Accelerating Technology for Sustainable Flight

Prof Carl Sangan

大家好！我叫 *Carl*。我在英国巴斯大学工作。很高兴来到西安！

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Contents:

Sustainable Propulsion

Pioneering research being conducted at IAAPS



Prof Carl Sangan

Professor of Sustainable Propulsion and Power

Fluid flows, heat transfer, rig design and instrumentation

- Director of Research (Mechanical Engineering)
- Director of Research Strategy (IAAPS)
- £8m+ industrial and research funding
- 24 PhD students, >140 peer-reviewed conference and journal publications
- ASME Fellow + winner of ASME Dilip R. Ballal award and several ASME Best Paper Awards

Propulsive Technology – *a sustainable future (?)*

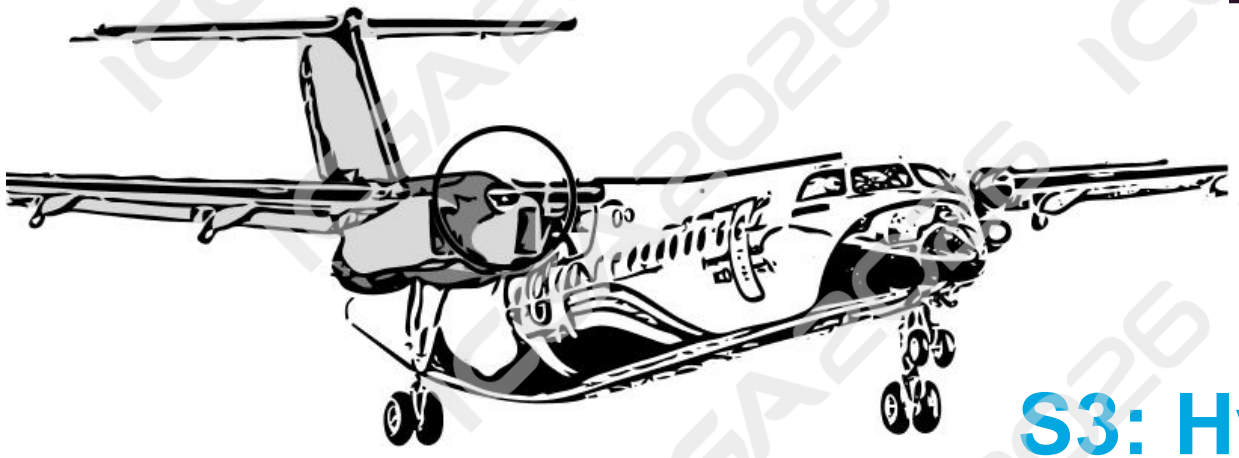


S1: Ultra-High Bypass Turbofans



S2: Urban Air Mobility





S3: Hydrogen-Electric Powertrains

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Aerospace Scenarios: Fuel of the Future?

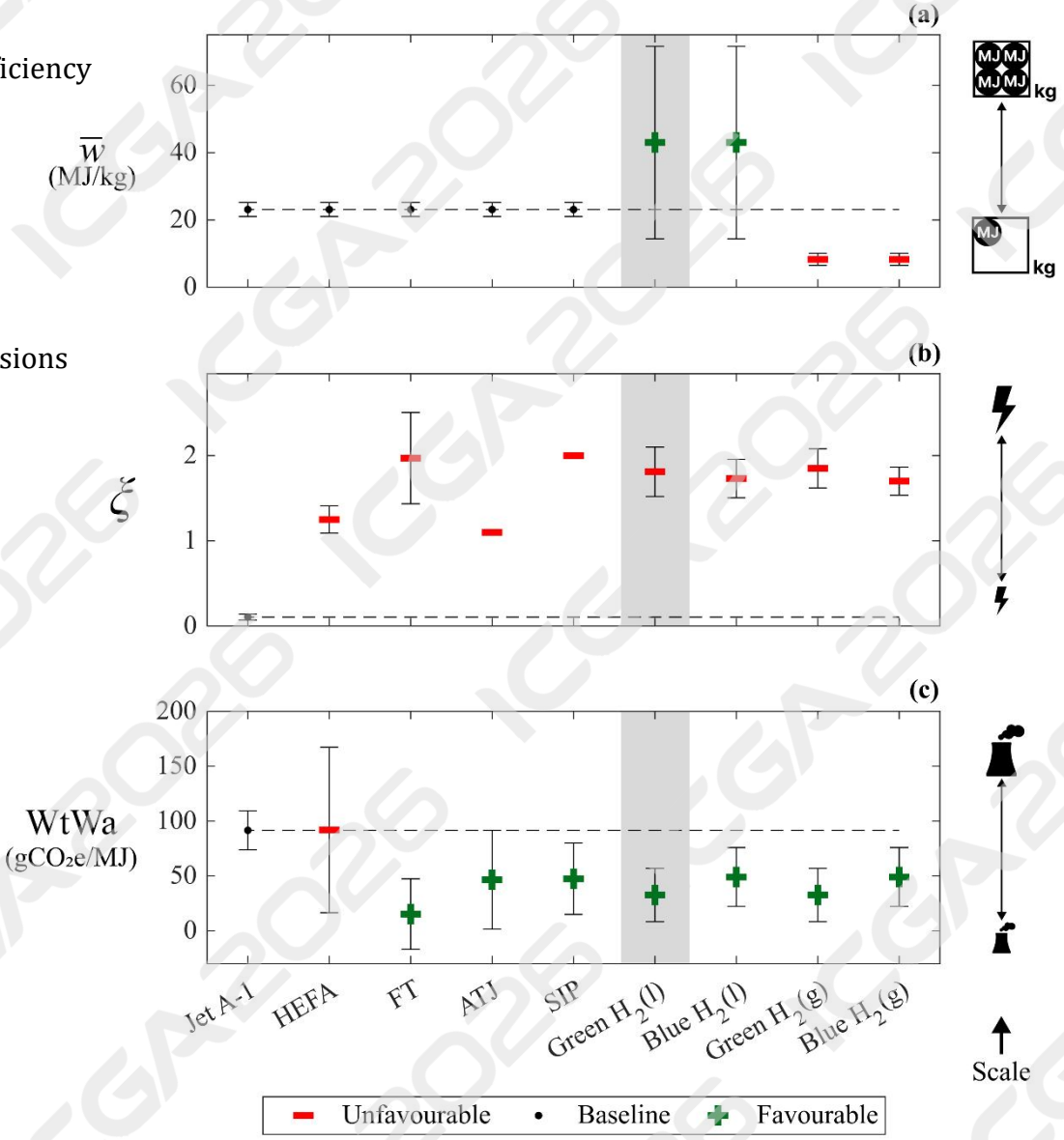
$$\bar{w} = \text{specific energy} \cdot \text{fuel: storage} \cdot \text{thermal efficiency}$$

$$\zeta = \frac{\text{Energy of Production}}{\text{Energy Output}}$$

$$\text{WtWa} = \text{Upstream} + \text{Downstream Emissions}$$

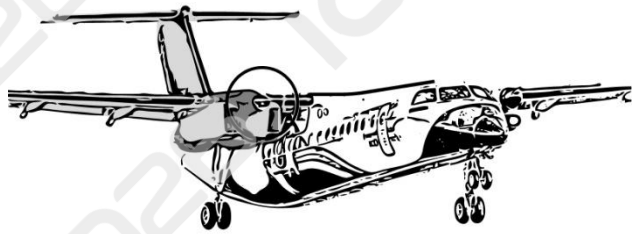


S1: Ultra-High Bypass Turbofans





S2: Urban Air Mobility



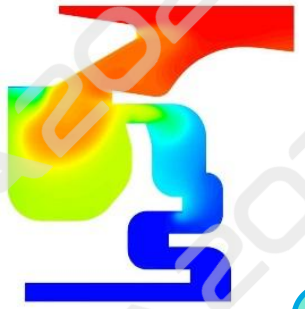
S3: Hydrogen-Electric Powertrains

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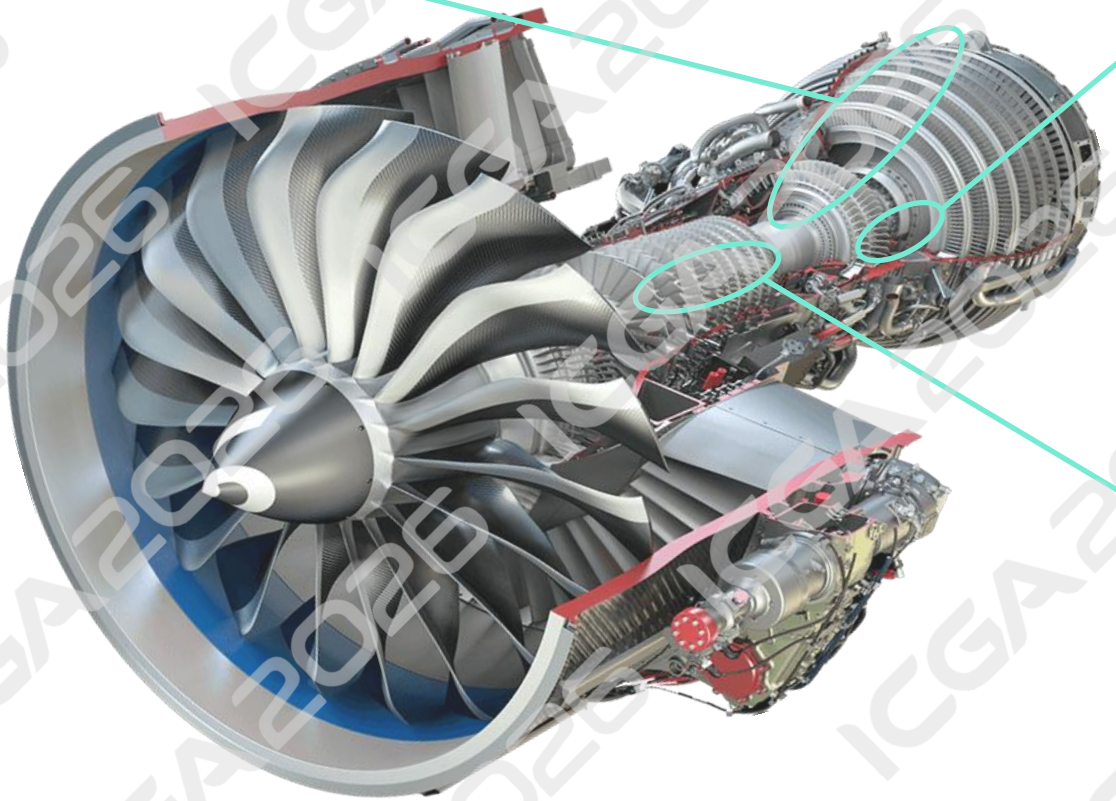
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S1: Ultra-High Bypass Turbofans

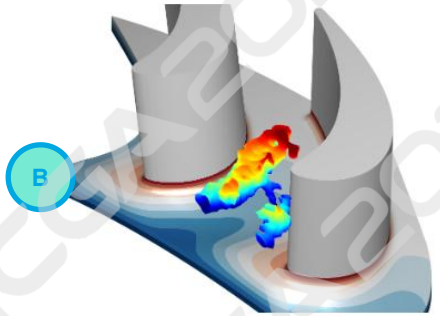
H_2-Compatible Sealing Technology



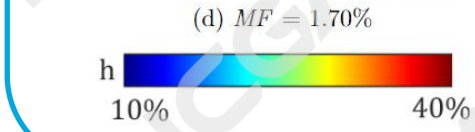
A

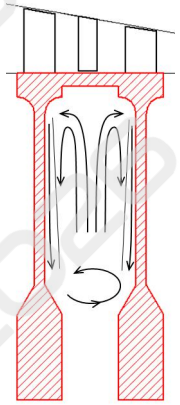


H_2-Compliant Aerodynamics



B





Core Downsizing to achieve Ultra-High Bypass Ratios

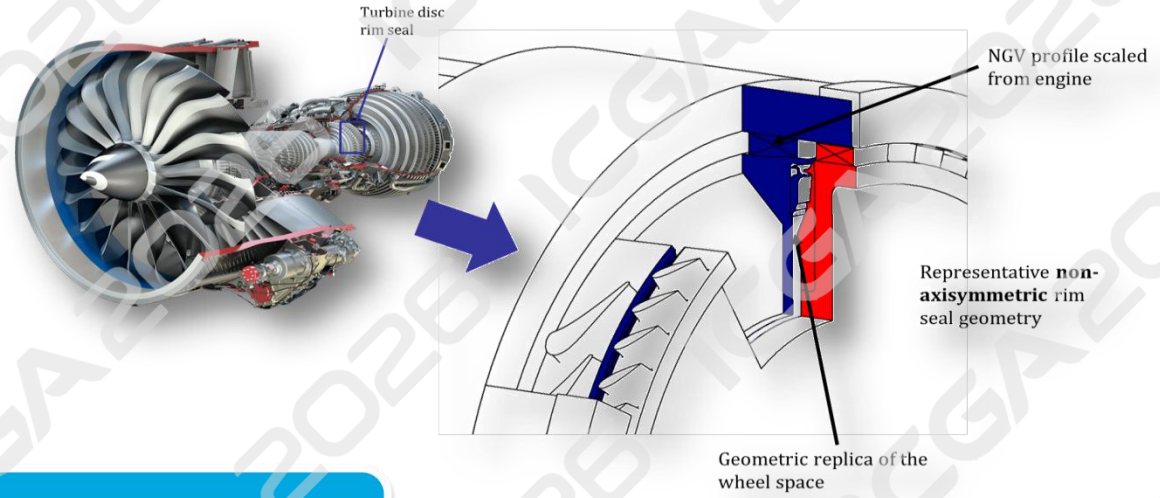
C

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S1A: Hydrogen-Compatible Sealing Technology





Design and manufacture 1.5-stage experimental facility

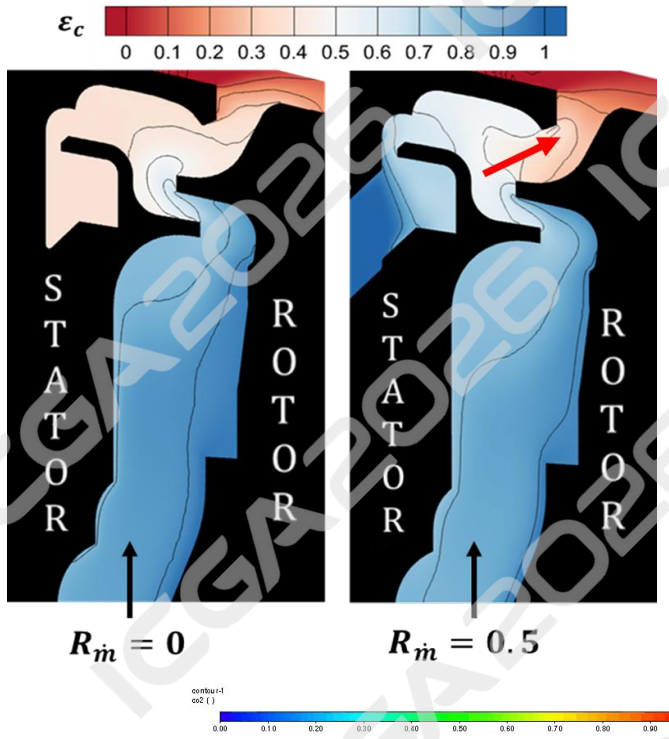
World-leading agreement between CFD and bespoke experimental measurements

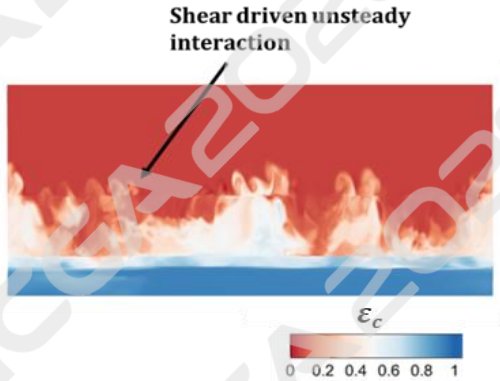


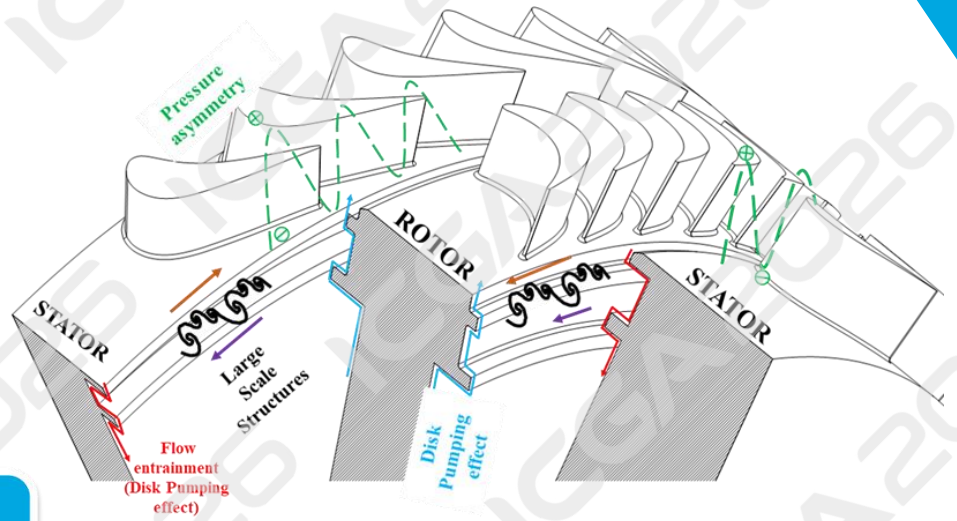
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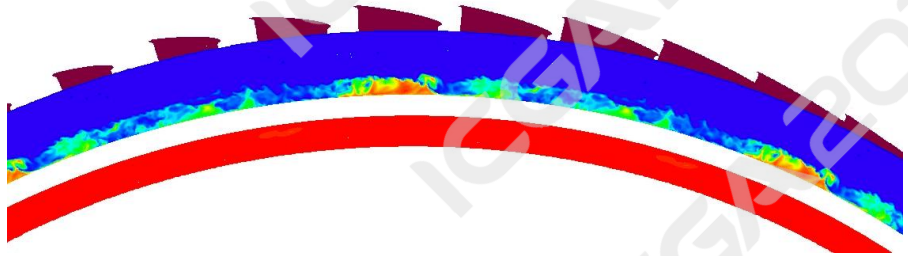
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S1A: Hydrogen-Compatible Sealing Technology









Design and manufacture 1.5-stage experimental facility

World-leading agreement between CFD and bespoke experimental measurements

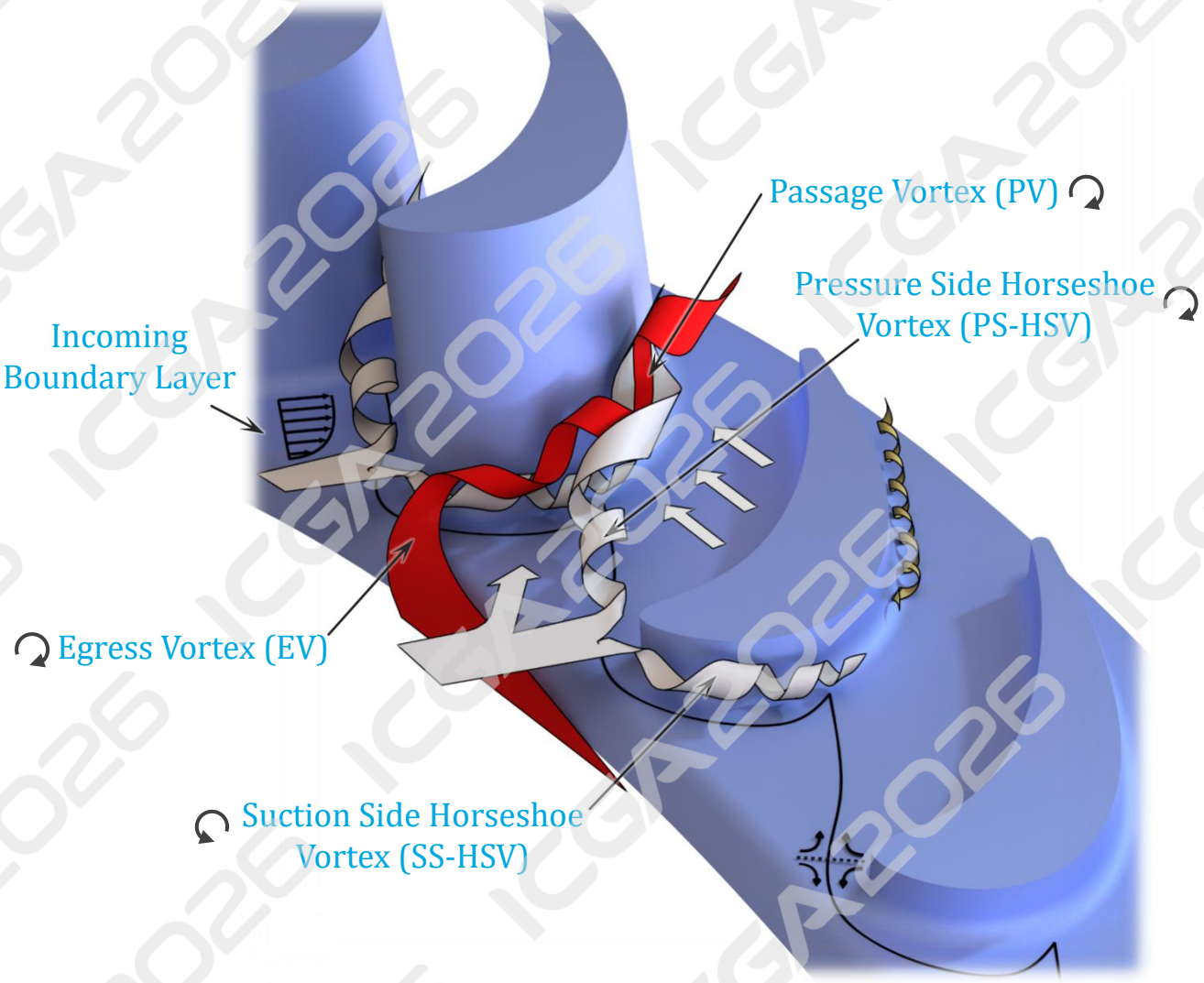


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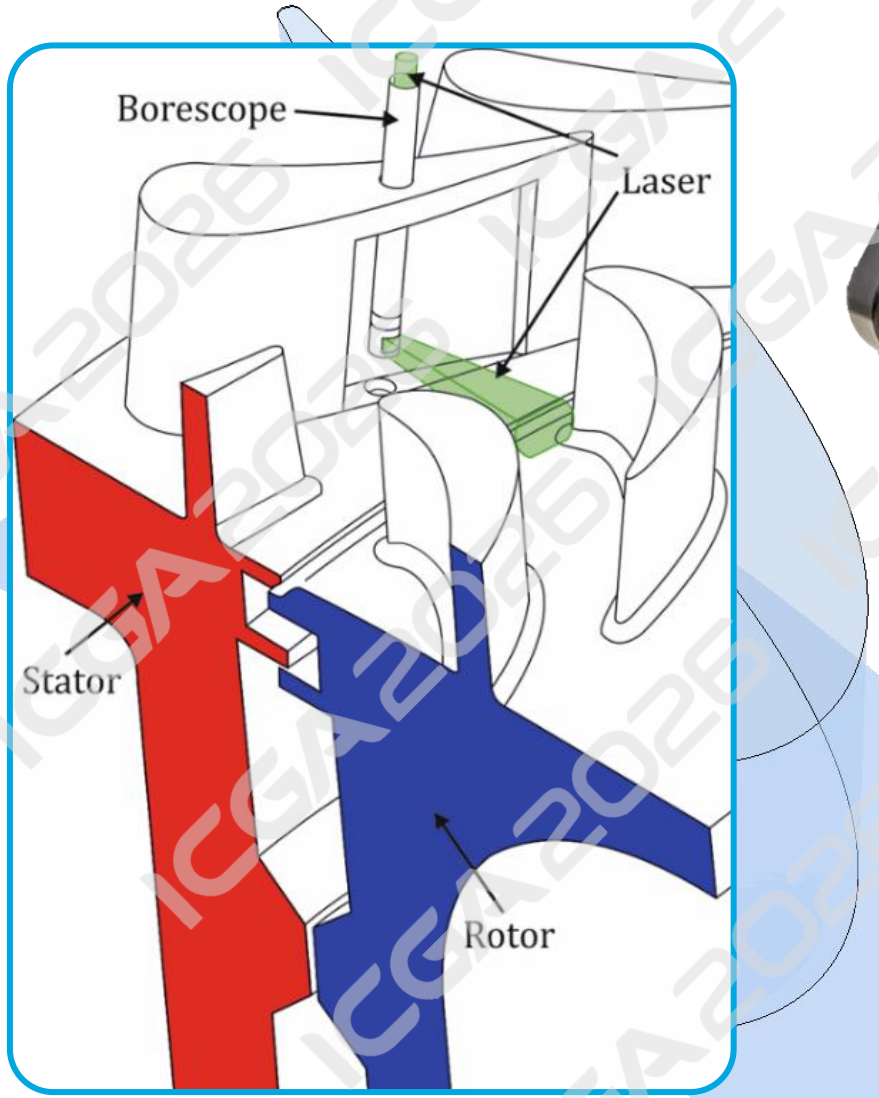
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S1B: Hydrogen-Compliant Aerodynamics

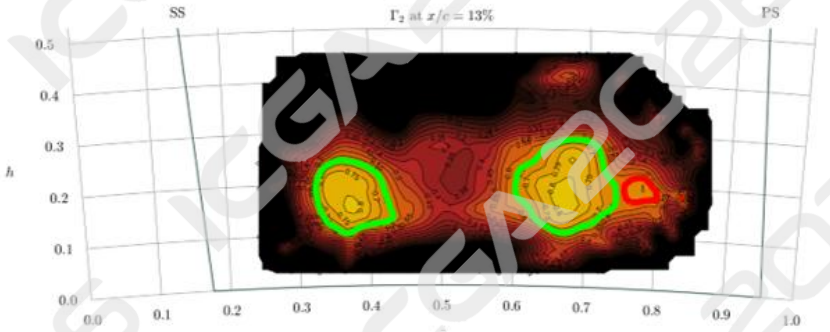


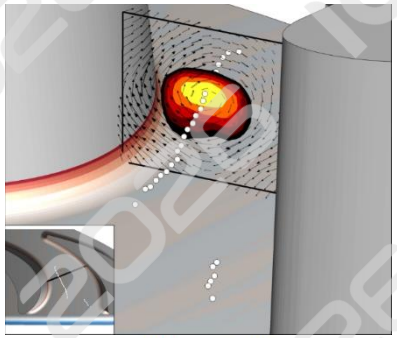


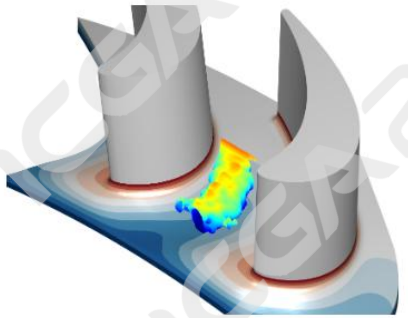
S1B: Hydrogen-Compliant Aerodynamics



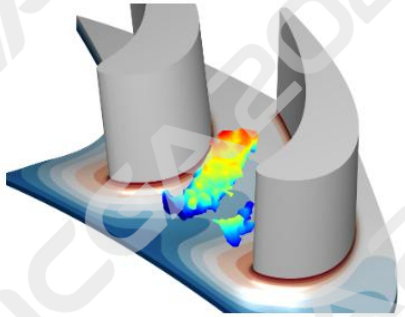


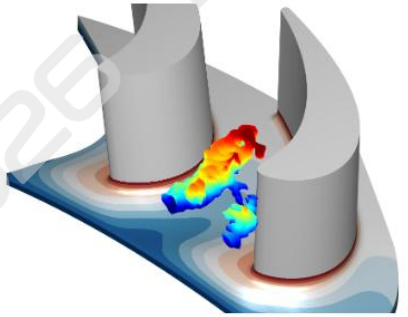




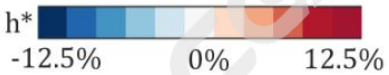


(a) $MF = 0.00\%$ (b) $MF = 0.26\%$



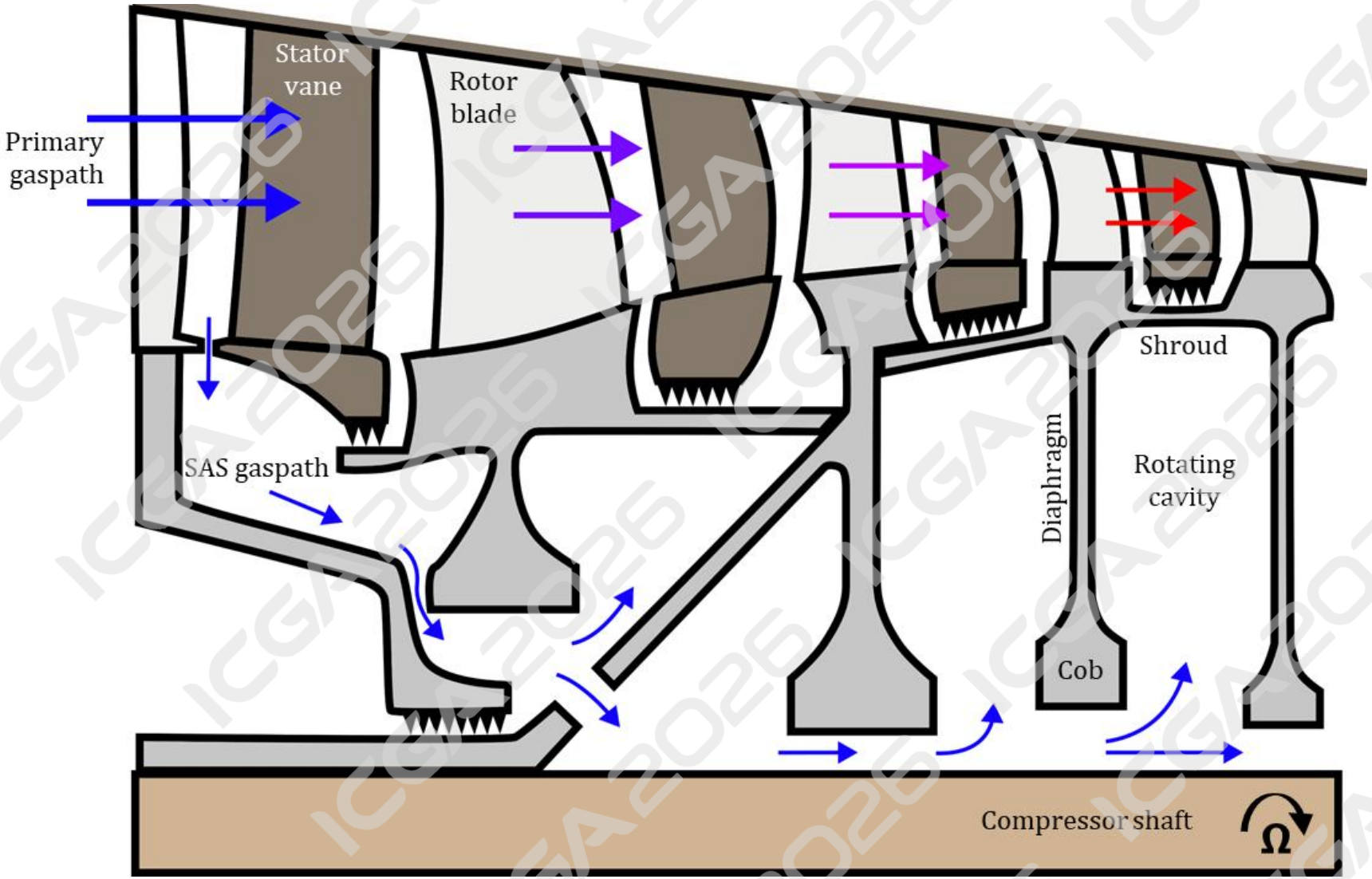


(c) $MF = 0.85\%$ (d) $MF = 1.70\%$



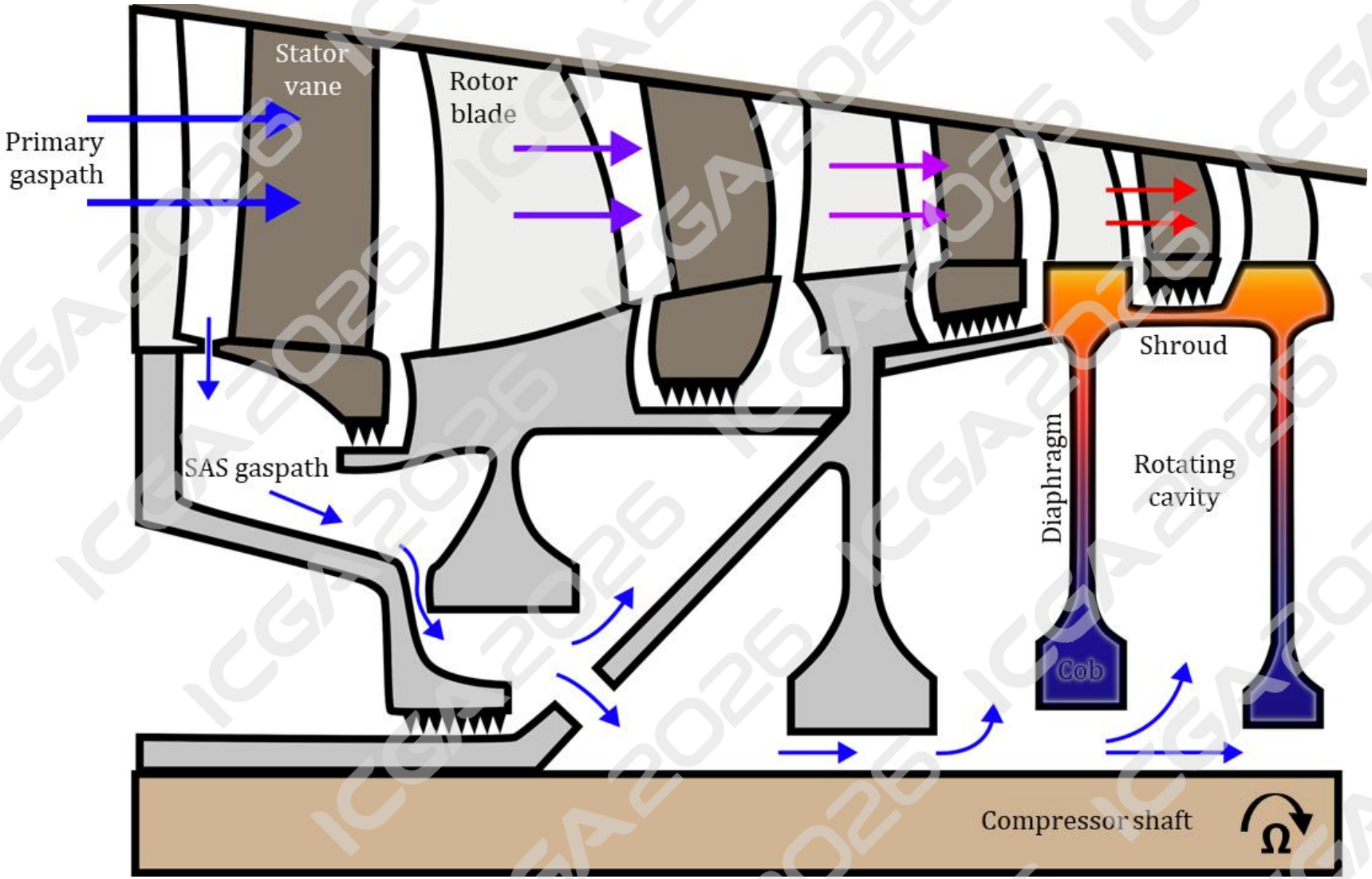


S1C: Core Downsizing to achieve Ultra-High BPRs



Temperature difference between annulus flow and cooling flow

S1C: Core Downsizing to achieve Ultra-High BPRs



Temperature difference between annulus flow and cooling flow

⇩

Temperature gradient on rotor discs

⇕

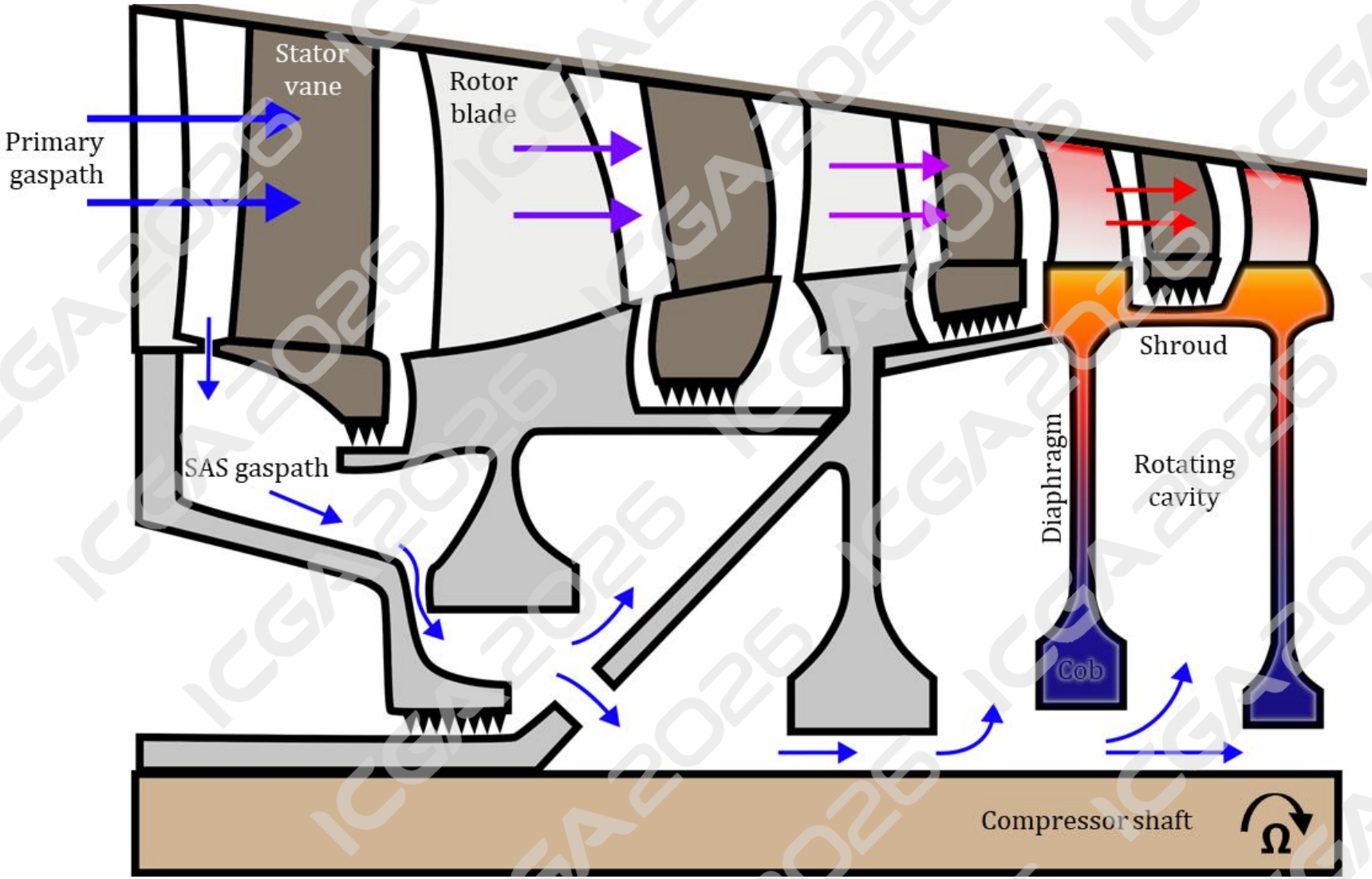
Buoyancy-induced flow

Conjugate heat transfer in the cavity core and rotor discs

⇩

Thermal growth

S1C: Core Downsizing to achieve Ultra-High BPRs



Temperature difference between annulus flow and cooling flow

⇩

Temperature gradient on rotor discs

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Buoyancy-induced flow

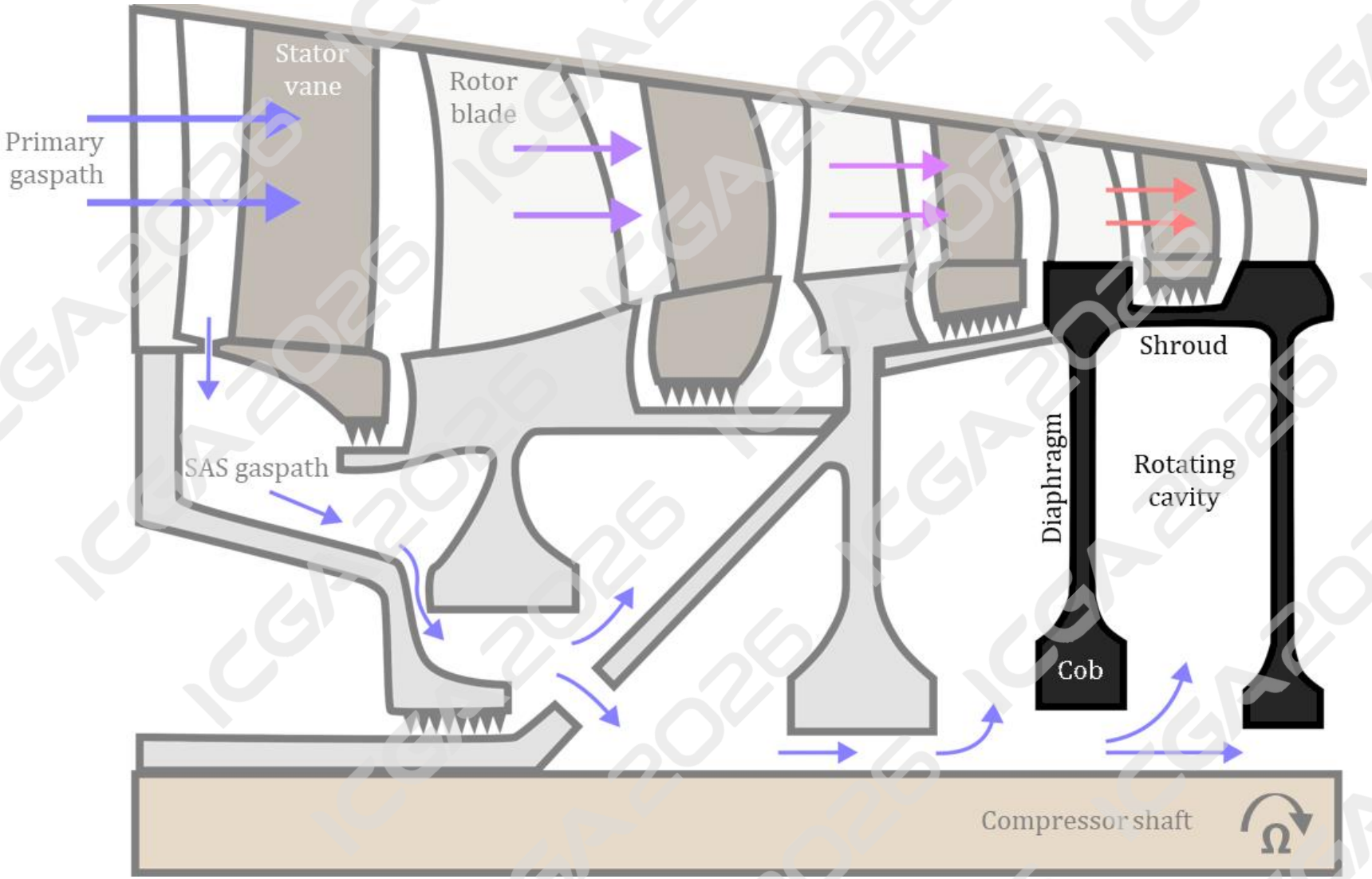
Conjugate heat transfer in the cavity core and rotor discs

⇩

Thermal growth

Tip clearance

S1C: Core Downsizing to achieve Ultra-High BPRs



Temperature difference between annulus flow and cooling flow

⇩

Temperature gradient on rotor discs

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Buoyancy-induced flow

Conjugate heat transfer in the cavity core and rotor discs

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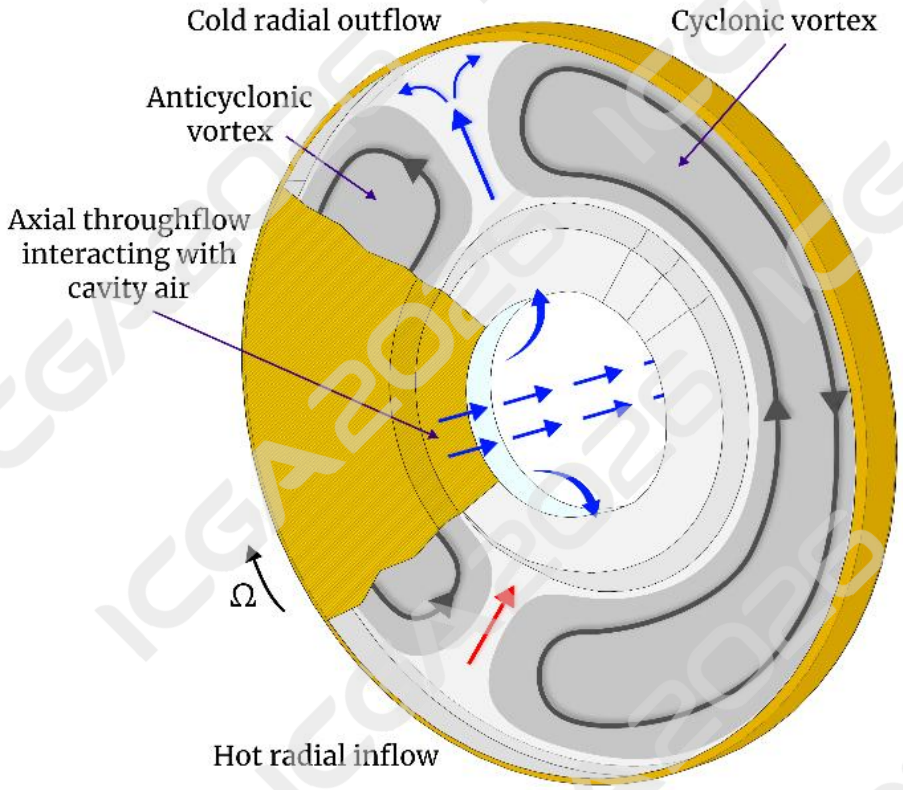
Thermal growth

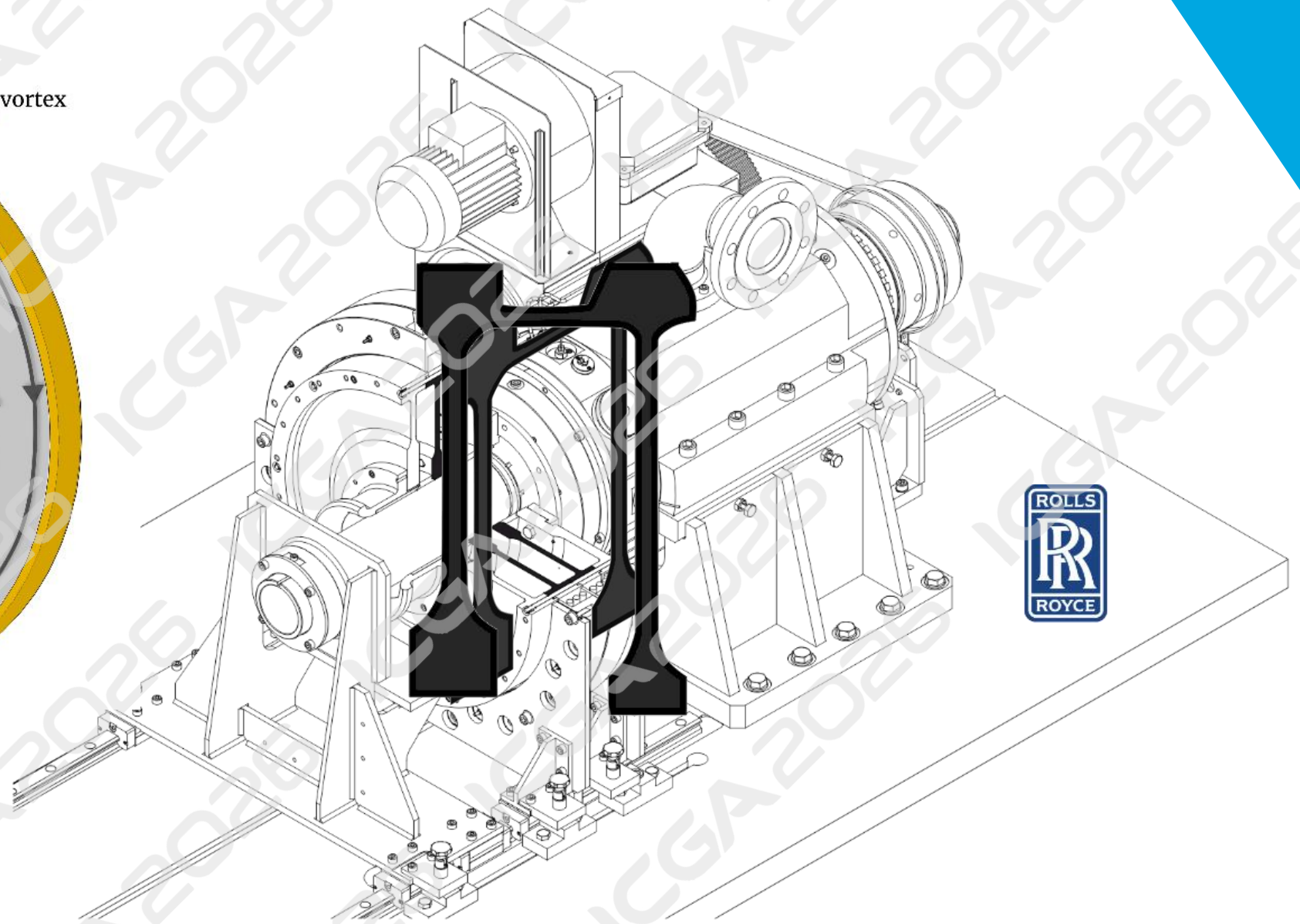
Tip clearance

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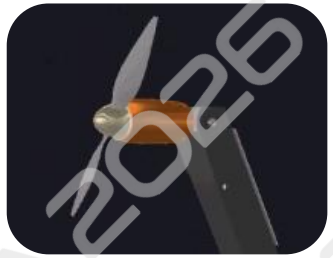
S1C: Core Downsizing to achieve Ultra-High BPRs





S2: Urban Air Mobility

Aerodynamics of Dynamic Transition



A

Optimisation of Proprotors for Performance and Noise



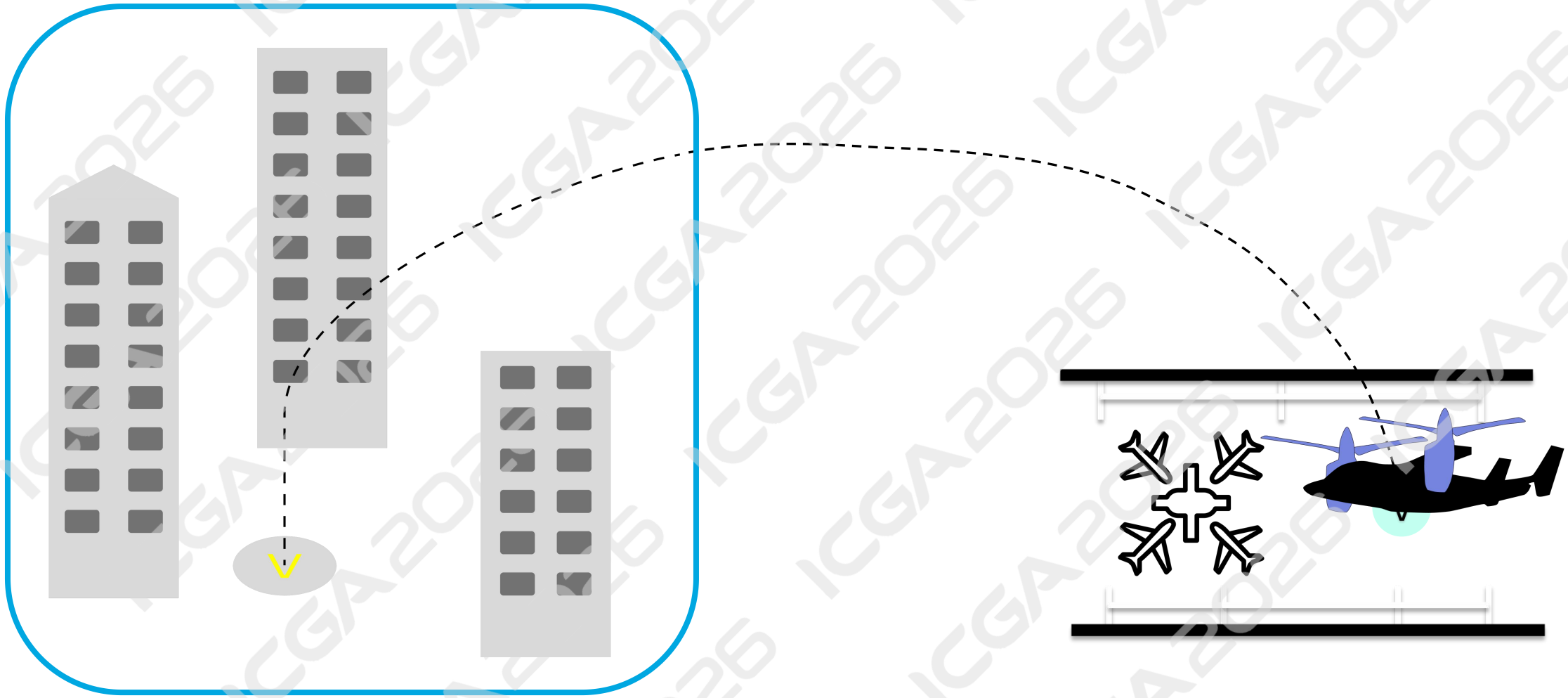
B



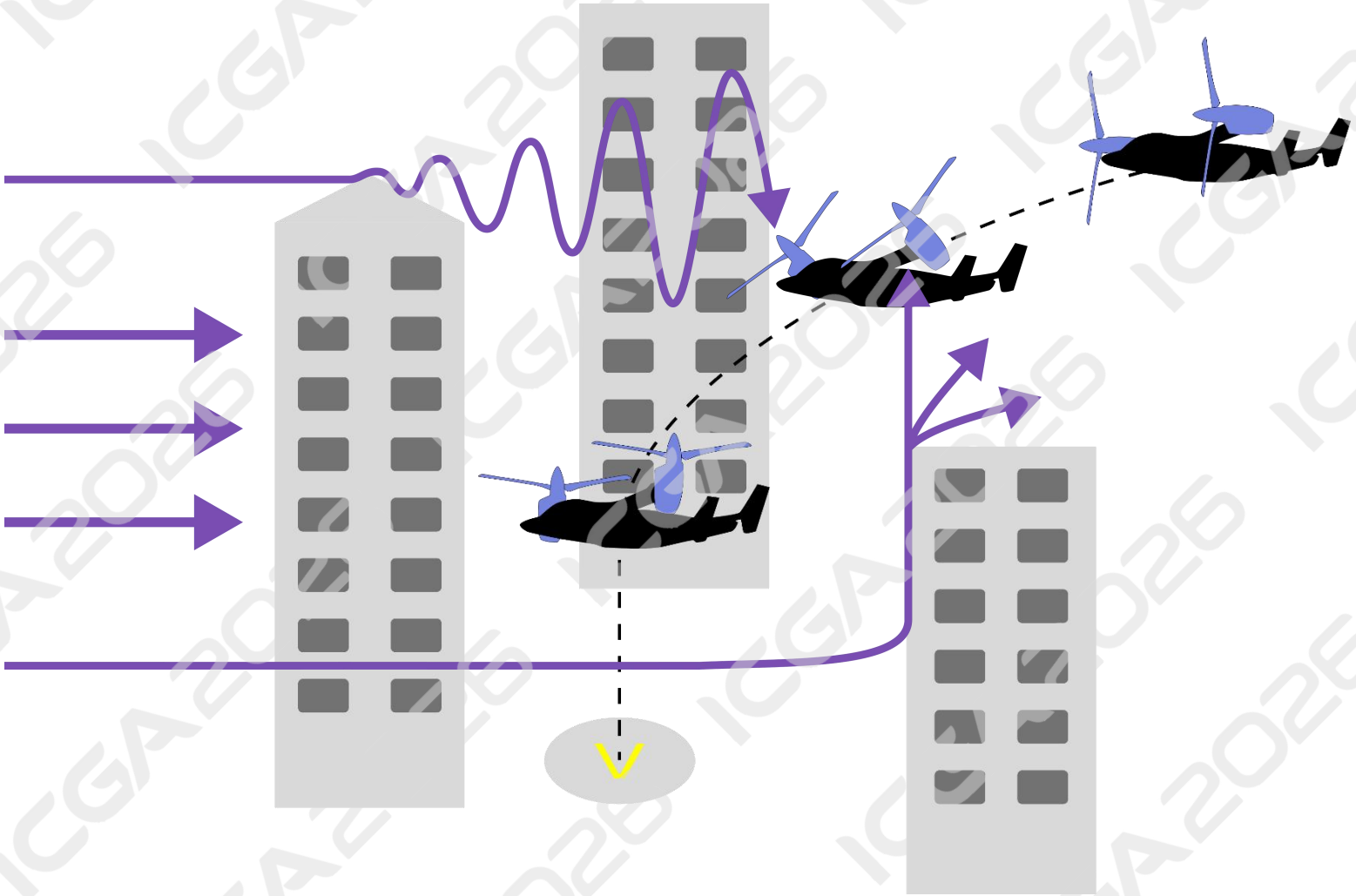
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S2: Urban Air Mobility

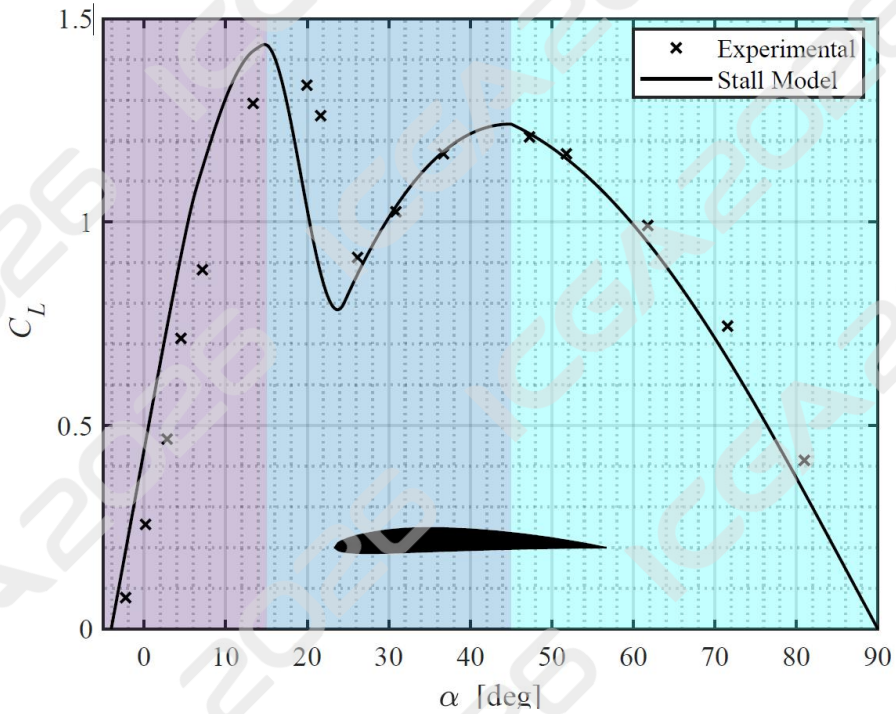


S2: Urban Air Mobility



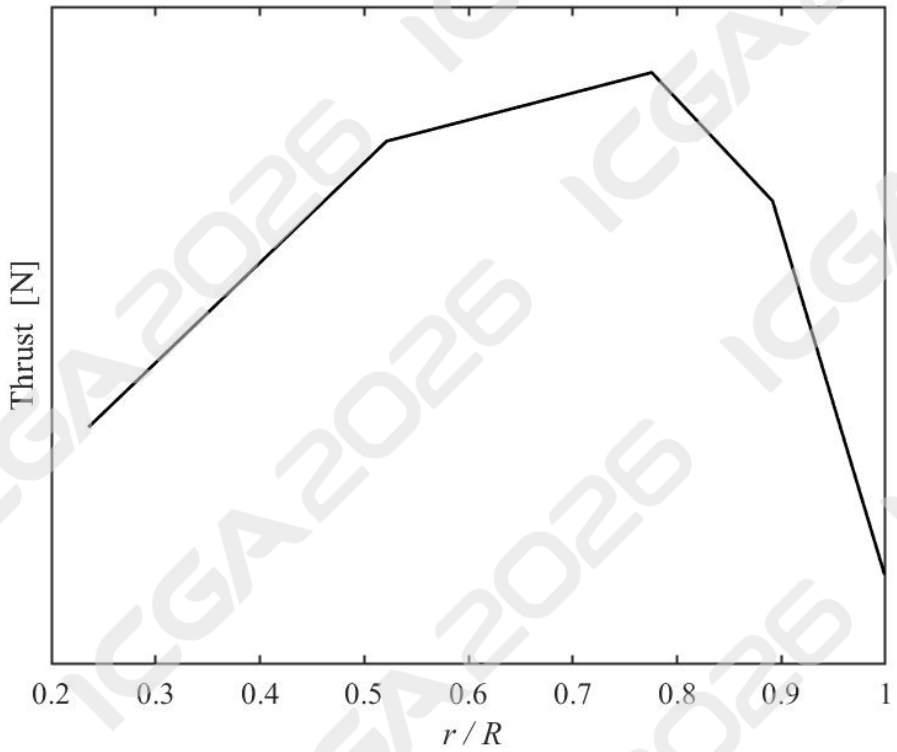
S2A: Aerodynamics of Dynamic Transition





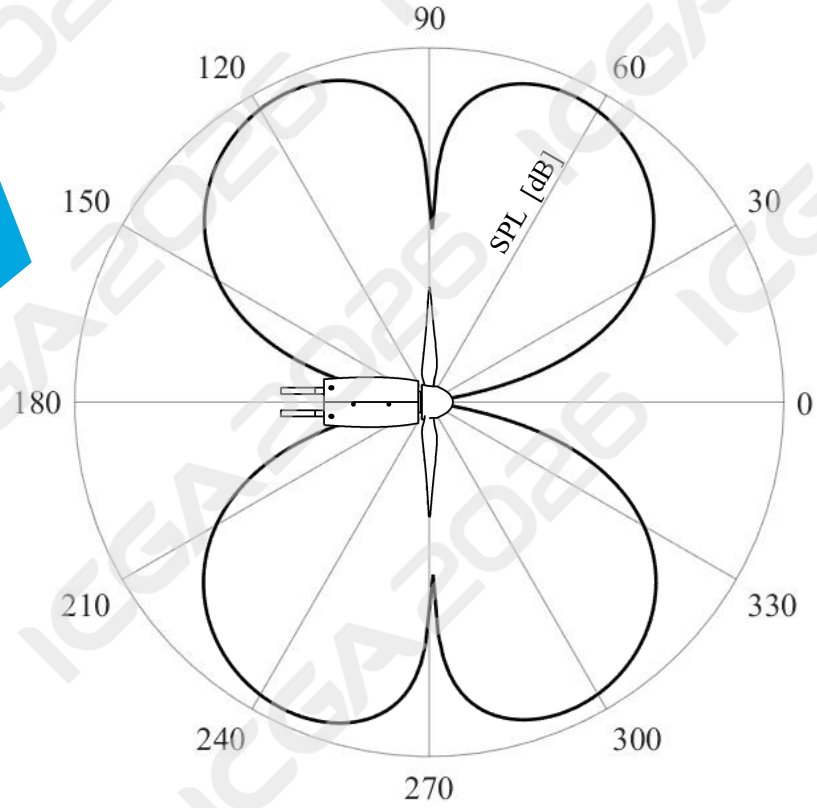
Bath University Low-speed eVTOL Experimental Test-rig (BULLET)

S2B: Optimisation of Proprotors





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BEMT & Aeroacoustics:

- *Optimised proprotors for performance and noise*
- *Numerical simulation and experimental campaigns*

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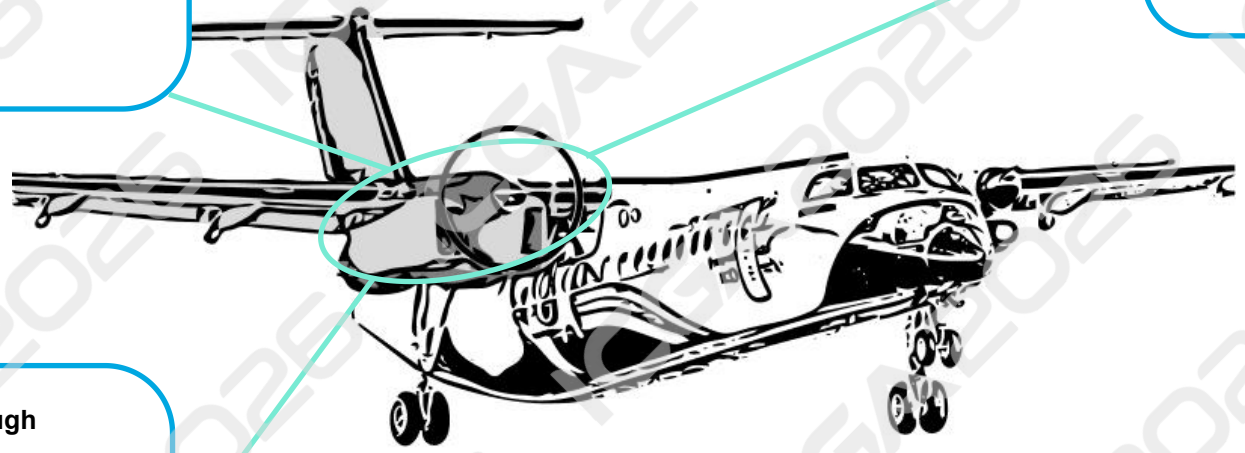
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S3: Hydrogen-Electric Powertrains

Powertrain-Airframe Integration



A



Hydrogen Fuel Systems

C

Cooling Technology through Additive Manufacture

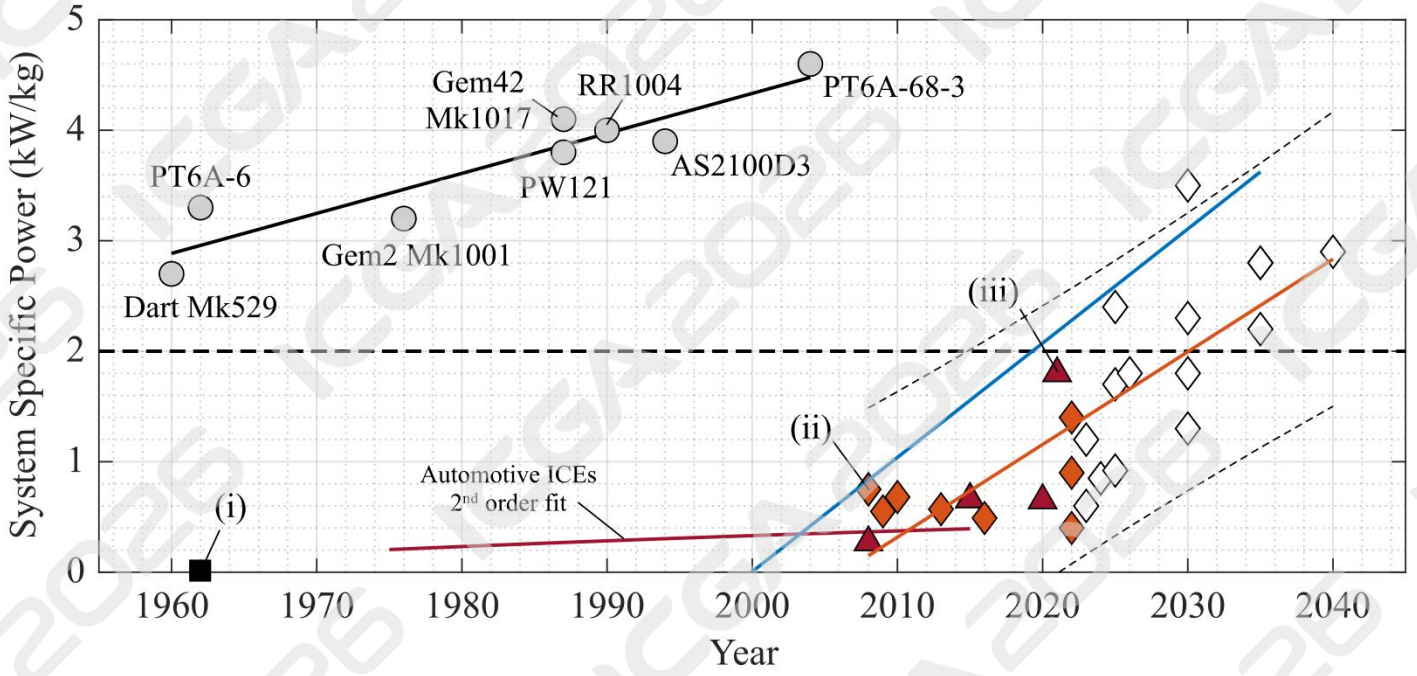


B

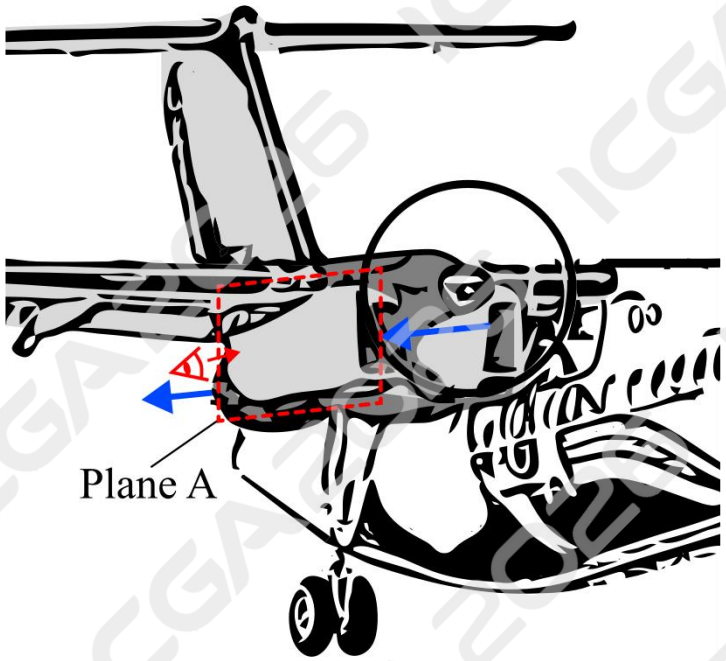
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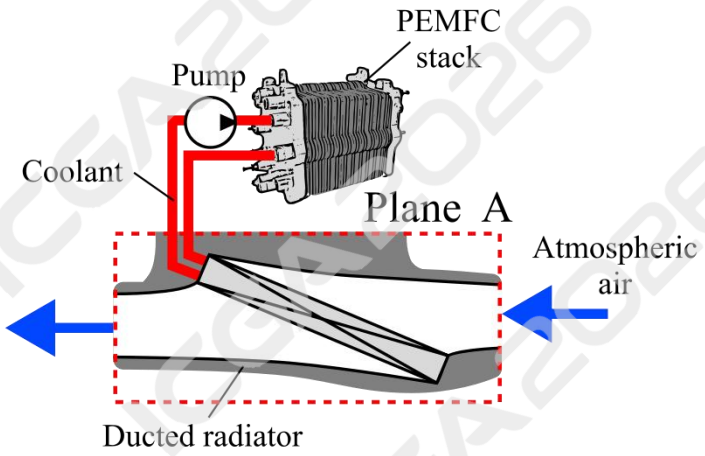
S3A: Powertrain-Airframe Integration



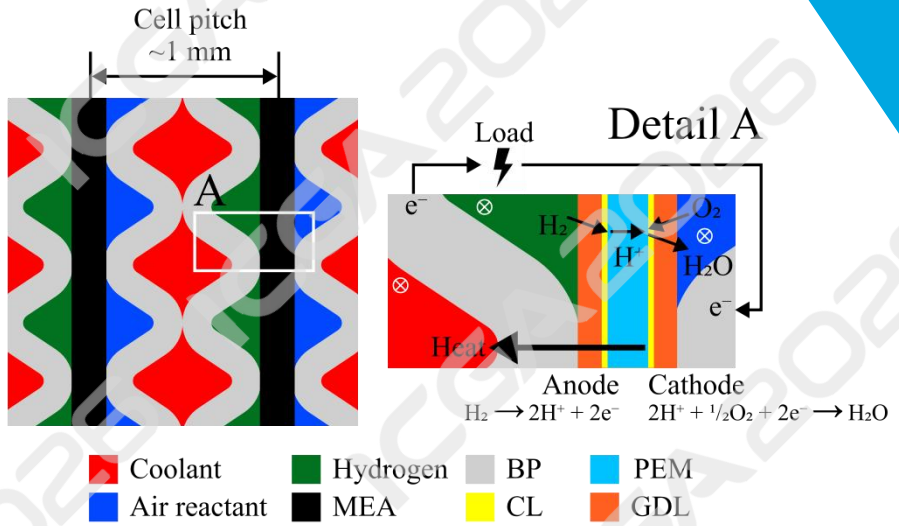
S3A: Powertrain-Airframe Integration



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Fuel Cell Design:

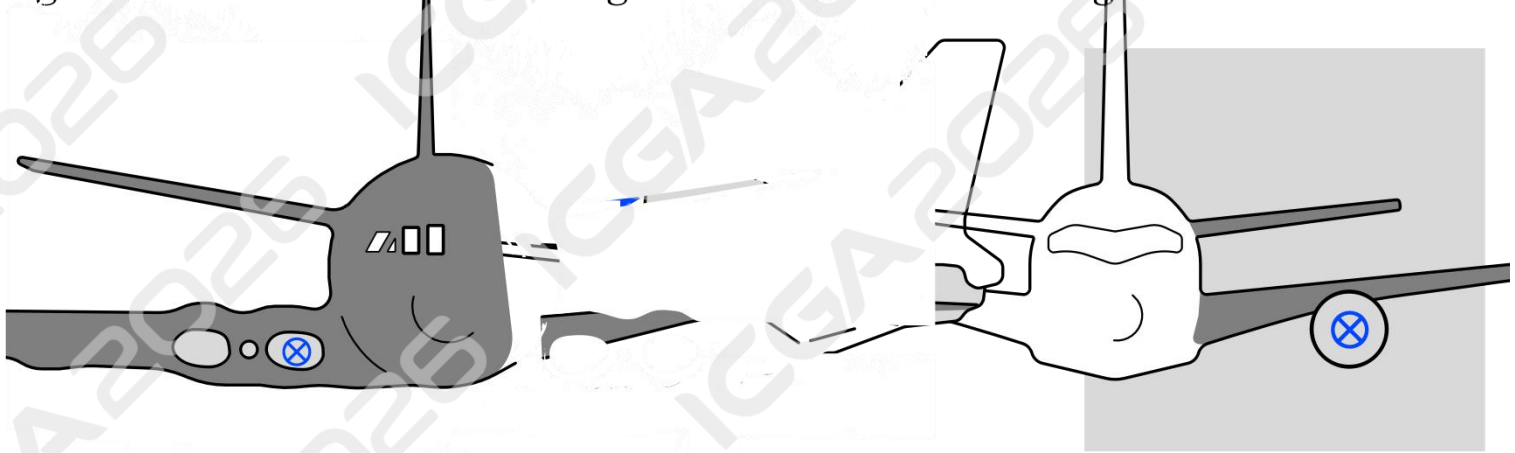


Installation Architecture:

(a) Buried at the wing root
e.g. de Havilland Comet

(b) Fuselage duct
e.g. Lockheed L-1011

(c) Pod beneath the wing
e.g. A320neo

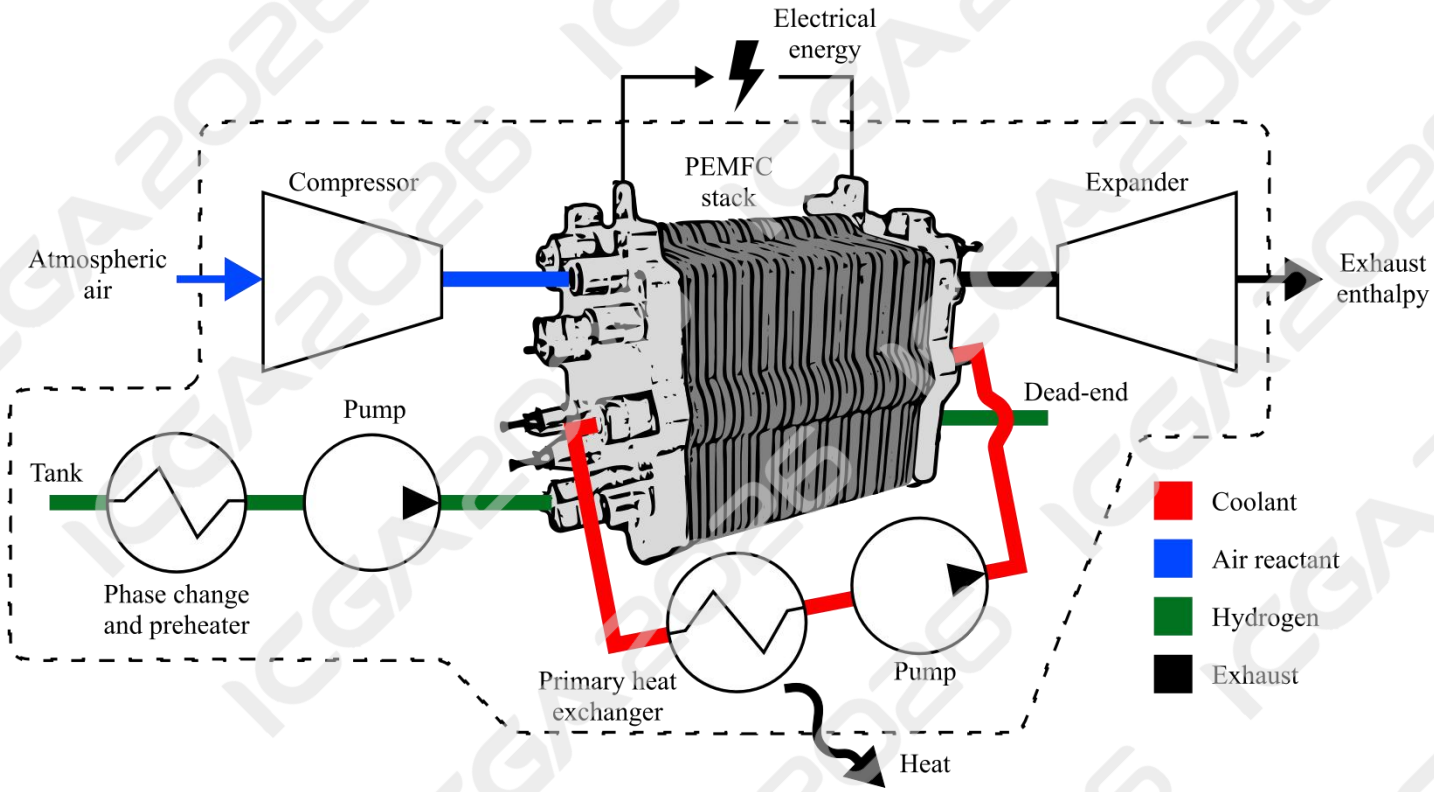


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S3A: Powertrain-Airframe Integration

Fuel Cell System Modelling:





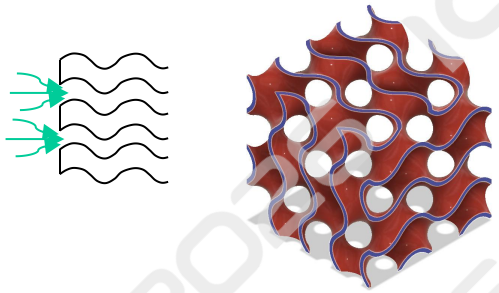
Effect on Aircraft Drag Polar



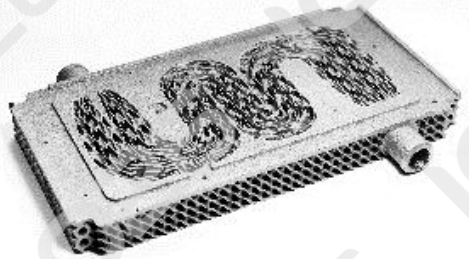
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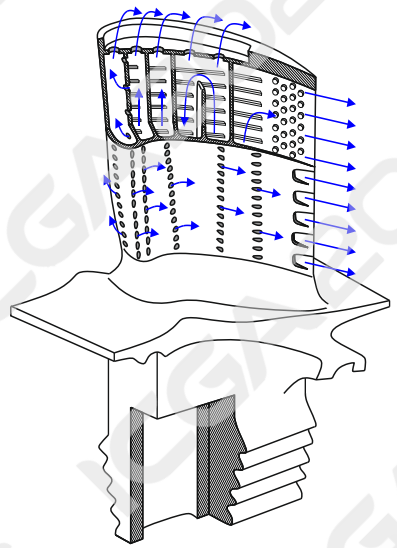
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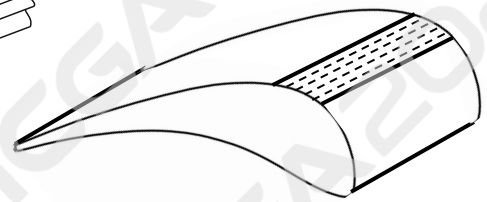
S3B: Cooling Technology through AM



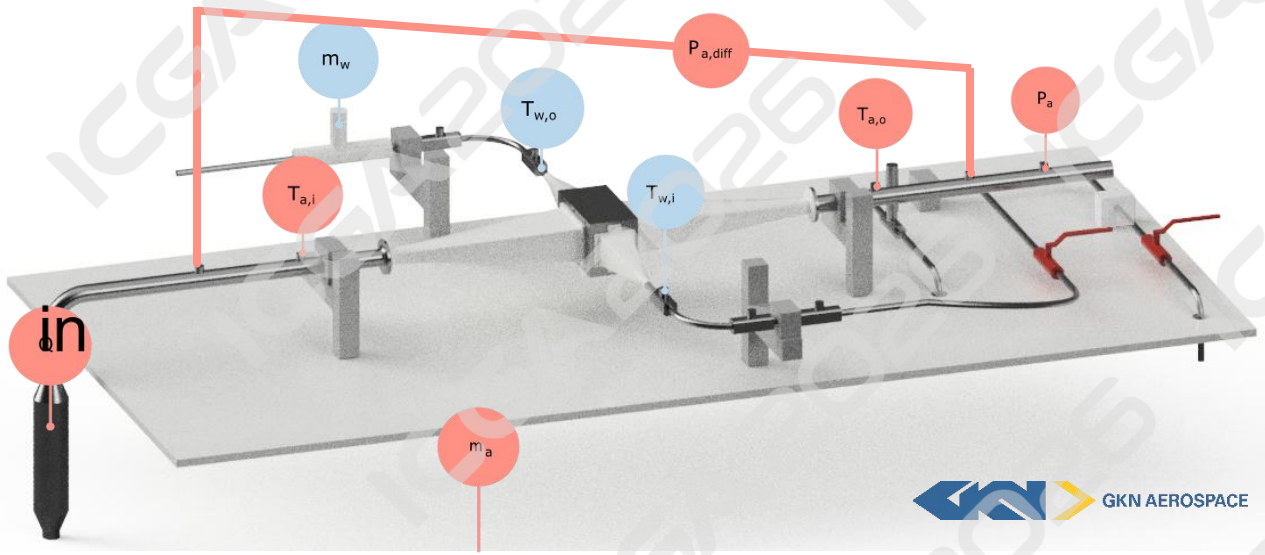
- Triply Periodic Minimal Surfaces are mathematically derived lattices
- They divide the volume into two sub-volumes separated by a wall
- They can only be produced by additive manufacturing







Conceptual Fuel Stack Cooling…*and beyond!*





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S3C: Hydrogen Fuel Systems



LH2 Pumping Technology

Storage
Fully integrated, flight worthy tank with innovative embedded fuel and health management

Conveyance
Develop composite/ metallic cryogenic pipe assemblies with integrated leak prevention & detection

Fueling
Work with airports, airlines & infrastructure partners to holistically satisfy hydrogen re/defuel requirements including turnaround time

HYFIVE

Indication
Develop a suit of embedded sensing technologies and integrated fuel management software

Venting
Design maturity for operational and abnormal conditions requiring hydrogen venting

MARSHALL
GKN AEROSPACE
Parker MEGGITT
MANCHESTER 1824 The University of Manchester
UNIVERSITY OF BATH
CARDIFF UNIVERSITY

£40m+

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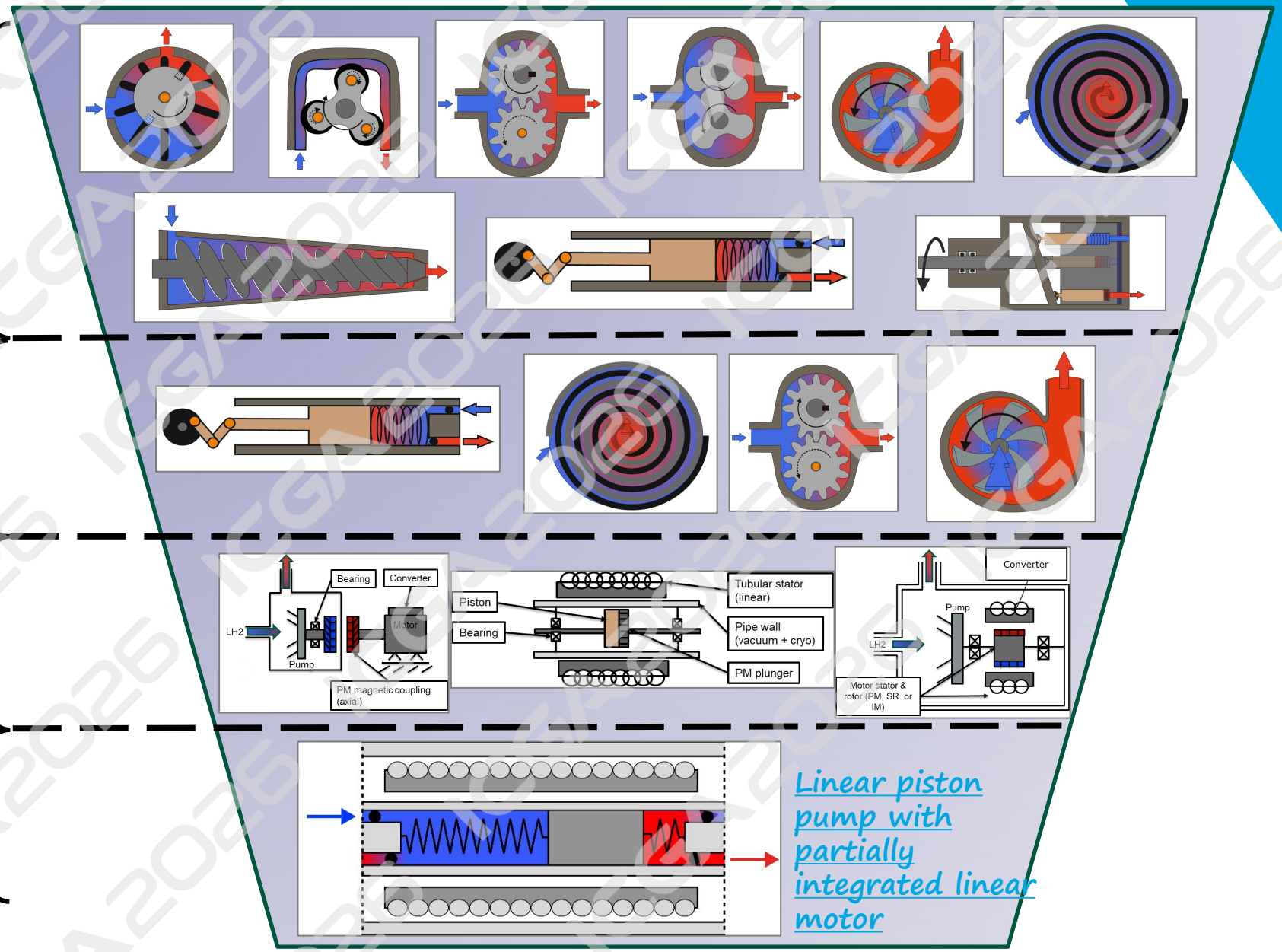
S3C: Hydrogen Fuel Systems

Review of varying pump **architectures** and their applications

Preliminary sizing of the most suitable candidates

Selection of **motor topologies and interfaces**

Final pump and configuration selection and specific design optimisation



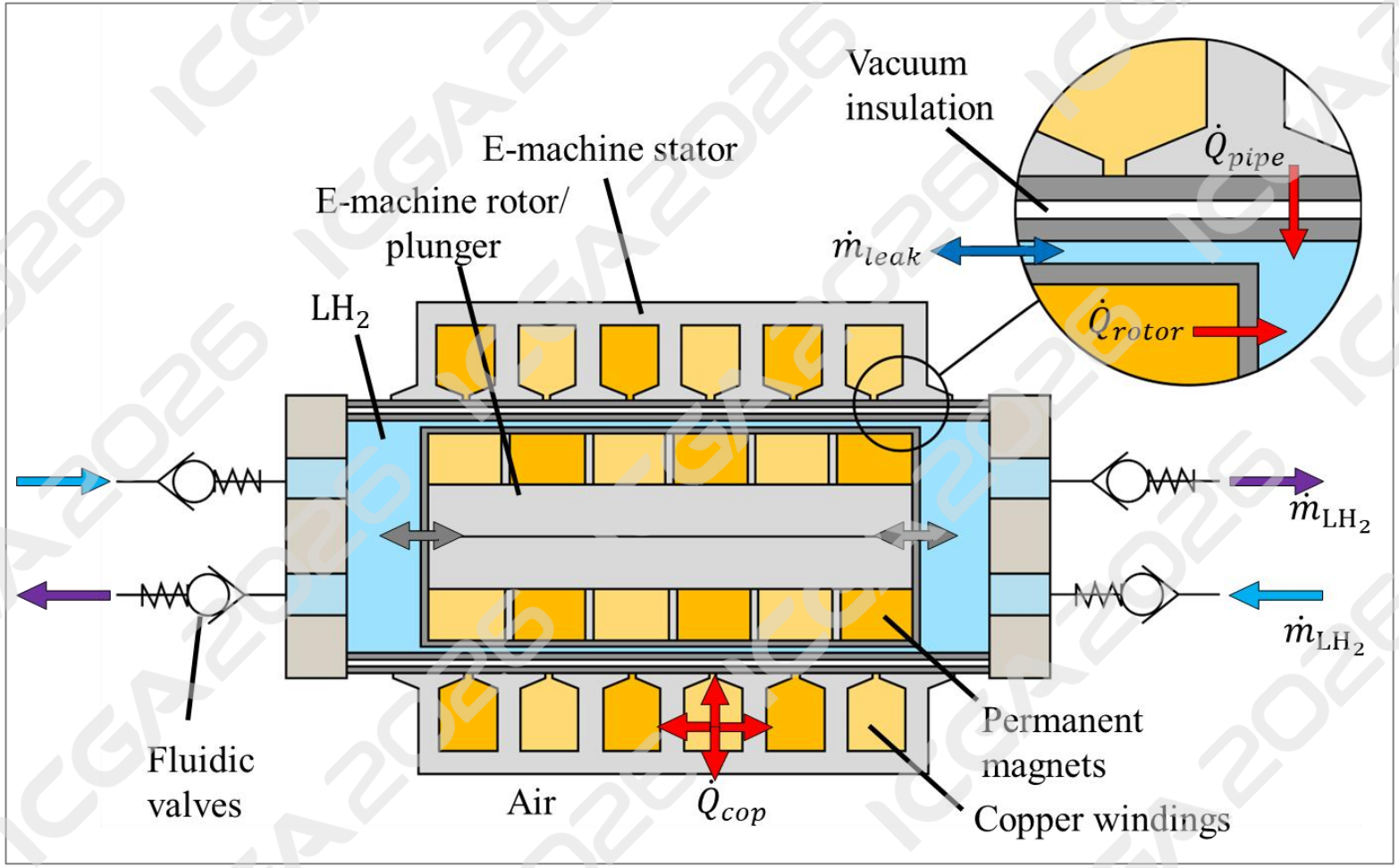
[Linear piston pump with partially integrated linear motor]

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S3C: Hydrogen Fuel Systems

Linear piston pump with partially-integrated linear motor



Propulsive Technology – *a sustainable future (?)*

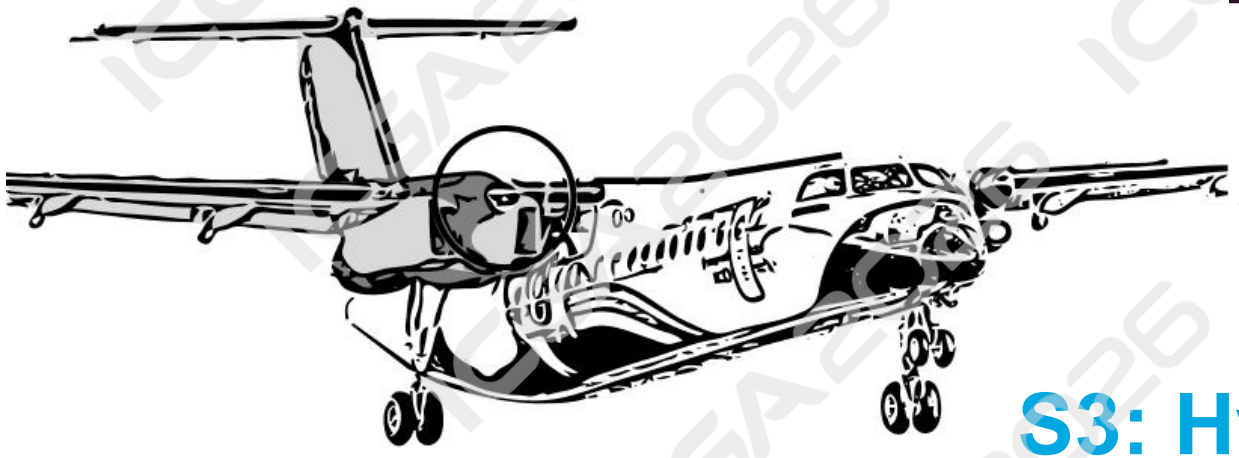


S1: Ultra-High Bypass Turbofans



S2: Urban Air Mobility





S3: Hydrogen-Electric Powertrains

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With thanks to our funders













EU
Clean Sky II









Engineering and
Physical Sciences
Research Council



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