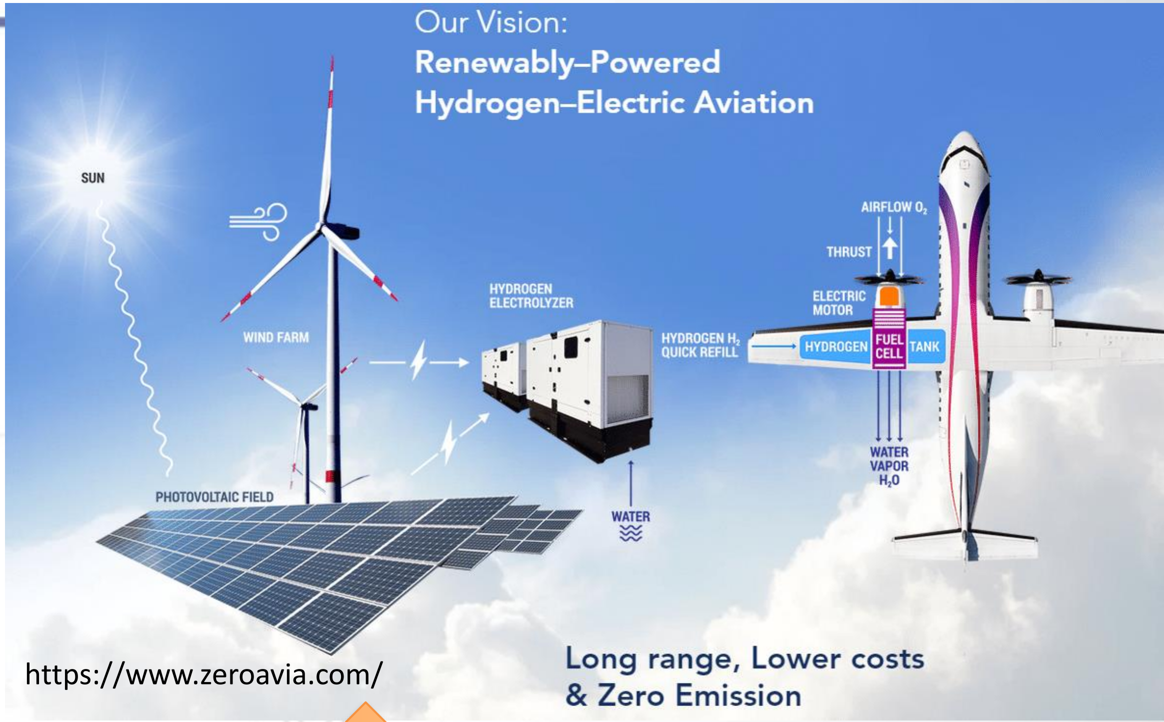
Why hydrogen for decarbonizing aviation?

- SA (& many parts of the world) has significant unrealized potential to generate low-cost "green" hydrogen
  - Significant investments to tap this potential are in pipeline
- This can support a competitive hydrogen fuelled aviation sector

Hydrogen production cost from hybrid solar PV and wind systems in 2030



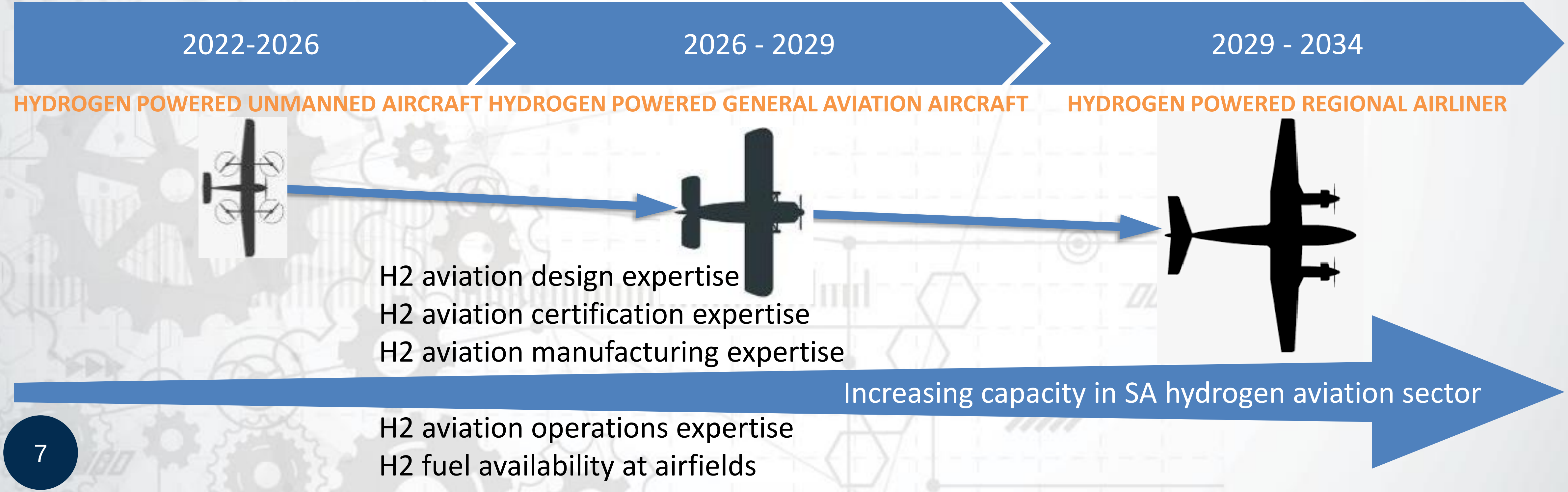
Global Hydrogen Review 2021, IEA



https://www.zeroavia.com/

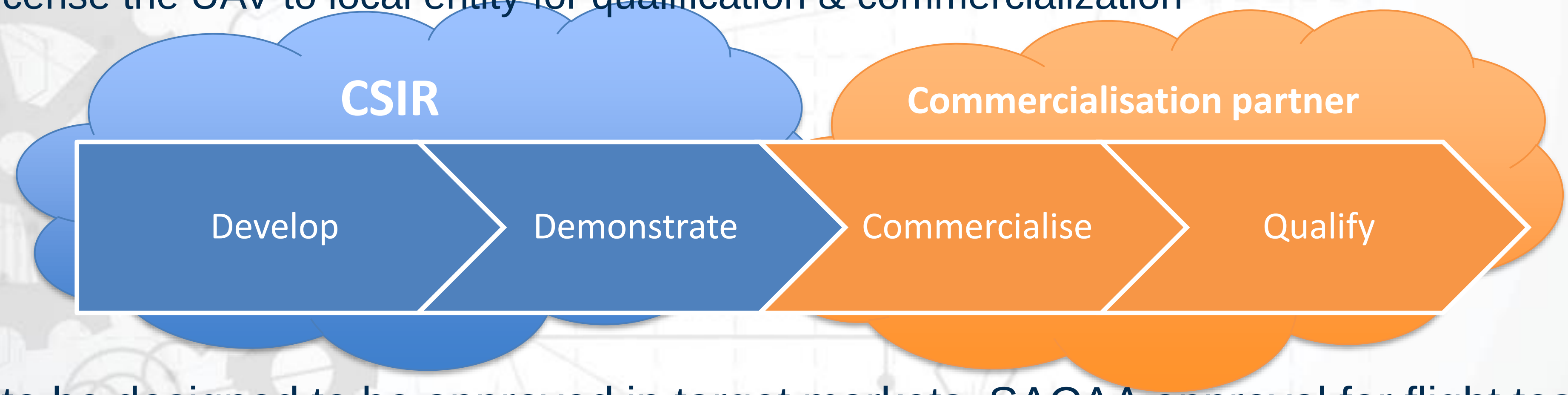
Why start with an UAV?

- Develop & demonstrate hydrogen powered UAV as a strategic demonstration project in aviation sector
  - First step towards a hydrogen powered aviation sector
    - Roadmap towards rapid expansion of hydrogen use in aviation



Project objectives

- Develop, demonstrate and prove an integrated airborne hydrogen fuel cell propulsion system for UAVs
  - License the fuel cell propulsion system to local entity for qualification & commercialization
- Develop, and demonstrate a hydrogen fuel cell powered UAV (using the above powerplant) designed to address real market use cases
    - A UAV with ground station & dummy payload
  - License the UAV to local entity for qualification & commercialization



- UAV to be designed to be approved in target markets, SACAA approval for flight tests & demonstrations in SA

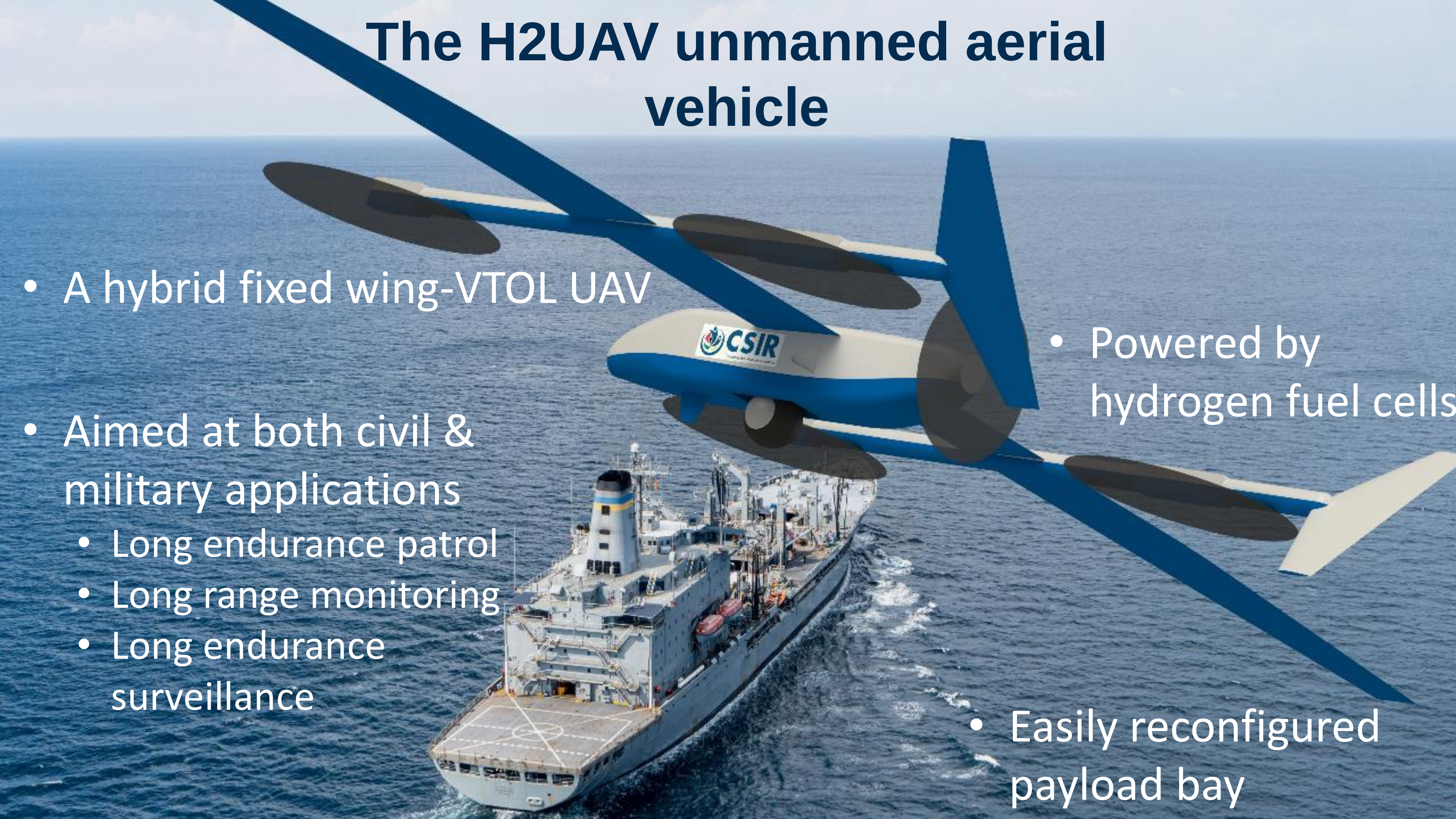
The market

Market analysis done to inform positioning of a H2 powered UAV for success in global marketplace.

- Starting point: fixed wing/vertical take-off and landing (VTOL) UAV
- H2 fuel cells are more expensive than other propulsion alternatives
  - Focus on H2 fuel cell strengths: higher-value payload / long endurance missions / low-noise
- Requirements validated by consultations with local & international UAV operators

https://www.mmcuav.com/hour15-flight-time-mmc-uav-launches-new-record-breaking-hydrone/

The H2UAV unmanned aerial vehicle



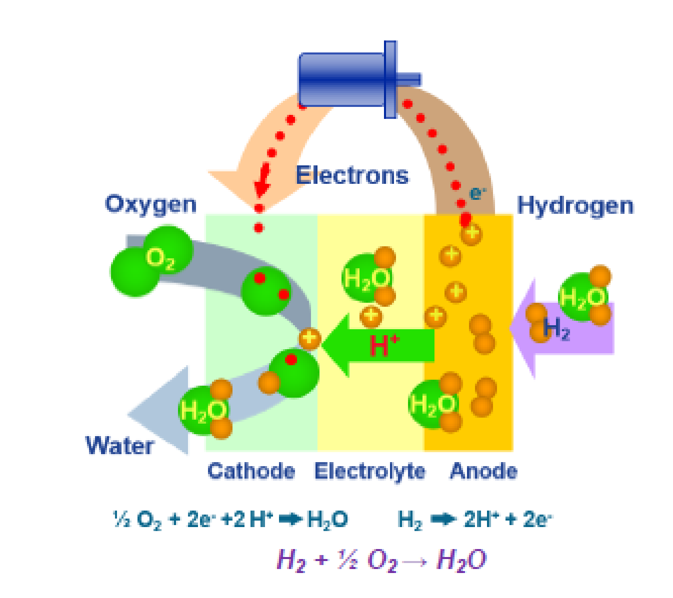
- A hybrid fixed wing-VTOL UAV
- Aimed at both civil & military applications
  - Long endurance patrol
  - Long range monitoring
  - Long endurance surveillance
- Powered by hydrogen fuel cells
- Easily reconfigured payload bay

The H2UAV unmanned aerial vehicle

- 5 kg payload
- 10+ hours endurance
- Quiet electric propulsion
- Robust operating limits
  - Take-off & land in:
    - 60 kph winds
    - 45degC+
    - 3,000 m altitude
  - Fly in 1-5 mm precipitation
- High reliability & integrity
- High altitude operations: 16,000 ft (4,877 m)

Hydrogen Propulsion Overview

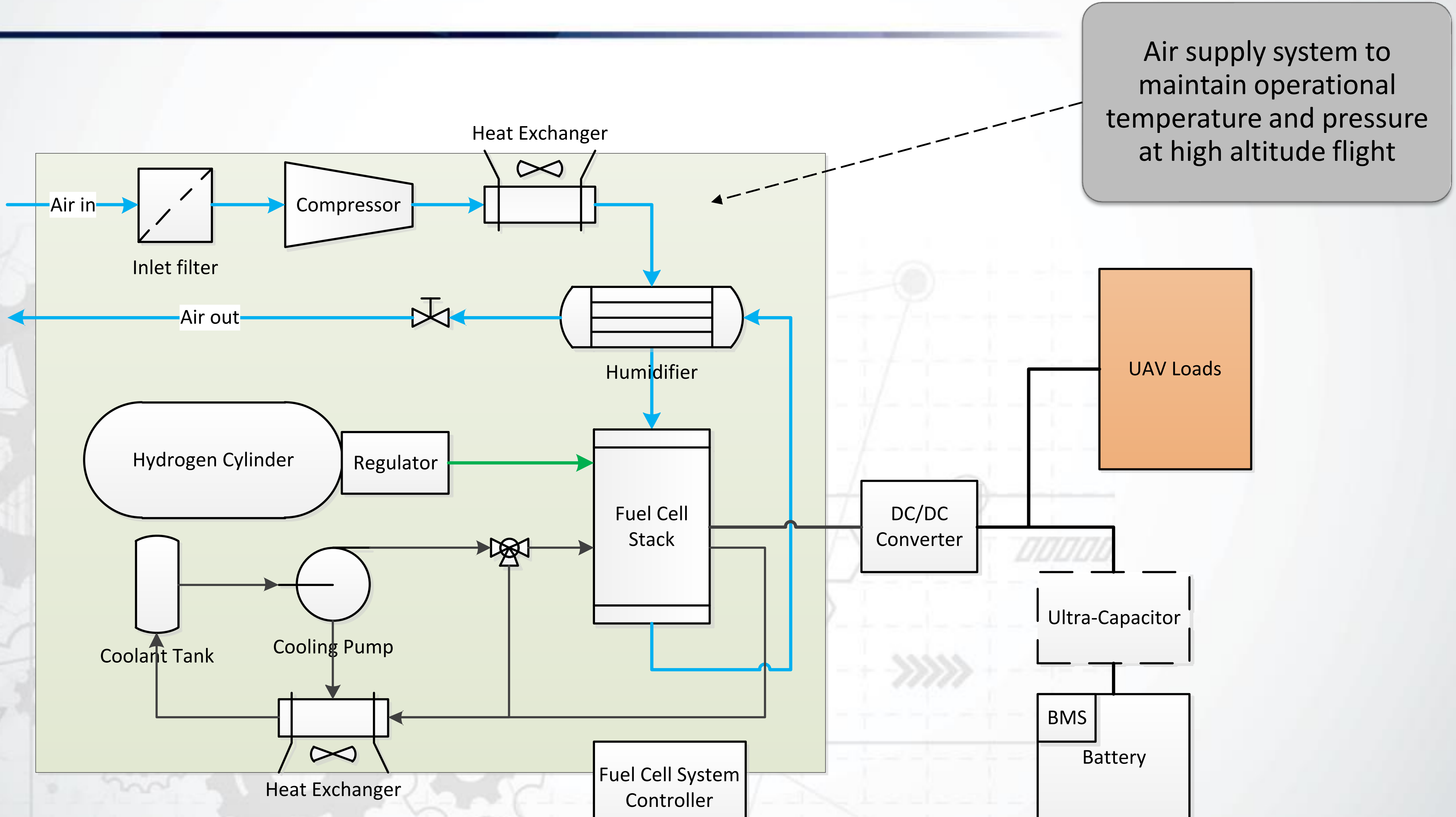
- Fuel Cells produce electricity through electrochemical reaction vs batteries that store energy
- Hydrogen gas vs Hydrogen Liquid for UAVs
- PEM FC have a higher stack specific power of 2 kW/kg[1] compared to other fuel cells used in aviation (SOFC ~ 0.17kW/kg stack specific power[1]).
- Hydrogen Safety Considerations – Detection System, Fire Suppression System



PEM FC Electrochemical Reaction[1]

[1]Electrochemical Energy Systems for Electrified Aircraft Propulsion: Batteries and Fuel Cell Systems course notes, Version 09222021
[2]https://www1.eere.energy.gov/hydrogenandfuelcells/pdfs/30535be.pdf

A concept of the Hydrogen Propulsion Architecture



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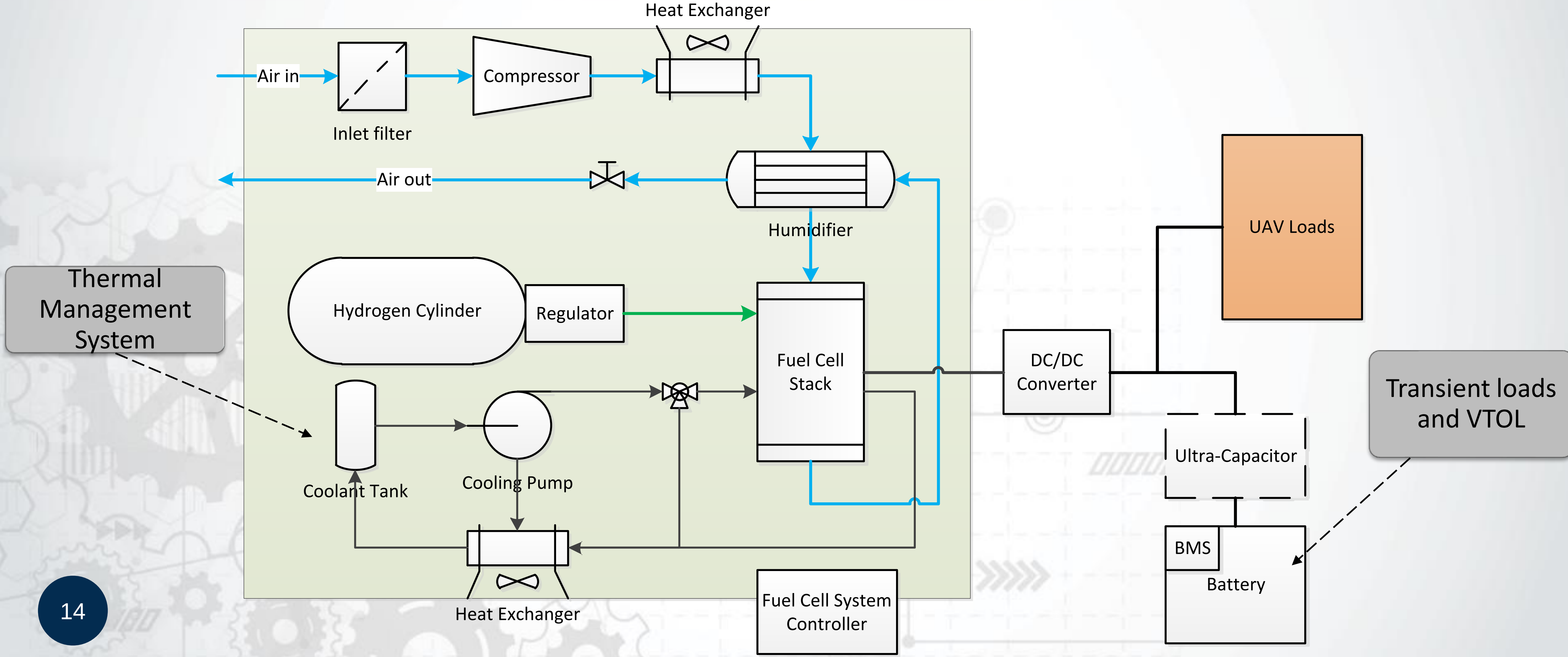
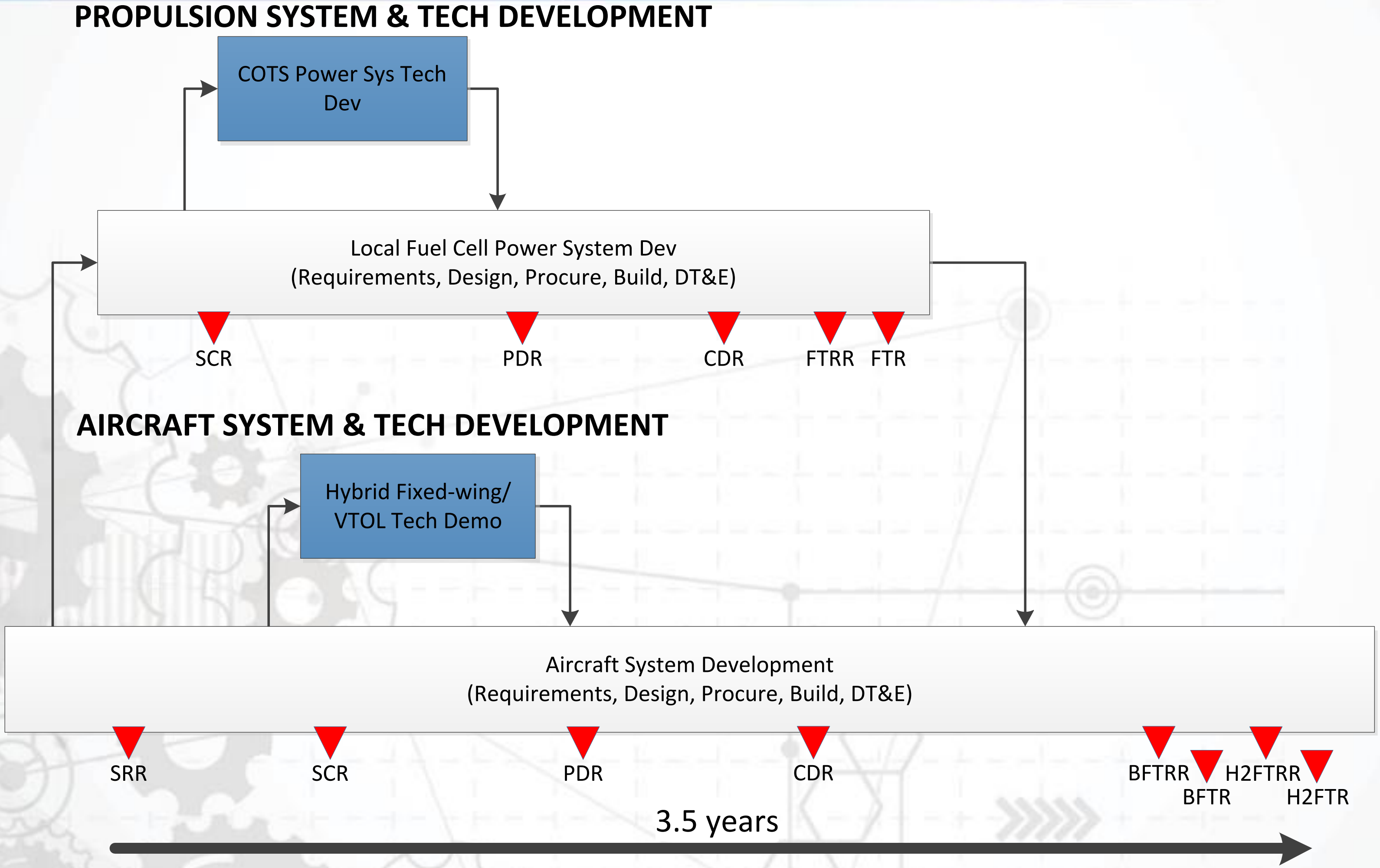
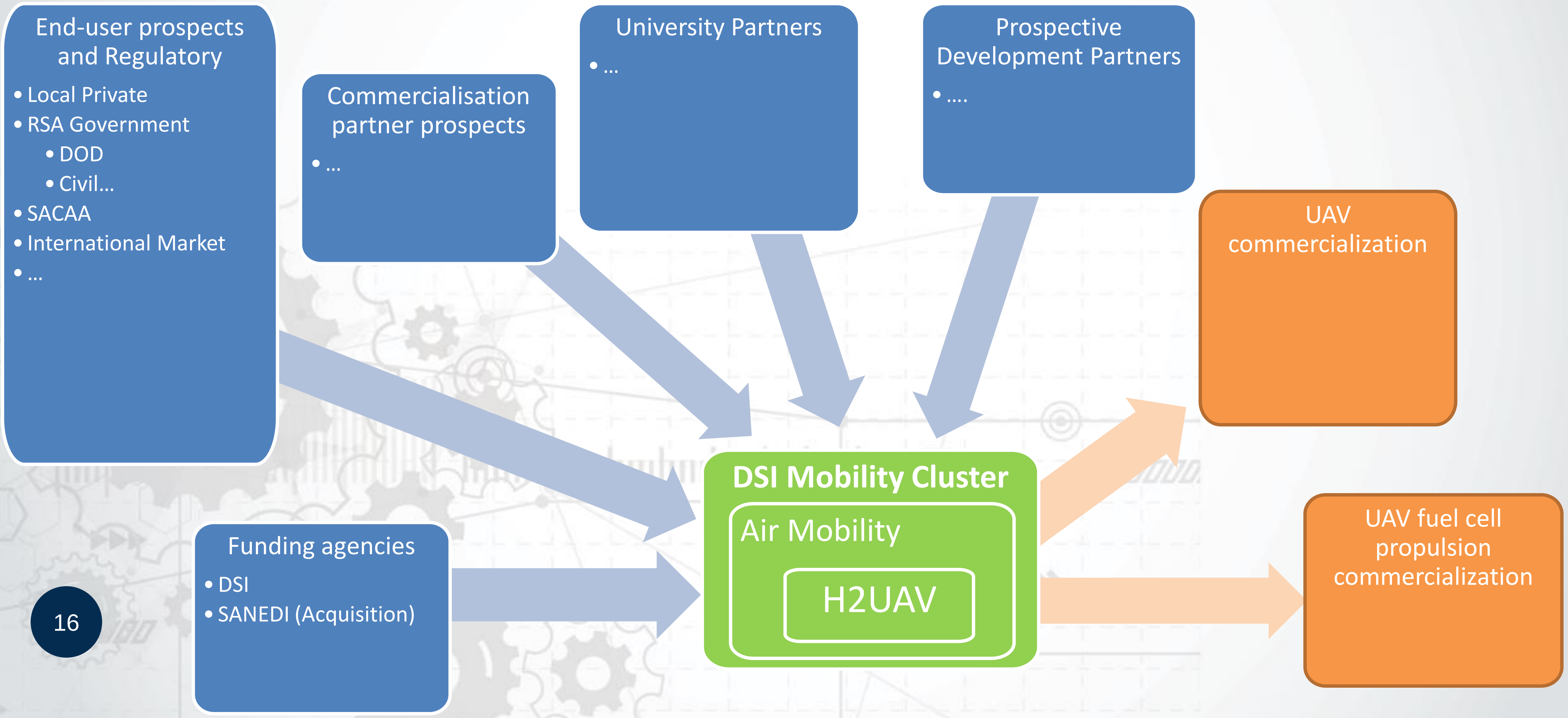


The development plan



BFTR - Battery Flight Test Report
BFTRR - Battery Flight Test Readiness Review
CDR - Critical Design Review
DT&E - Developmental Test & Evaluation
FTR - Flight Test Report
FTRR - Flight Test Readiness Review
FxW - Fixed-Wing
H2FTR - Hydrogen Flight Test Report
H2FTRR - Hydrogen Flight Test Readiness Review
PDR - Preliminary Design Review
SCR - System Concept Review
SRR - System Requirements Review
VTOL - Vertical Take-off and Landing

Key stakeholder management



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