



42nd Annual Student Design Competition

Pioneering Hydrogen- Electric VTOL



Politecnico
di Torino

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**Politecnico
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DIMEAS

**Department of Aerospace Engineering
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To the Vertical Flight Society:

The members of Politecnico di Torino, ZEFIRO graduate student Team, hereby grant VFS full permission to distribute the enclosed Executive Summary and Final Proposal for the 42nd Annual Design Competition as they see fit.

Thank you,

The ZEFIRO Team

RED Ferraris: VTOL Hydrogen Aircraft

Aviation evolved rapidly during the last century, from wooden plane to space flight and Vertical Take Off and Landing (VTOL) aircrafts.

Nowadays hydrogen-propulsion aims to revolutionize aircraft industry, by allowing great performance at low emission impact.

RED Ferraris main objectives are to allow **eco-friendly** transportation and to push the **development** of an unprecedented mode of **transportation**. RED Ferraris due to his **electric-VTOL** abilities, will surely challenge currently available configurations, like helicopters.



“Every great breakthrough starts with someone brave enough to dream differently”

RED Ferraris: Conceptual design

Thrust vectoring,
double wing
architecture



Considered configurations



Distributed
Propulsion



Ducted
Propeller

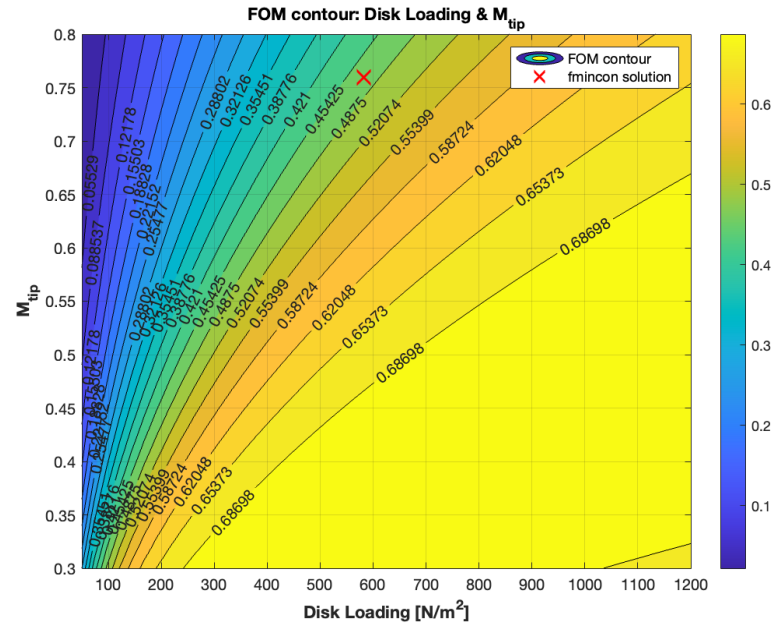


Requirements and constrains:

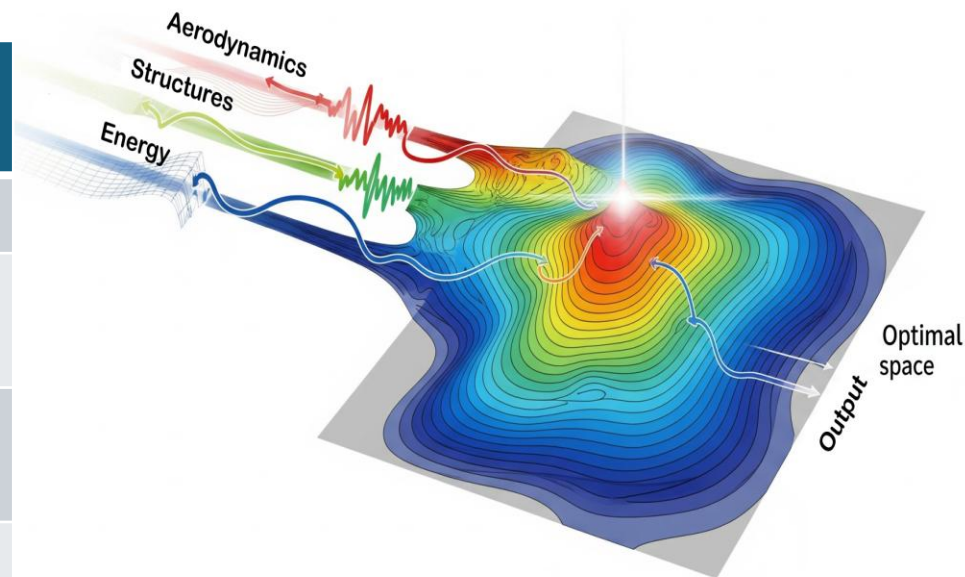
- PEM fuel cell powered
- 2 people and luggage
- Max envelope 10x10x4 m
- Min cabin floor 1.25x1.5 m

RED Ferraris: MDO

Integrating aerodynamics, propulsion, structural sizing and energy management MDO has allowed the transformation of qualitative trade-offs into **quantitative engineering objectives**, providing insights into which **design directions are most influential**.

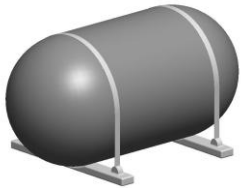


Parameter	MDO	R&D FERRARIS
MTOM	2312 kg	2200 kg
Loiter endurance	1.09 h	2 h
Hydrogen mass	15.82 kg	19.5 kg
Rotors radii	0.538 m	0.36 m

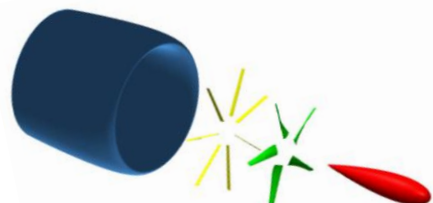


RED Ferraris: Cooler than a Ferrari

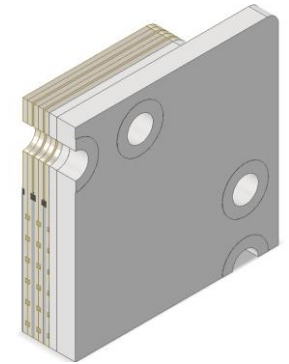
Characteristics	RED Ferraris
Hydrogen Stored	19.5 kg (@70MPa)
Max disk loading	2911 N/m^2
Peak Power	1868 kW
Continuous Power	1400 kW
MTOM	2200 kg



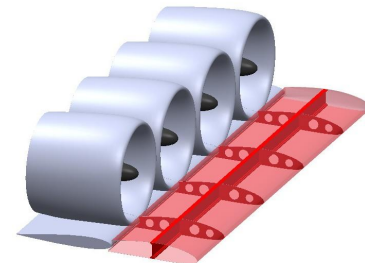
High stiffness, low weight hydrogen tank



Optimized rotor, stator blades and duct design

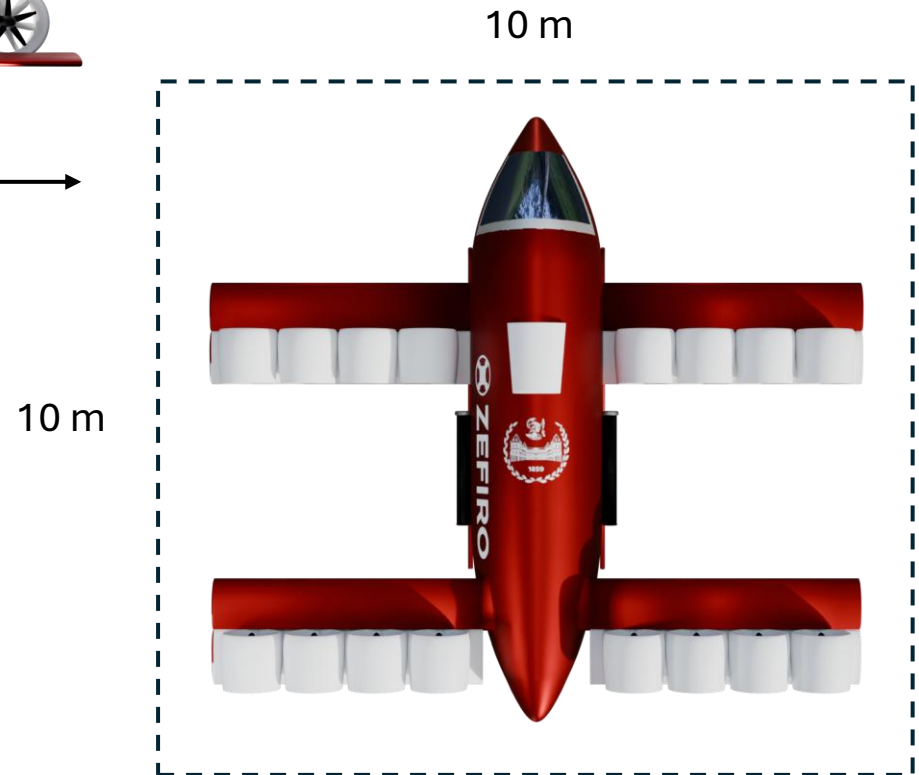
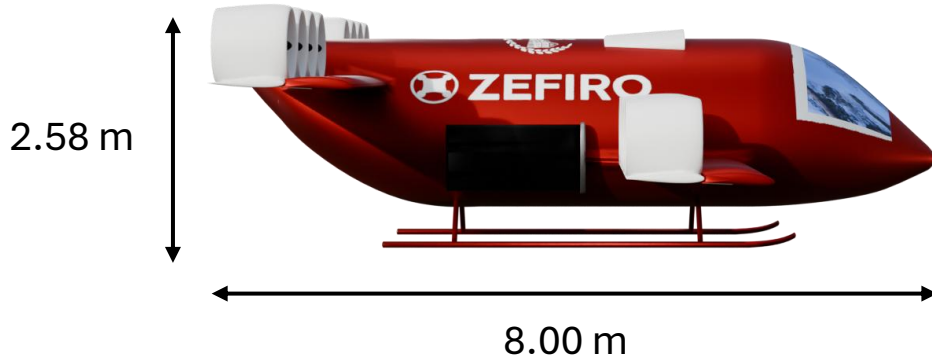
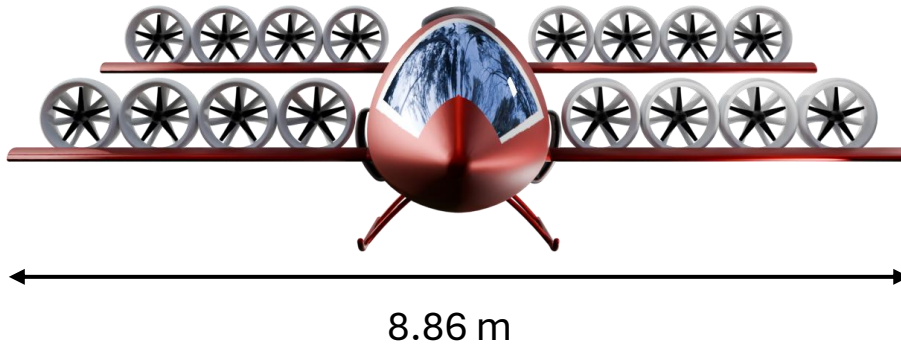


Efficiency maximization Fuel Cell

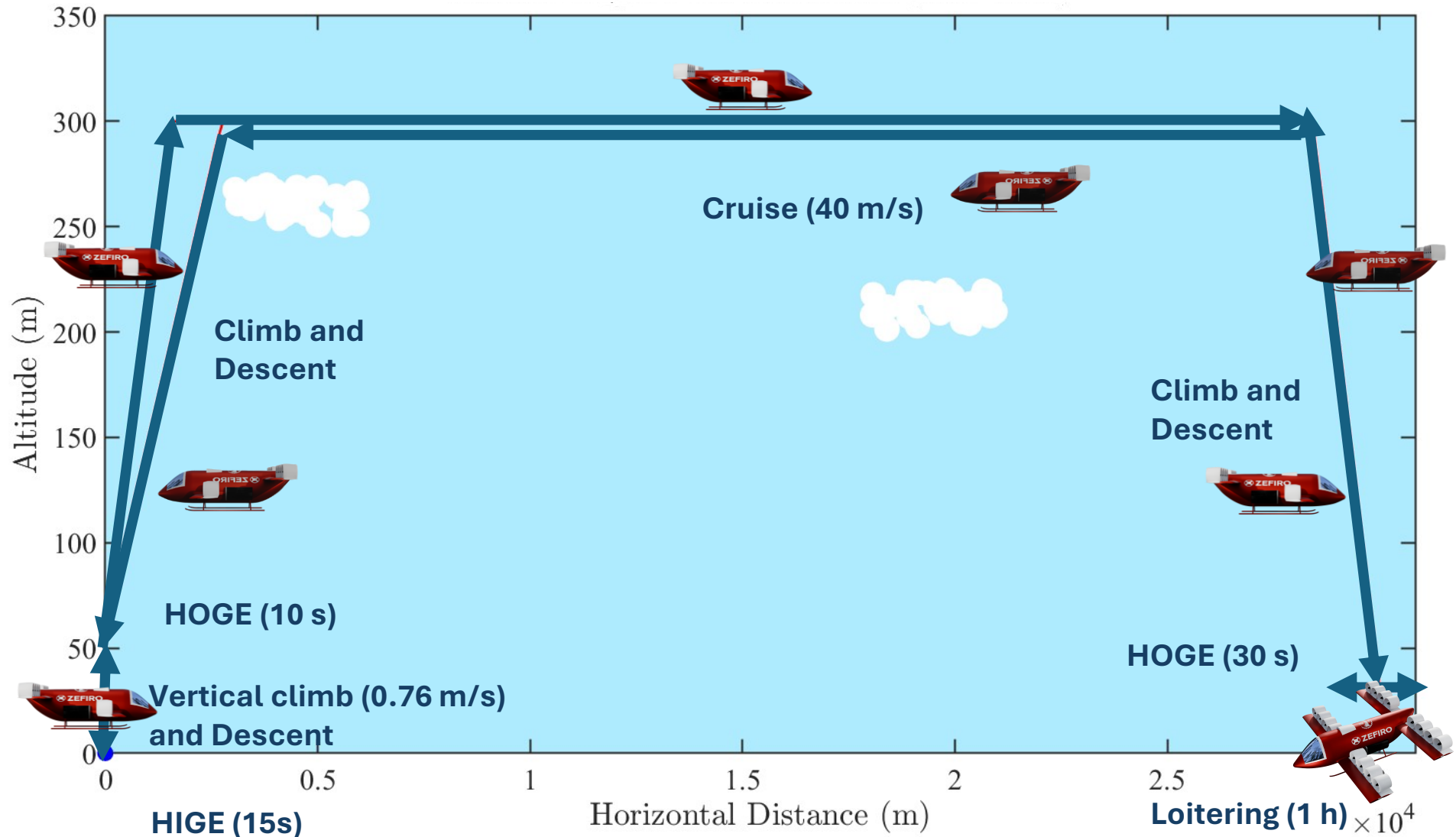


Low weight tilt rot

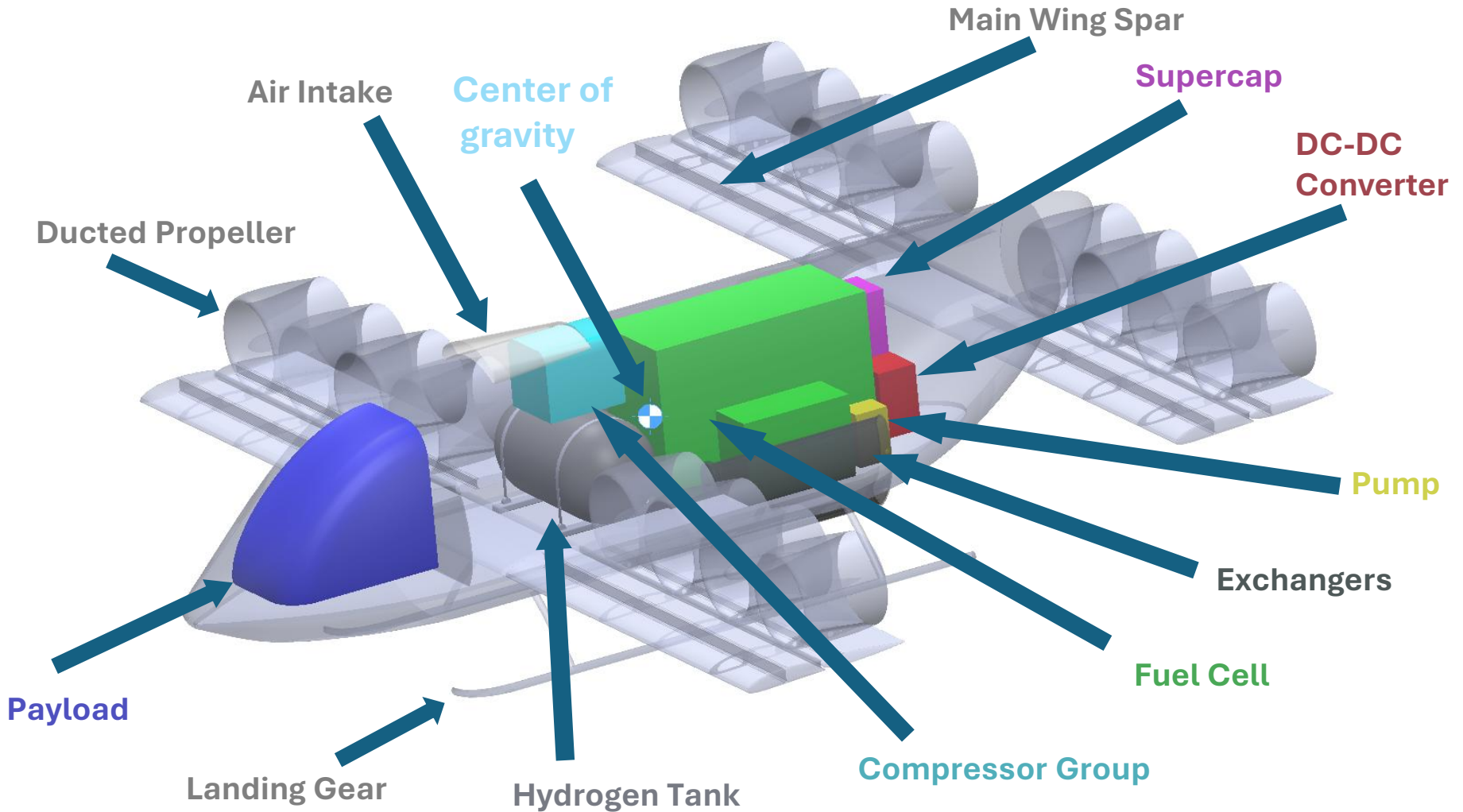
RED Ferraris: Aircraft Dimensions



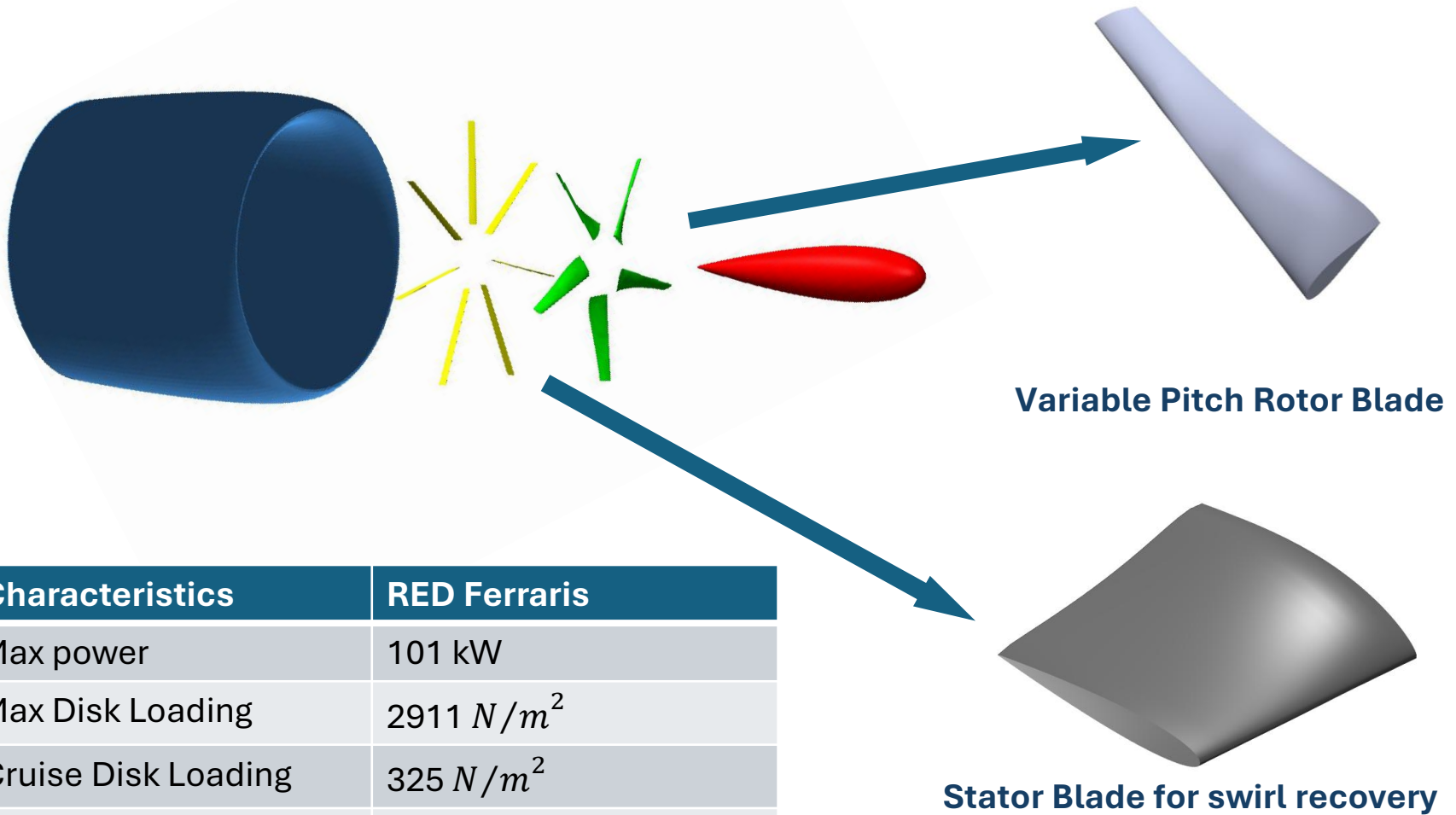
RED Ferraris: Aircraft Mission Breakdown



RED Ferraris: Aircraft Layout



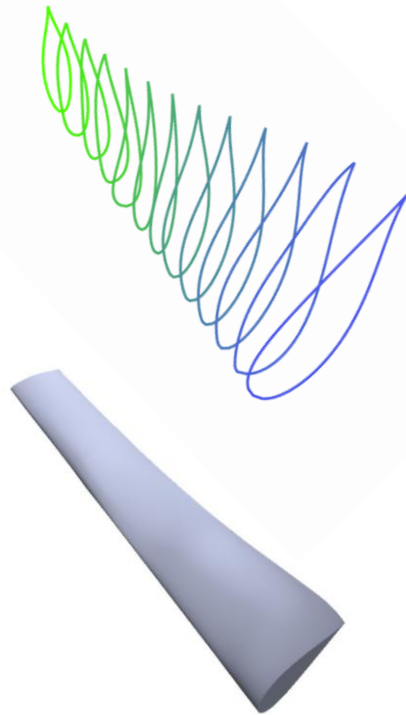
RED Ferraris: Aircraft Propulsion System



Characteristics	RED Ferraris
Max power	101 kW
Max Disk Loading	2911 N/m^2
Cruise Disk Loading	325 N/m^2
Max Swirl Recovery	252 N

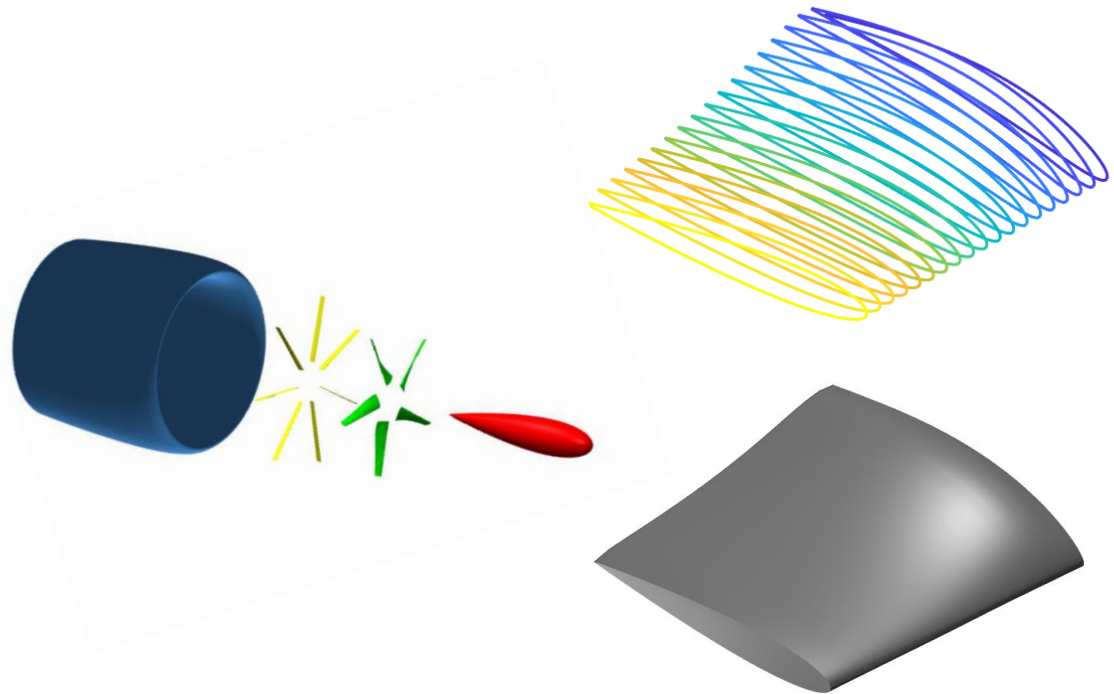
RED Ferraris: Aircraft Propulsion System

Rotor Blade Optimization



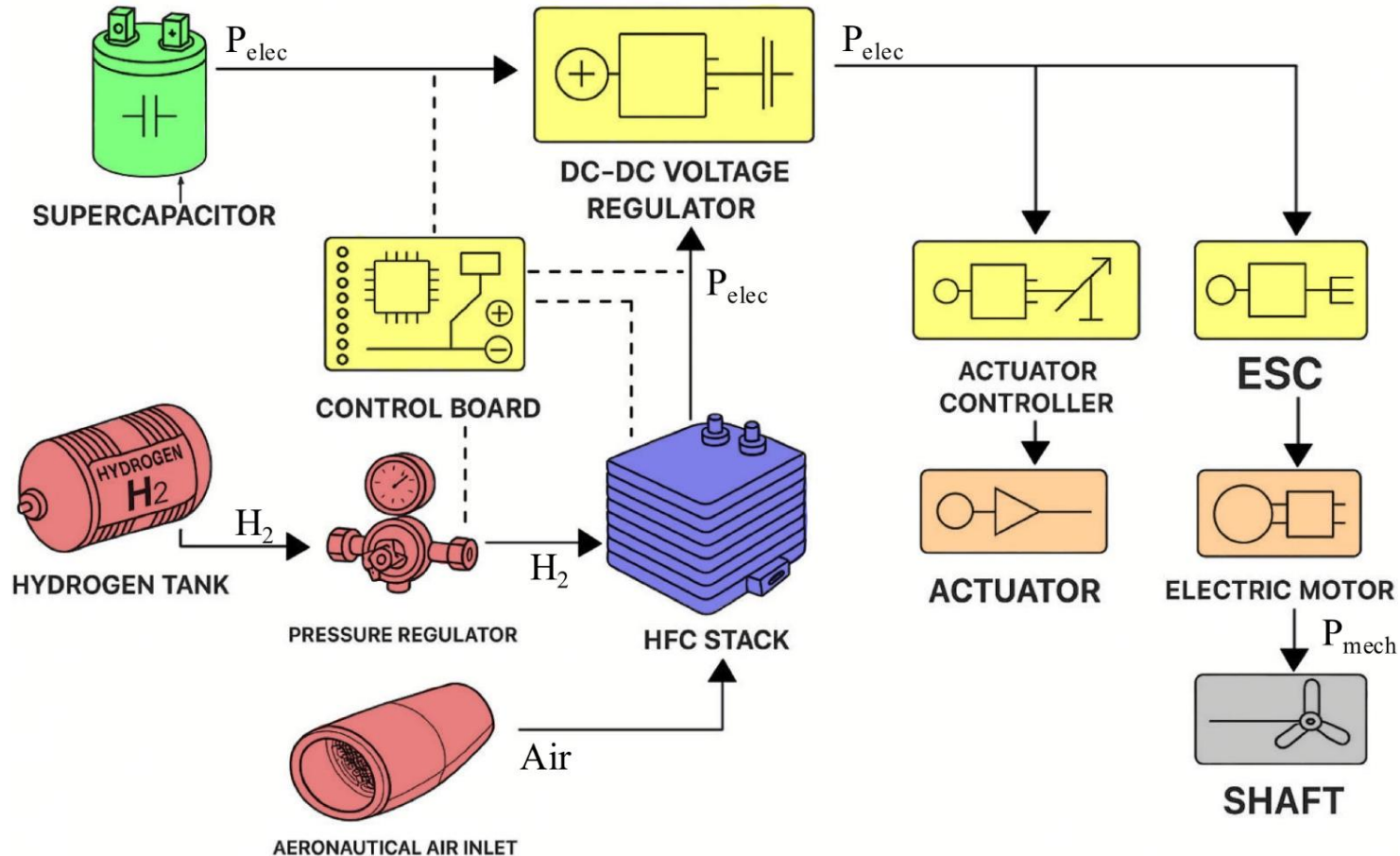
**Bayesian Optimization
to maximize performance**

Stator Blade Design



**Design Development
to straighten flow**

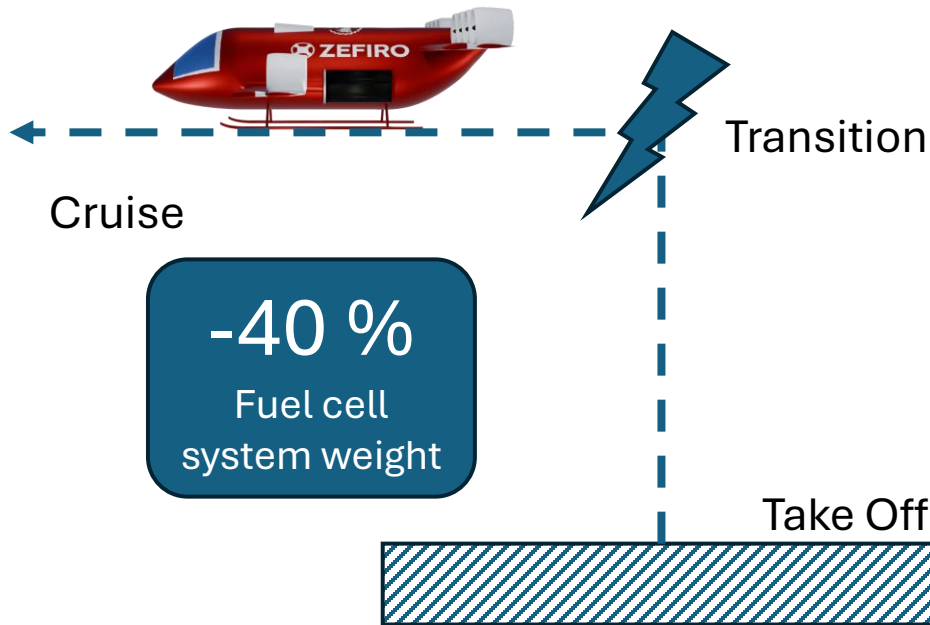
RED Ferraris: Electric Drive Train



Hydrogen is stored in pressure vessels and delivered to the **fuel cell**, with downstream power conditioning by a **DC/DC converter**. Power is routed to **propulsion units** and **actuators**, while the **supercapacitor** module supports transient loads and regenerative braking.

RED Ferraris: Electronic power

Supercapacitor: the power behind the transition



Power where it matters, only when it matters.

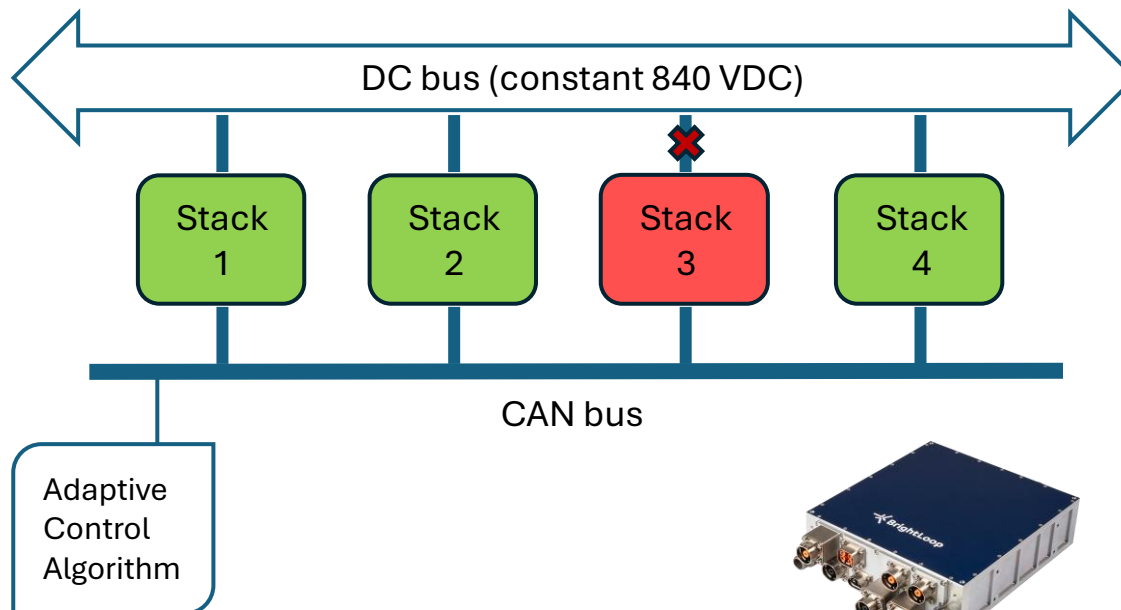


700 kJ - enough to feed a building... for two seconds!

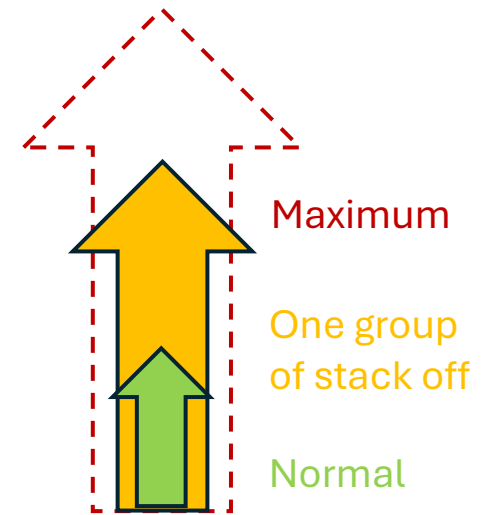
Specifications	
Event Duration:	~2 seconds
System Weight:	30 kg
Energy Capacity:	705 kJ
Control:	CAN-enabled bidirectional DC/DC

RED Ferraris: Electronic power

Reliability: what if a full stack is faulty?



The key enabler behind this functionality is the use of high-performance **DC/DC converters**, allowing for real-time power redistribution and system adaptability

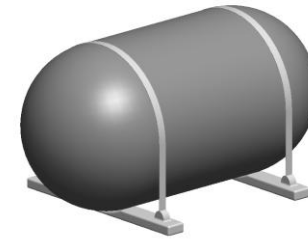
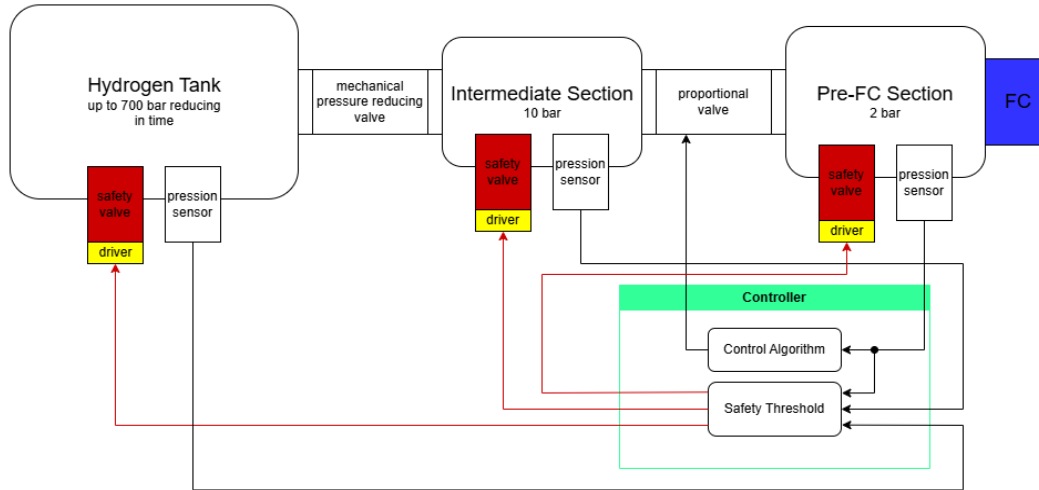


Power per stack

Intelligent tuning of the fuel cell working point cuts weight, boosts payload, and provides fail-safe operation when a stack group fails

RED Ferraris: Electronic power

Hydrogen safety



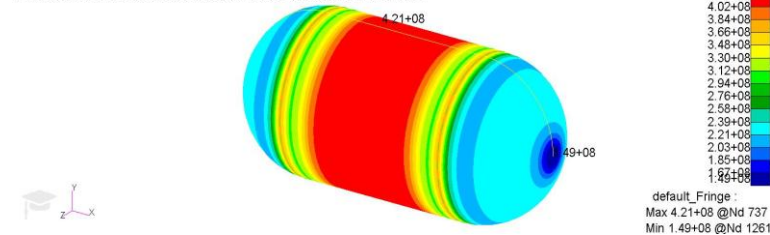
Pressure sensors empower real-time control.



Safety valves safeguard the system against failures.

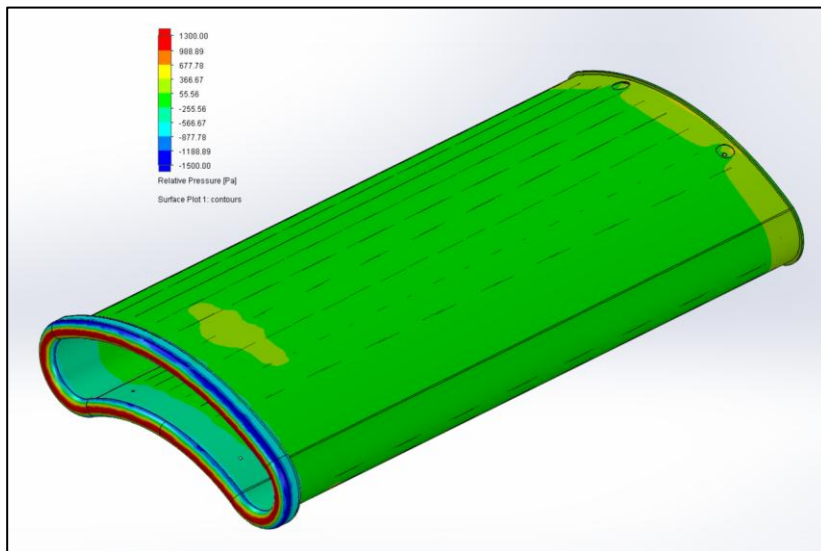
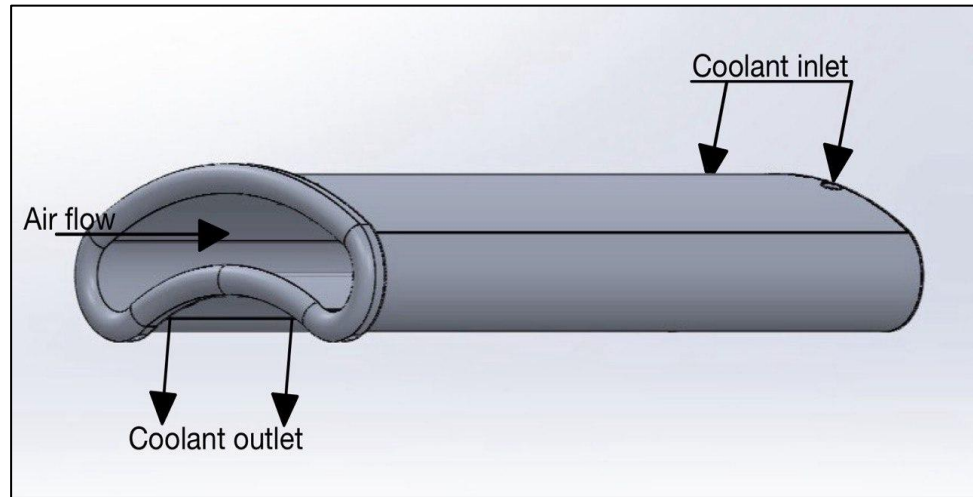
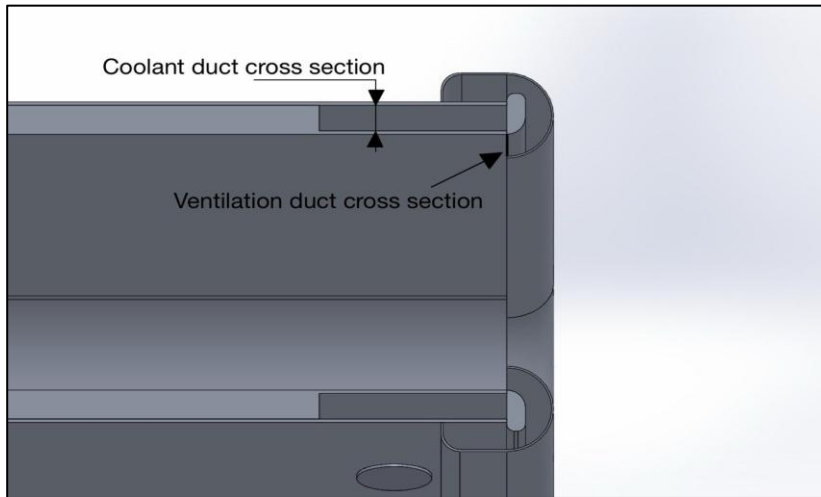
Patran 2024.1 (Student Edition) 18-May-25 17:12:25

Fringe: SC1:DEFAULT, A1:Static subcase, Stress Tensor, von Mises, At Z1



Stress distribution on the tank structure according to Von Mises stress theory.

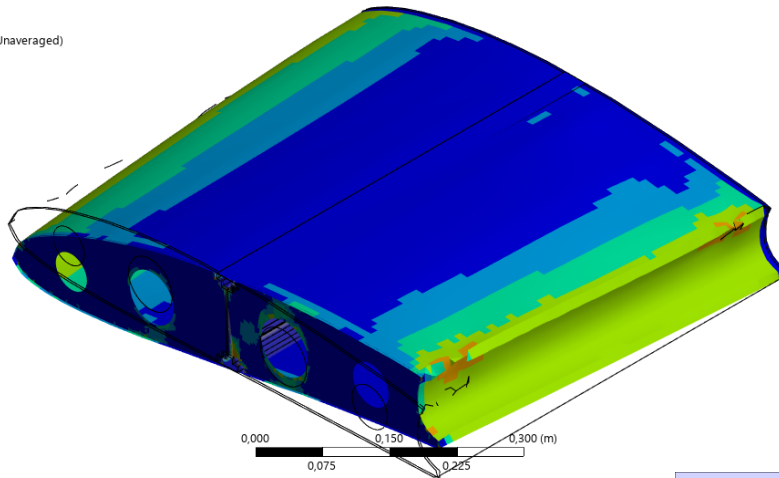
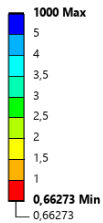
RED Ferraris: Innovative Heat Exchanger



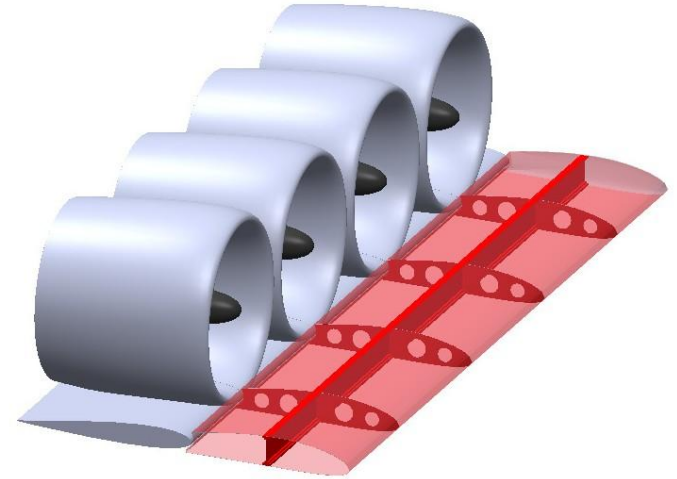
- Passive external cooling
- Beneficial propulsive effect
- Increased usable fuselage volume
- Reduced thermal system weight
- Reliability: oversizing for failure management

RED Ferraris: Wing Box

B: Static Structural
Safety Factor
Type: Safety Factor (Unaveraged)
Time: 1
26/05/2025 17:08:45



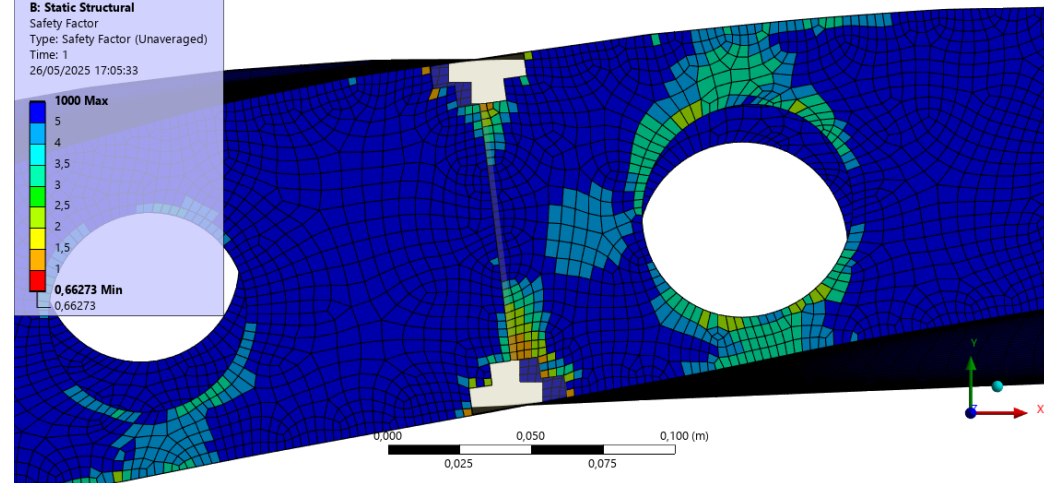
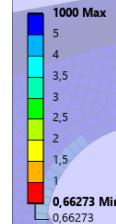
Ansys
2025 R1
STUDENT



Static linear analysis of the wing box under torsional loading during take-off phase

T800 carbon fiber enables the ultralight design of skin panels and ribs

B: Static Structural
Safety Factor
Type: Safety Factor (Unaveraged)
Time: 1
26/05/2025 17:05:33

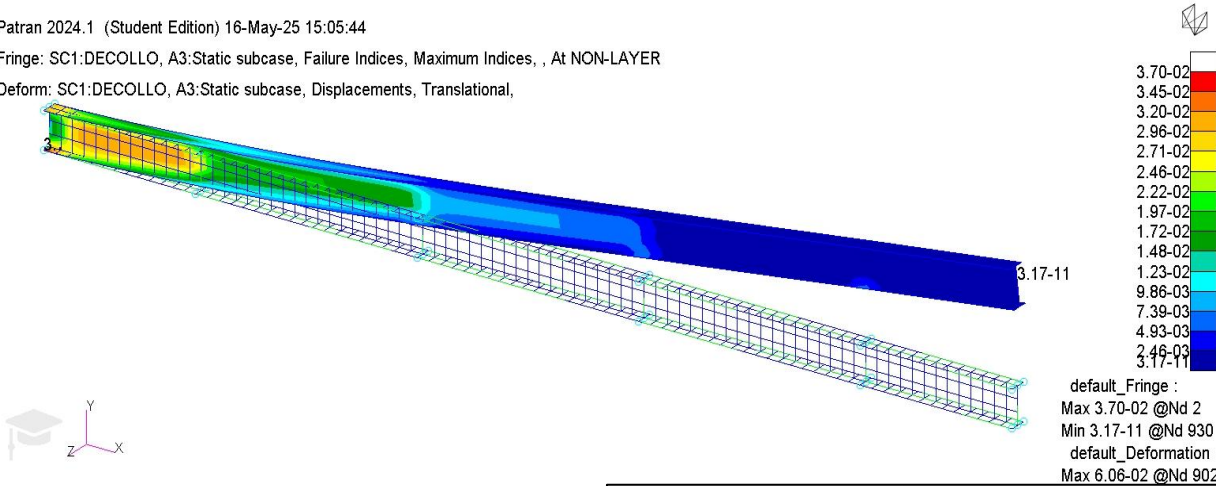


RED Ferraris: Main Wing Spar & Landing Gear

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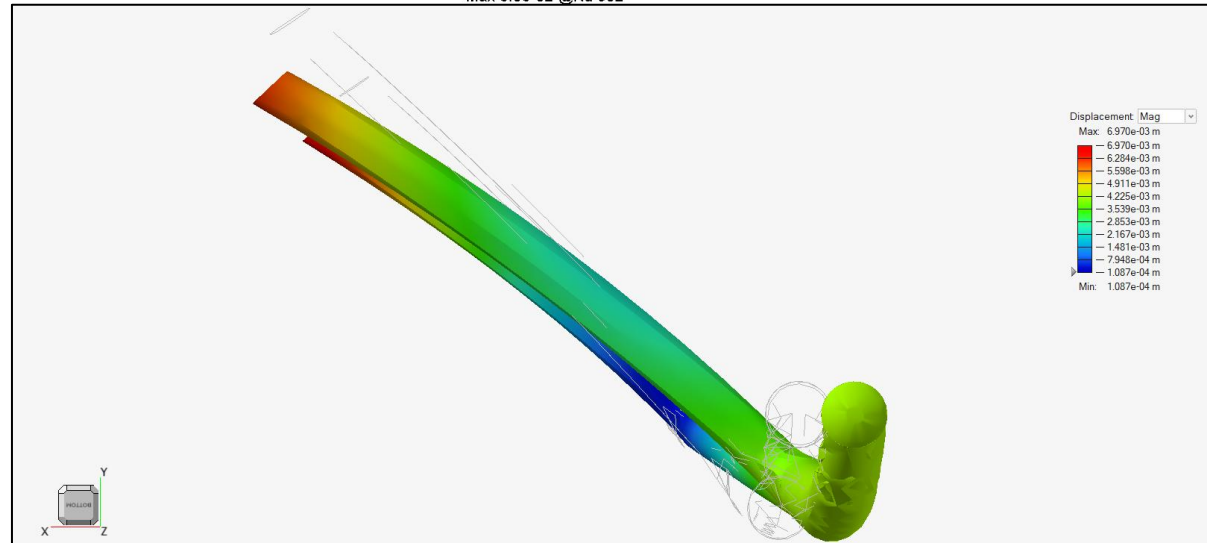
Fringe: SC1:DECOLLO, A3:Static subcase, Failure Indices, Maximum Indices, , At NON-LAYER

Deform: SC1:DECOLLO, A3:Static subcase, Displacements, Translational,

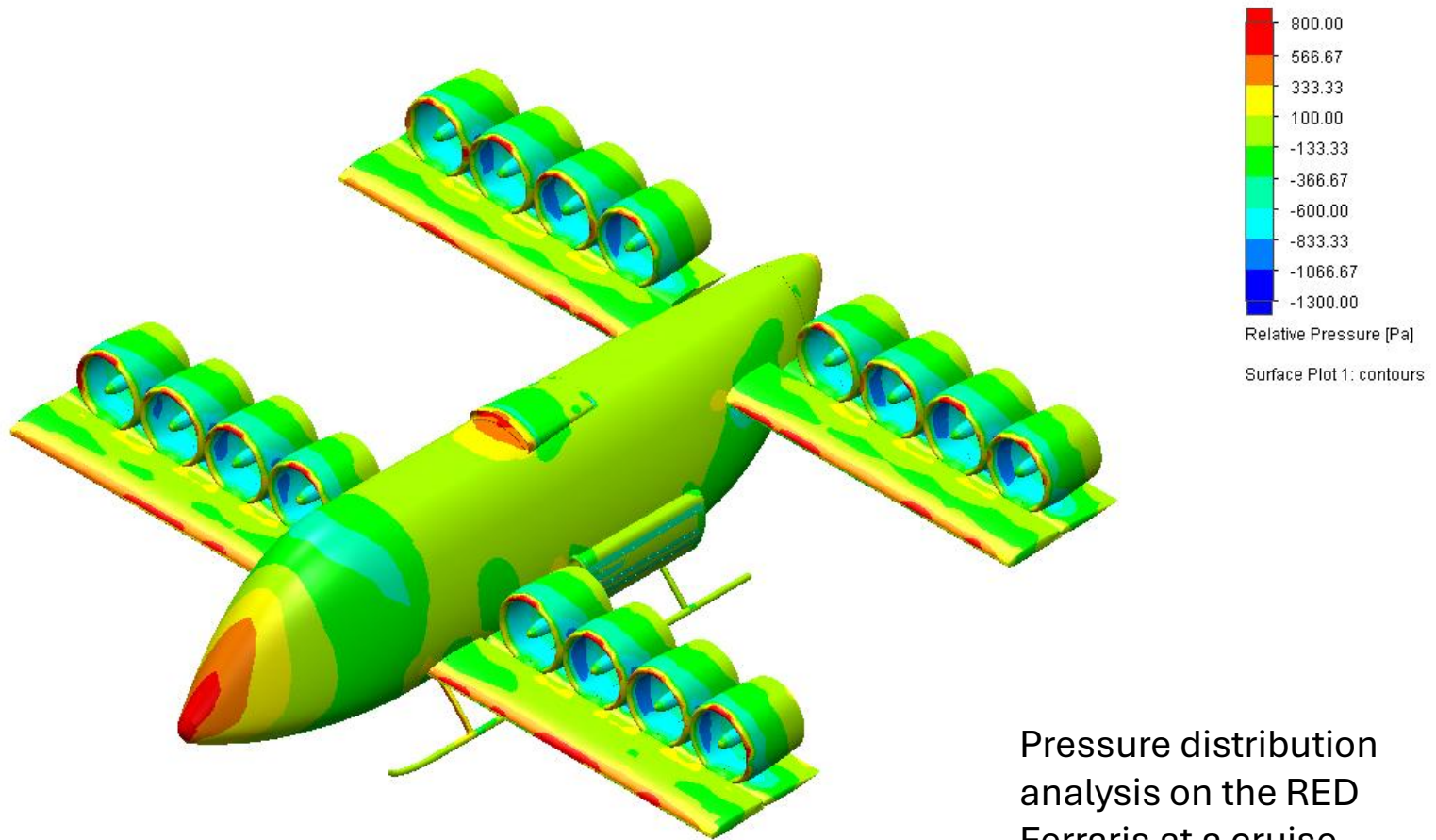


Structural integrity and reliability of the ultralight design of the Main Wing Spar

Linear, modal and buckling analysis of the Landing Gear were successfully conducted



RED Ferraris: Overall vehicle CFD



Pressure distribution analysis on the RED Ferraris at a cruise speed of 40 m/s