WYVERN

42nd Annual VFS Student Design Competition

Pioneering Hydrogen-Electric VTOL

Sponsored by: AIRBUS

UNIVERSITY OF MARYLAND

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College Park, MD 20742 U.S.A.

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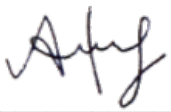

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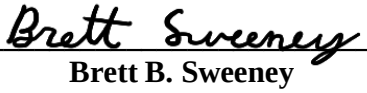

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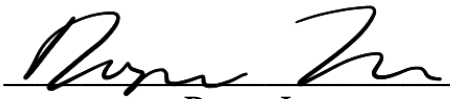

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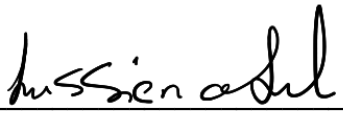

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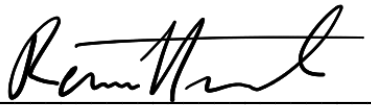

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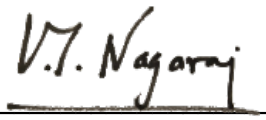

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To the Vertical Flight Society:

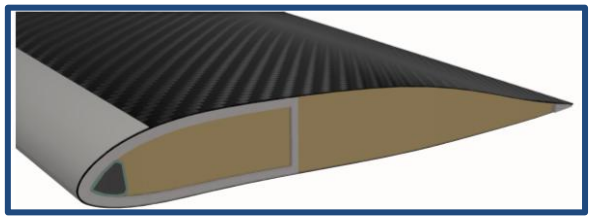
The members of the University of Maryland Graduate Student Design Team hereby grant VFS full permission to distribute the enclosed Executive Summary and Final Proposal for the 42nd Annual Design Competition as they see fit.

Thank you,

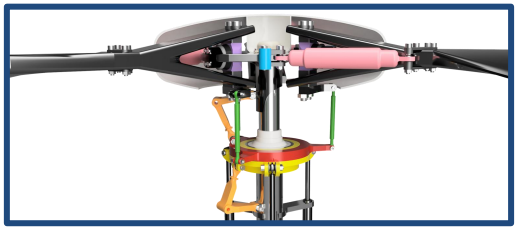
The UMD Graduate Design Team

Wyvern: Key Features

WYVERN



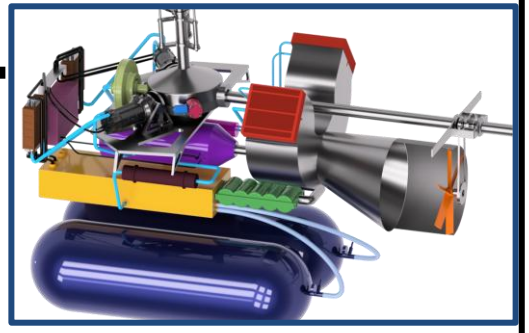
Lightweight Composite Blades



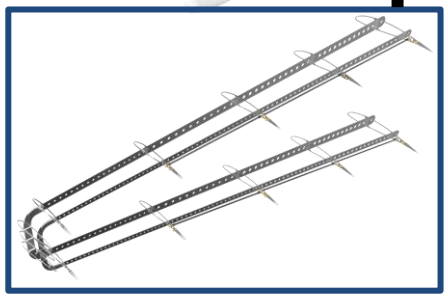
Simple and Robust Articulated Hub

Ultra Light Weight Drivetrain

Modern Glass Cockpit



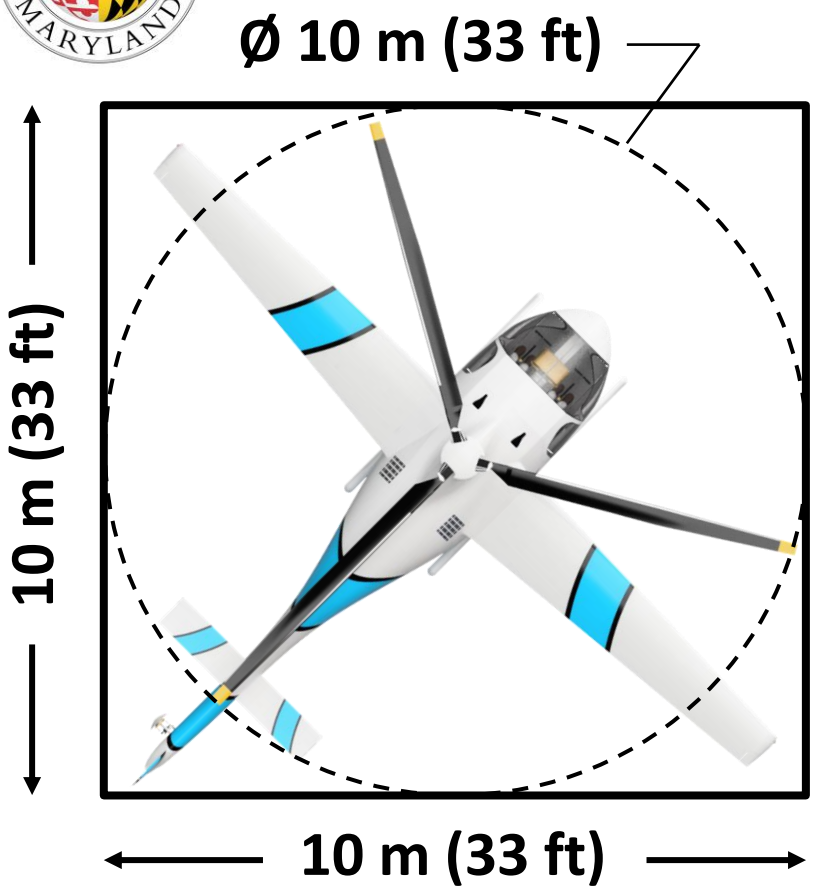
Efficient PEMFC Powerplant

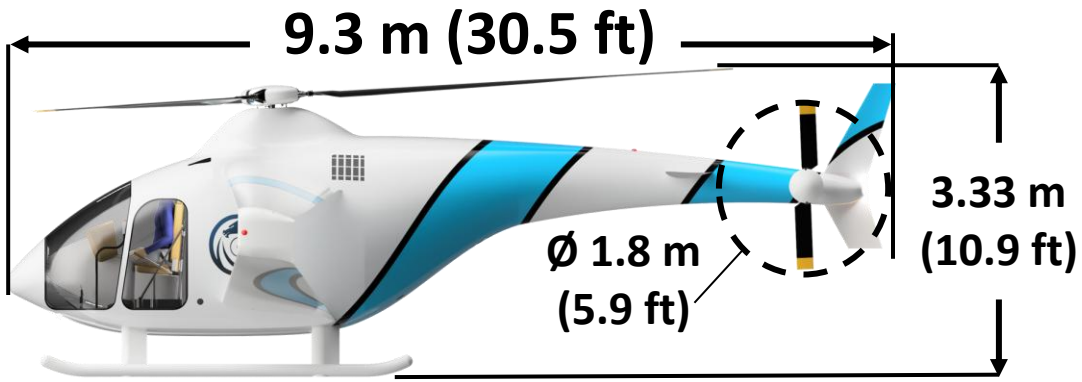


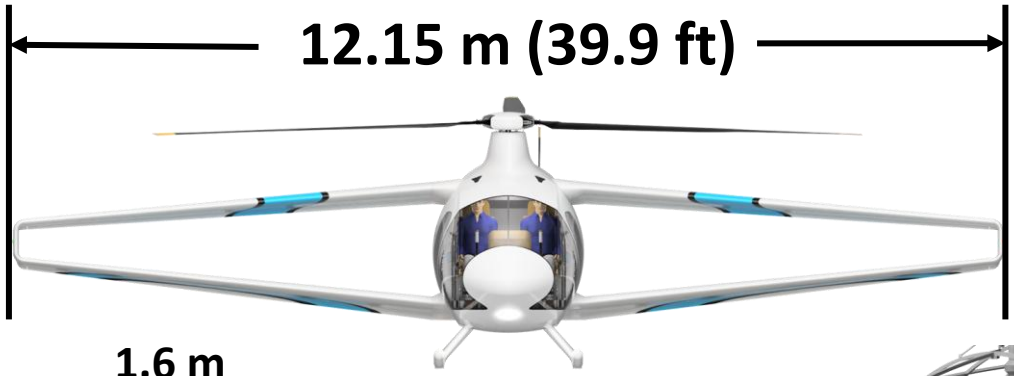
Aerodynamically Efficient Box Wing

Compact *Floiler* Mechanism

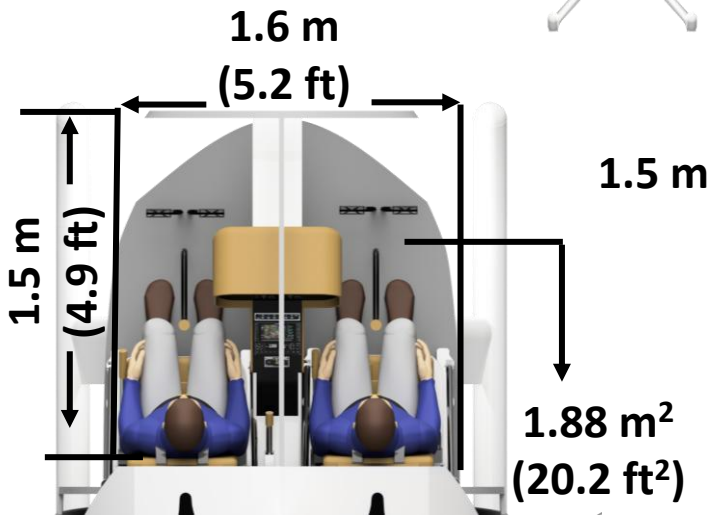
Vehicle Overview

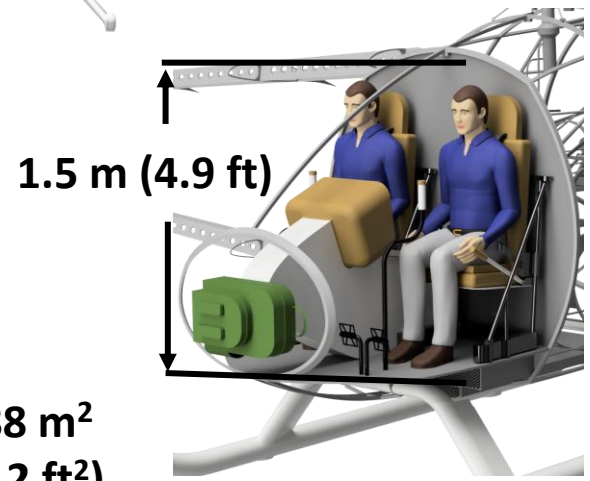






Characteristics	Value
GTOW	1648 kg (3633 lb)
Installed Power	277 kW (371 hp)
Hydrogen Mass	24.8 kg (55 lb)
Loiter Endurance	4.5 hours @ 57 knots
Payload	185 kg (408 lb)





WYVERN: A Flame-Free Hydrogen Hybrid Helicopter

Like the majestic, agile, and flame-free mythical dragon that lends its name, **Wyvern** rises as the first manned hydrogen-powered all-electric fuel cell compound rotorcraft.

With a **1648 kg GTOW**, **277 kW installed power**, **5 m radius rotor** and a highly efficient **box-wing, Wyvern** achieves **over four hours of zero-emission** flight time with a modest **25 kg of gaseous H_2** and a large **185 kg dual-occupant payload.**

A **composite skin**, **lightweight low-vibration articulated rotor hub**, **super-critical driveshaft, high-endurance gearing, weight-efficient wing structure, custom-designed PEM fuel cell stack, and hybrid battery** compress the **Wyvern** empty weight fraction to **47%**. The all-electric drive train achieves over **35% tank-to-shaft efficiency** while a **210 kW PEM fuel-cell stack**, boosted by a **high-C-rate** Li-ion battery with silicone[1] anode, feeds **twin 180 kW high power-density motors.**

Crash-worthy **700 bar Type-IV hydrogen tanks** sit behind fire barriers, **Nomex/Kevlar honeycomb mesh** protects the cockpit and tanks, **dual-loop cooling** keeps the PEM stack at 80°C, and simplex hydraulic actuated flight-control channels pair with predictive health-monitoring across all critical systems.

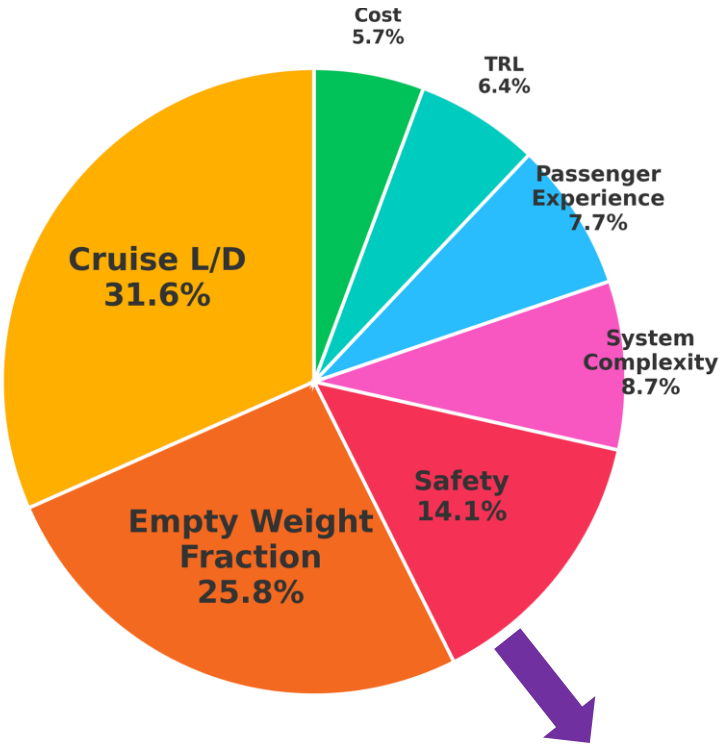
Combined with **fail-safe autorotation capability** and compliance with **EASA CS-27 guidance at TRL ≥ 6**, these features provide pilots with the endurance of a fixed-wing platform and the agility of a helicopter, along with additional payload capacity for sensors or supplies, which lets **Wyvern** patrol sensitive habitats in near silence.

Configuration Selection

Not Feasible

Feasible With Significant Innovation

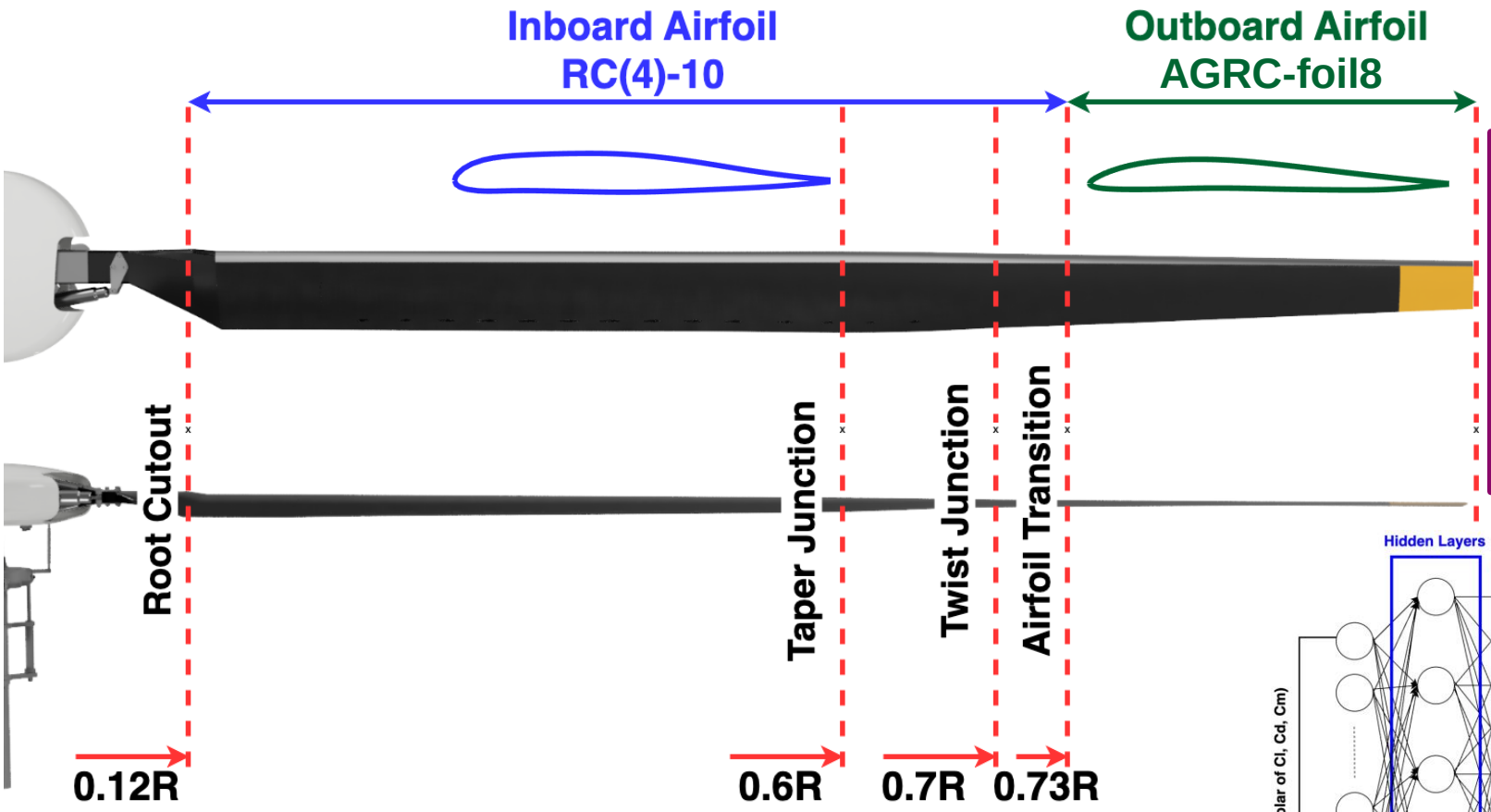
Design Drivers



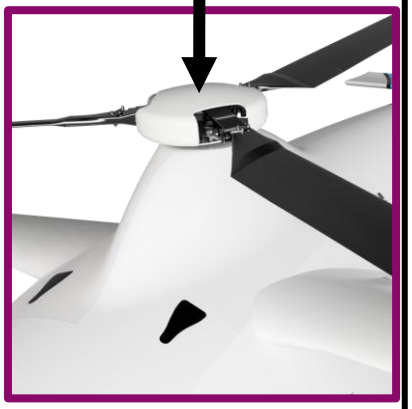
UMD's Innovative Solution

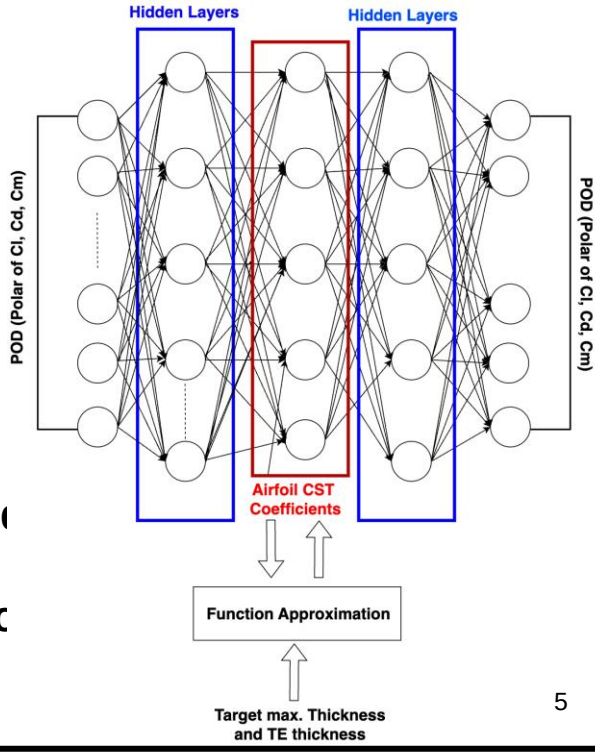
- **Rotor RPM slowed by 33% in Loiter**
- **Box wing with high L/D of 16.5**
- **Custom *floilers***
- **Custom-designed PEM fuel cell stack**

Aerodynamically Optimized Main Rotor



Aerodynamic Hub Fairing



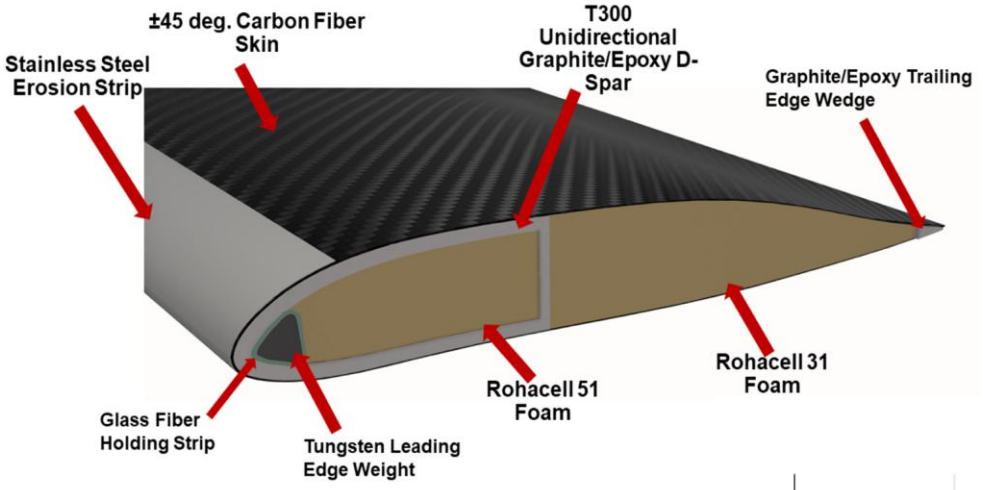


FM	0.786
L/D	9.03
PL (lb/hp)	14

Best of 8000 designs
from the Genetic Algorithm couple
with an in-house Tandem Neural
Network-based airfoil optimization to

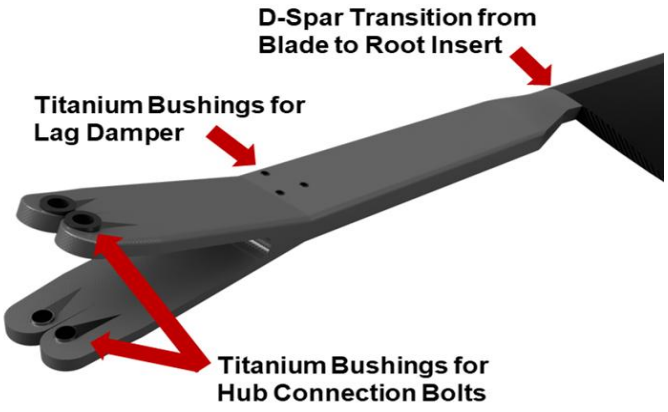
Variable RPM Ground Resonance-Free Rotor

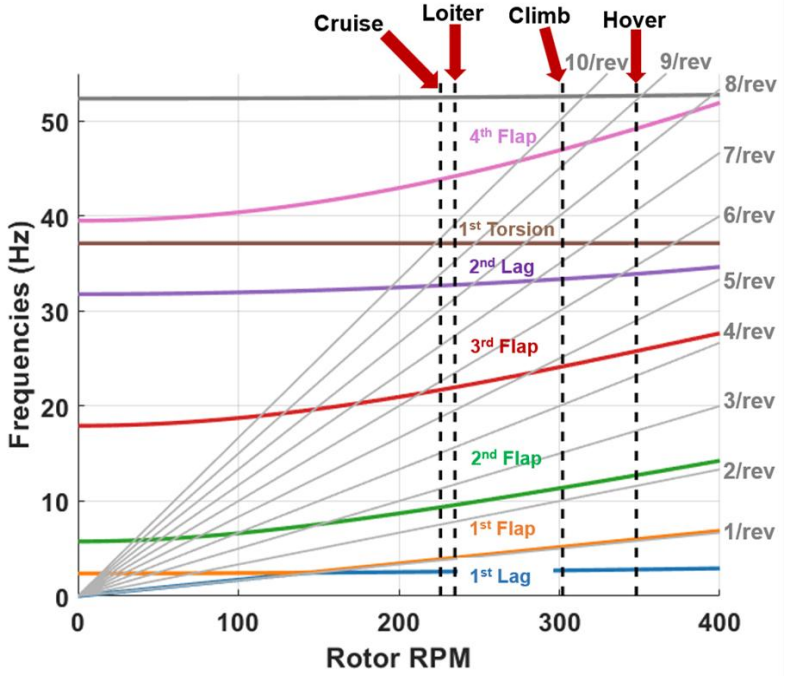
WYVERN



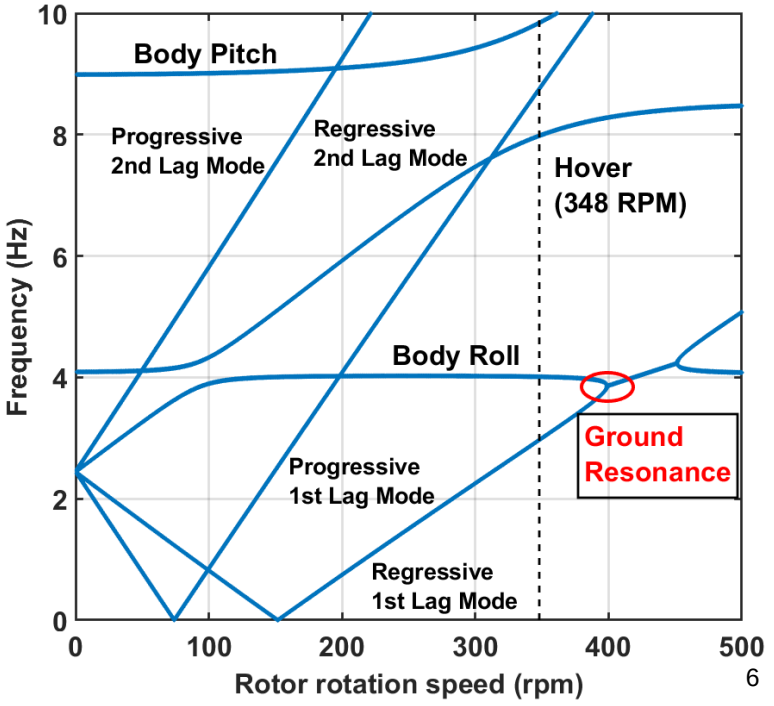
Antinodal tuning mass clears the 2nd Flap from resonance

Forked cuff to absorb CF

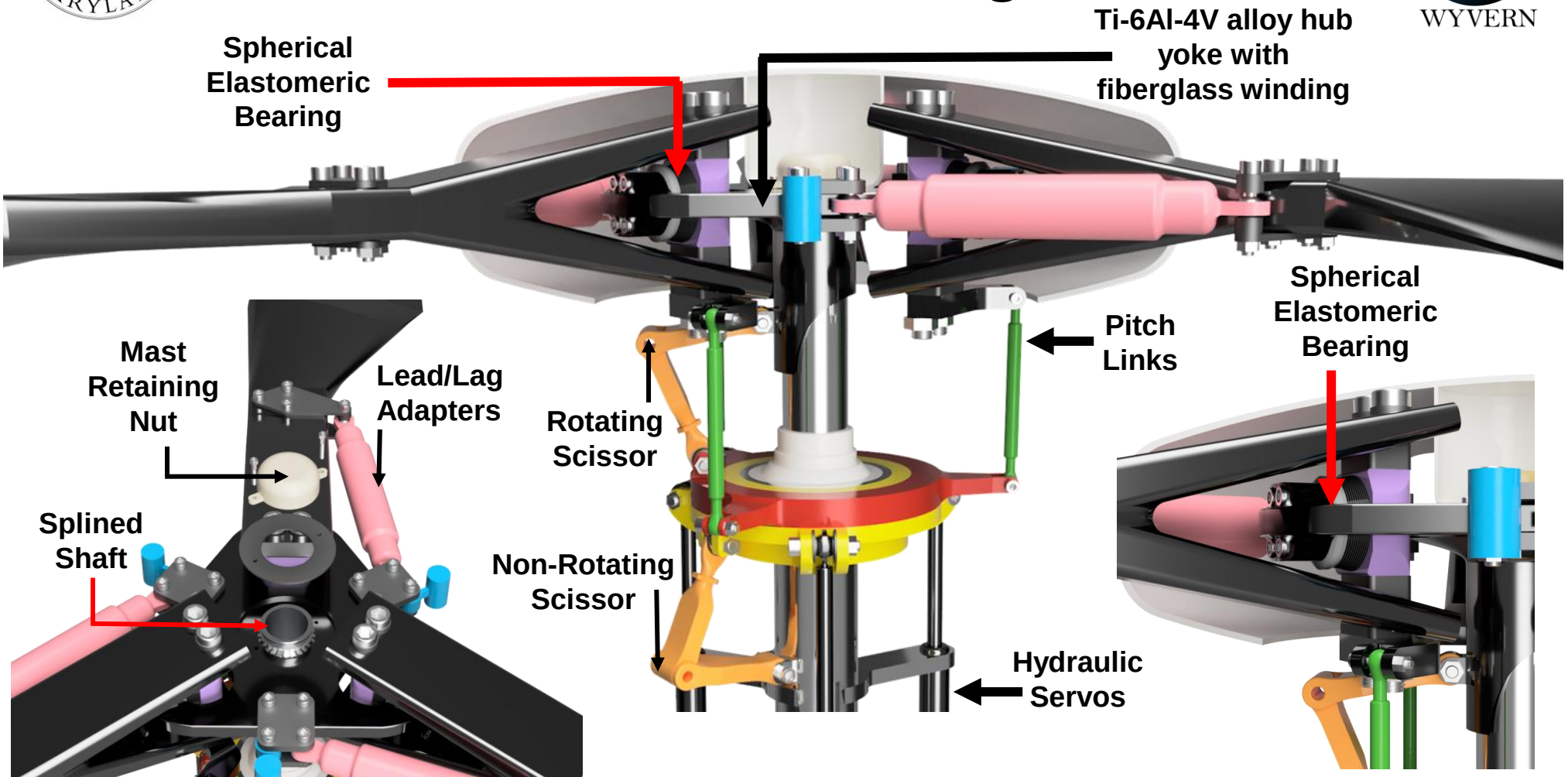




Omega (RPM)	1st Lag (/rev)	1st Flap (/rev)	1st Torsion
348 (Hover)	0.49	1.03	6.40
302 (Climb)	0.54	1.03	7.38
235 (Loiter)	0.66	1.03	9.48
226 (Cruise)	0.68	1.03	9.86



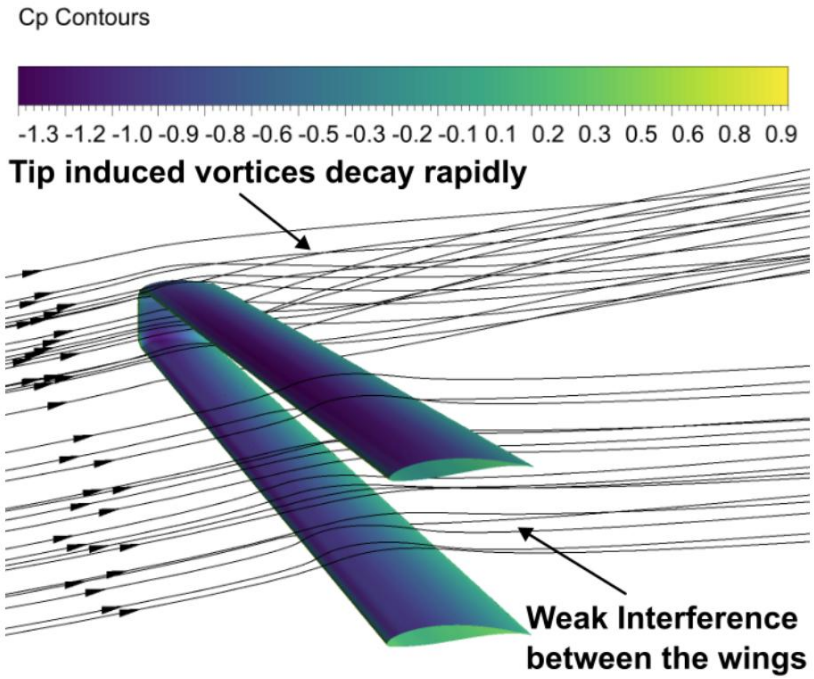
Articulated Hub with Low-Maintenance Elastomeric Hinges

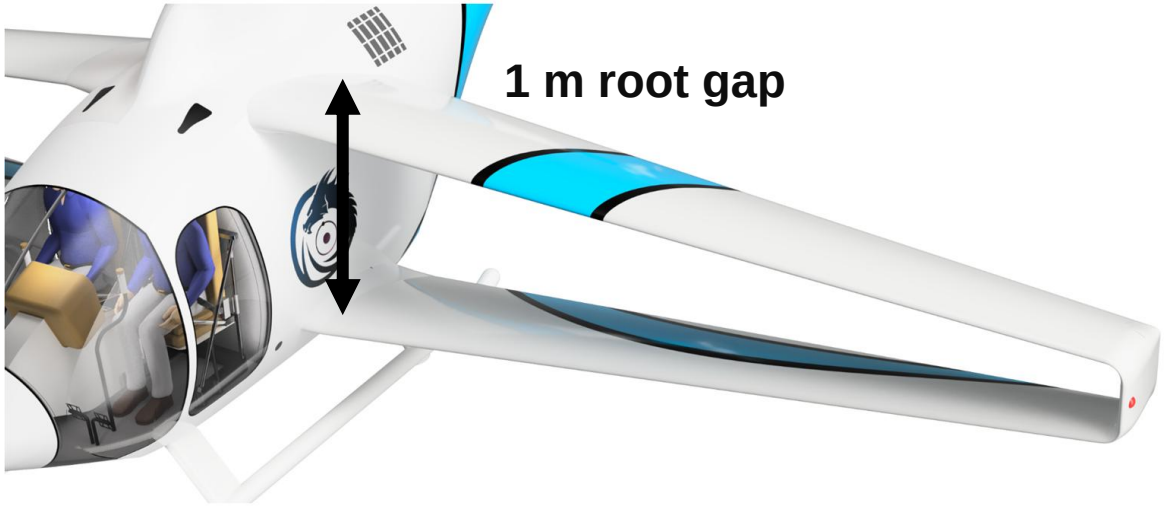


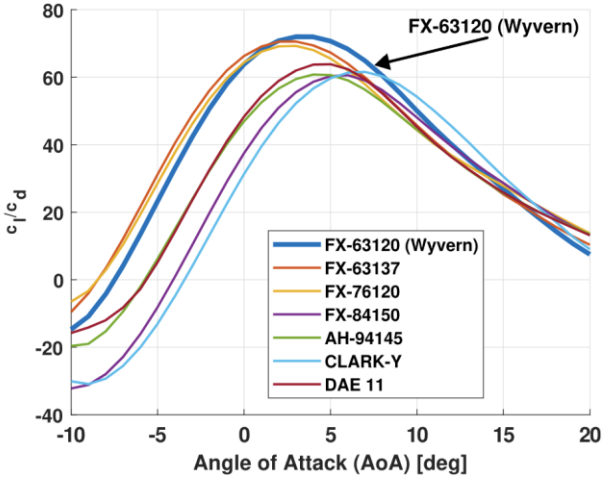
- Compact design reduces drag
- Simple and robust
- Elastomeric bearing enables lightweight design with minimal maintenance
- Reduced manufacturing complexity

Tapered, Tuned Incidence Box Wing

Innovative box-wing offloads 55% of rotor lift during loiter

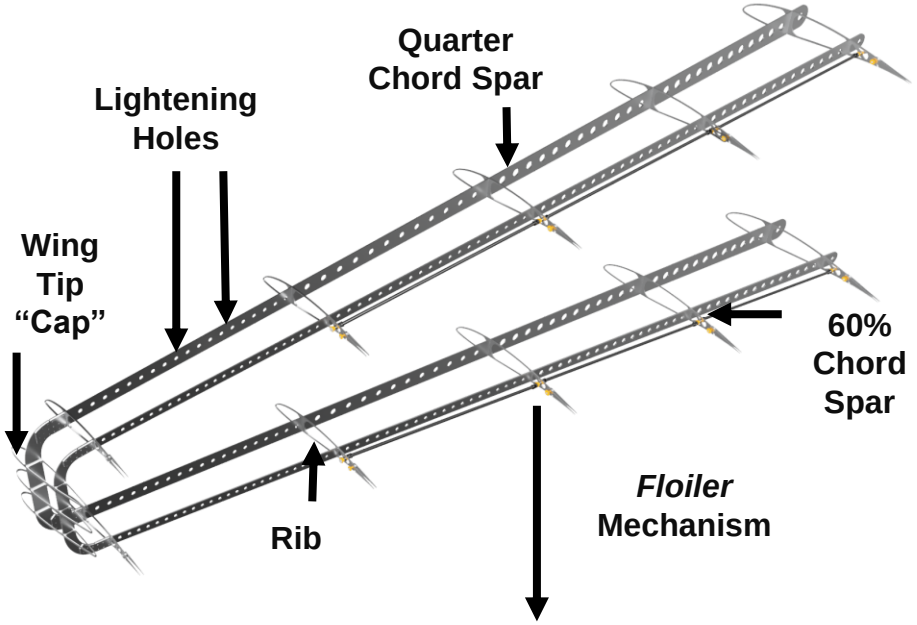


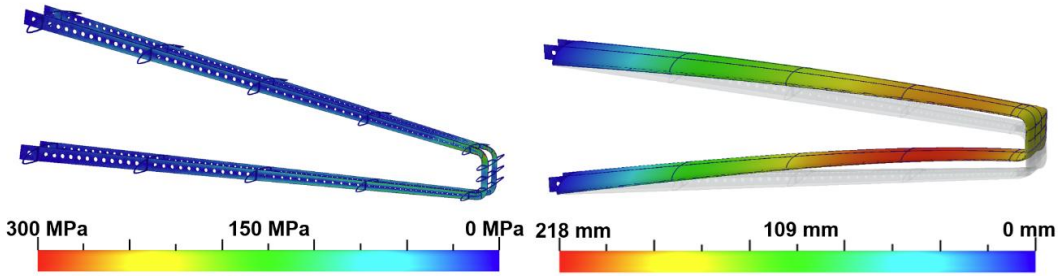




- 2:1 Taper promotes efficient lift distribution
- Tuned wing incidences for equal wing lift share
- Gap optimized to reduce aerodynamic interference
- Induced drag reduced by 18% compared to a planar wing
- Zero stagger reduces download
- Special airfoil FX 63-120 minimizes load and stabilizer

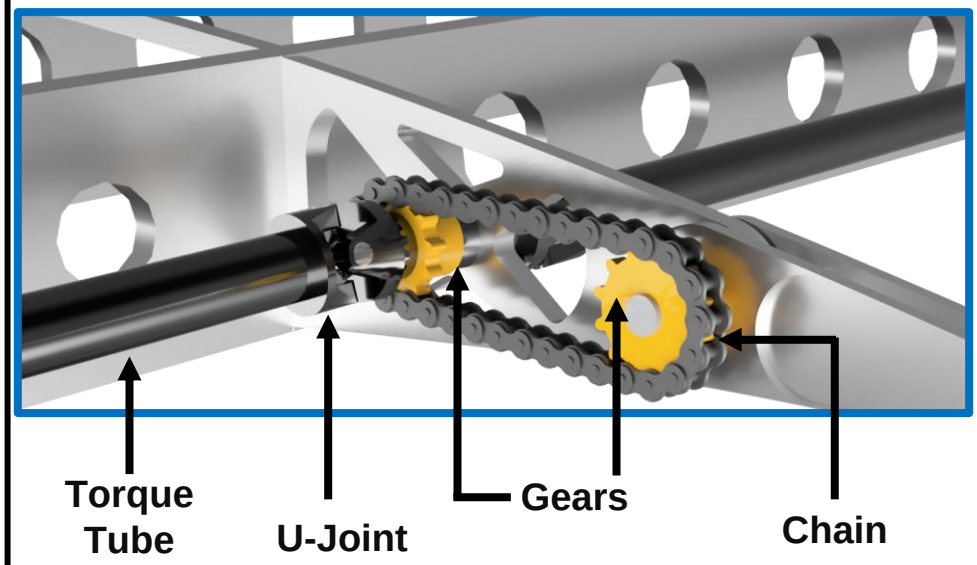
Dual Spar Box Wing Structure With *Floilers*

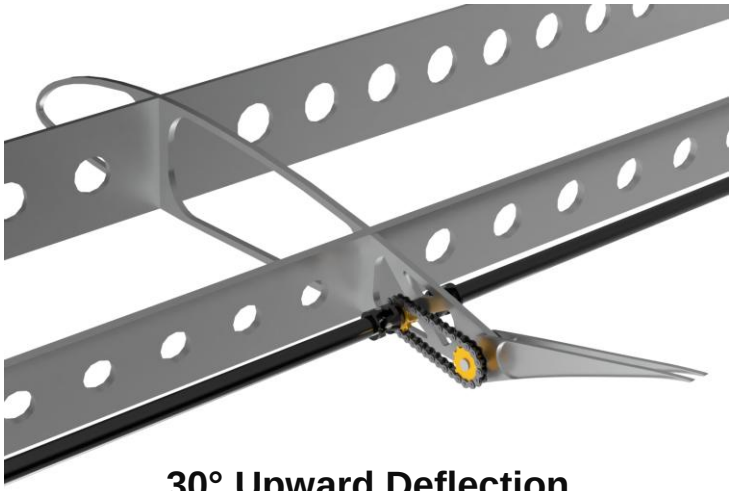




Wyvern **wing attached to fuselage through hinges.**

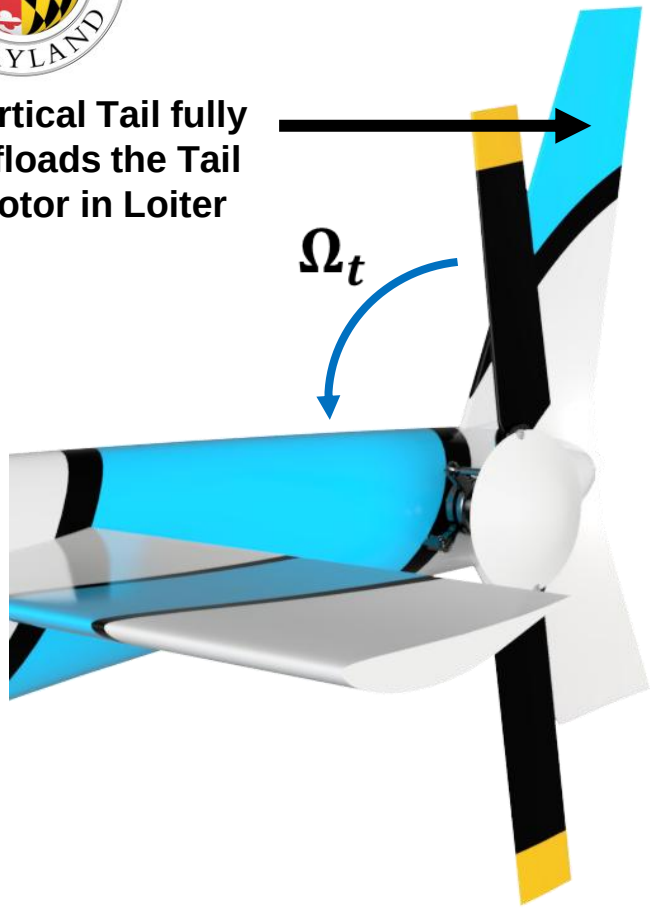
Wyvern **box wing features a** ***floiler*** **that reduces lift during steep descent (deflection up) and enhances hover performance (deflection down)**

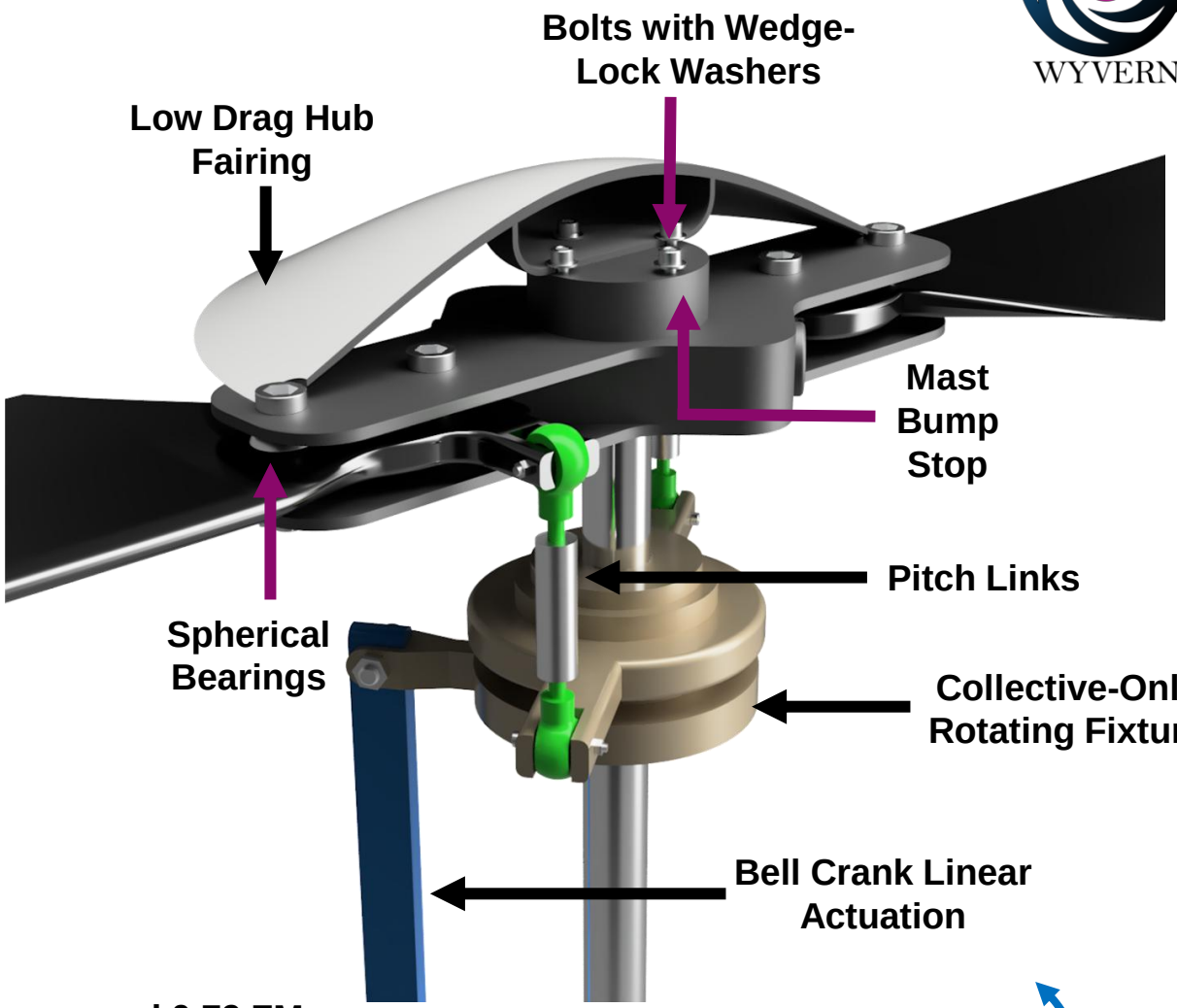




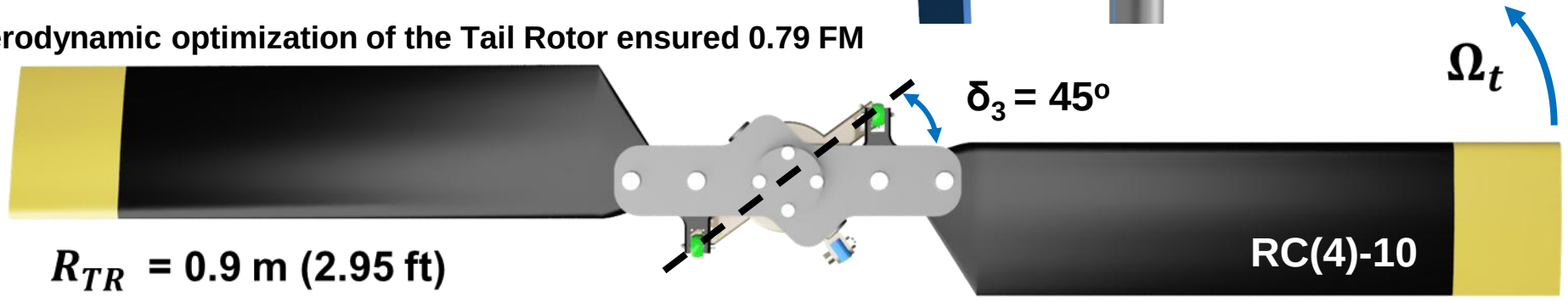
30° Upward Deflection

Tail Rotor and Empennage



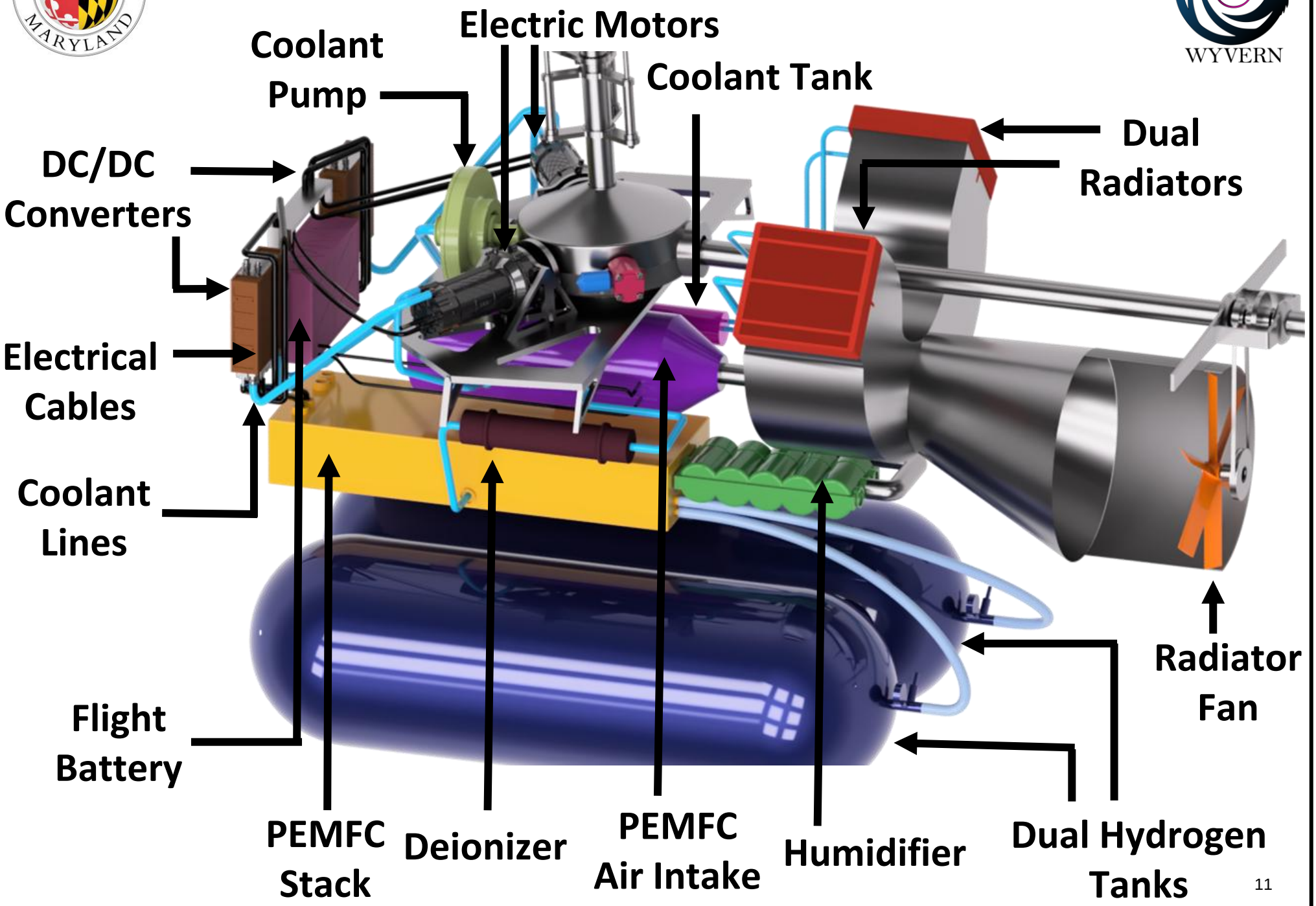


Aerodynamic optimization of the Tail Rotor ensured 0.79 FM



R_{TR} = 0.9 m (2.95 ft)

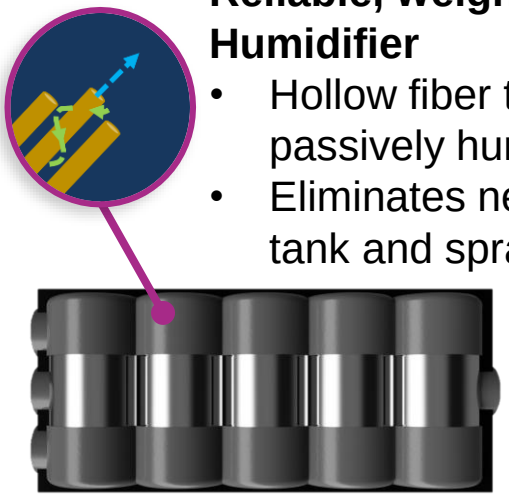
Integrated PEMFC Powerplant Architecture

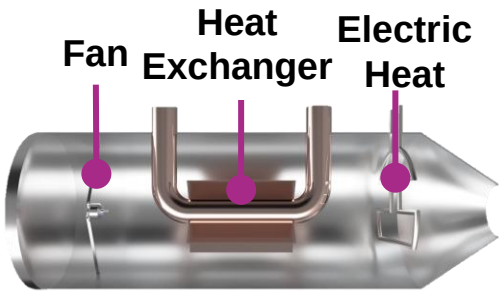


Detailed Stack and BOP Design

Reliable, weight-saving Humidifier

- Hollow fiber technology passively humidifies
- Eliminates need for water tank and spray nozzles



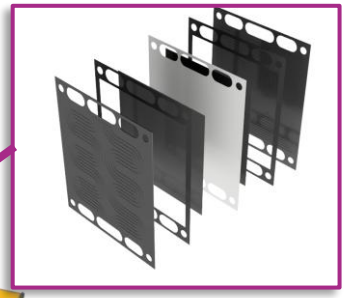


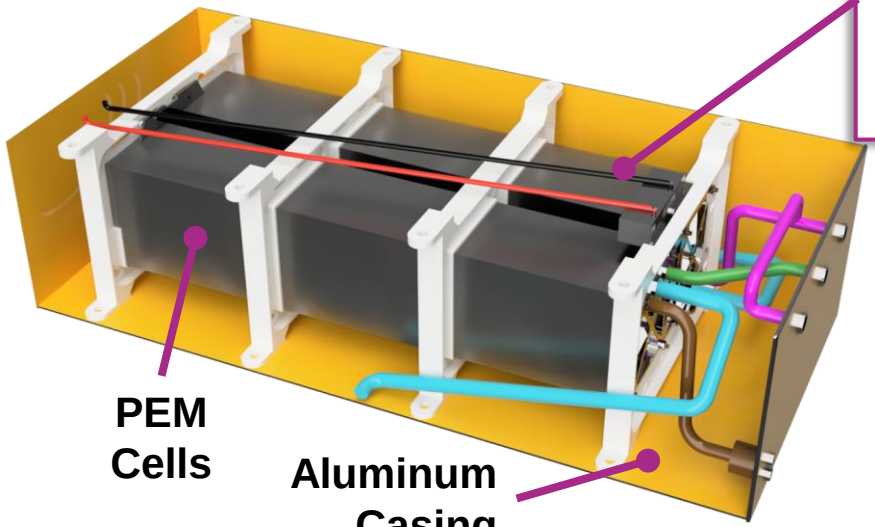
Low Power Air Intake

- Provides up to 0.32 kg/s of warm air

Lightweight PEM Cell

- 112 grams
- Nafion™ PEM
- Graphite Bi-polar plates
- 327 cm^2 Active Area



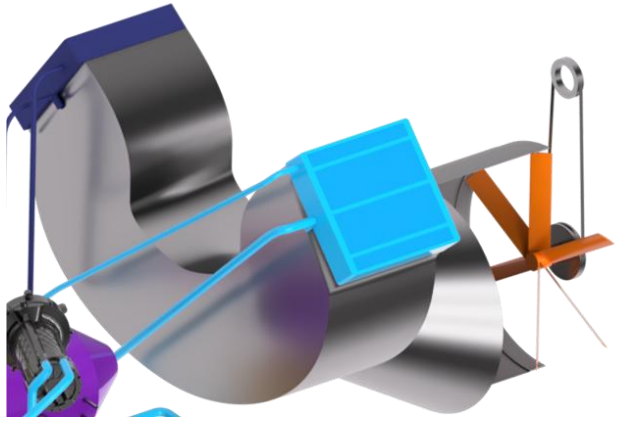


Integrated Cooling System

- Dual radiators remove up to 300 kW of heat
- Simple control via mechanical thermostats

Rugged PEMFC

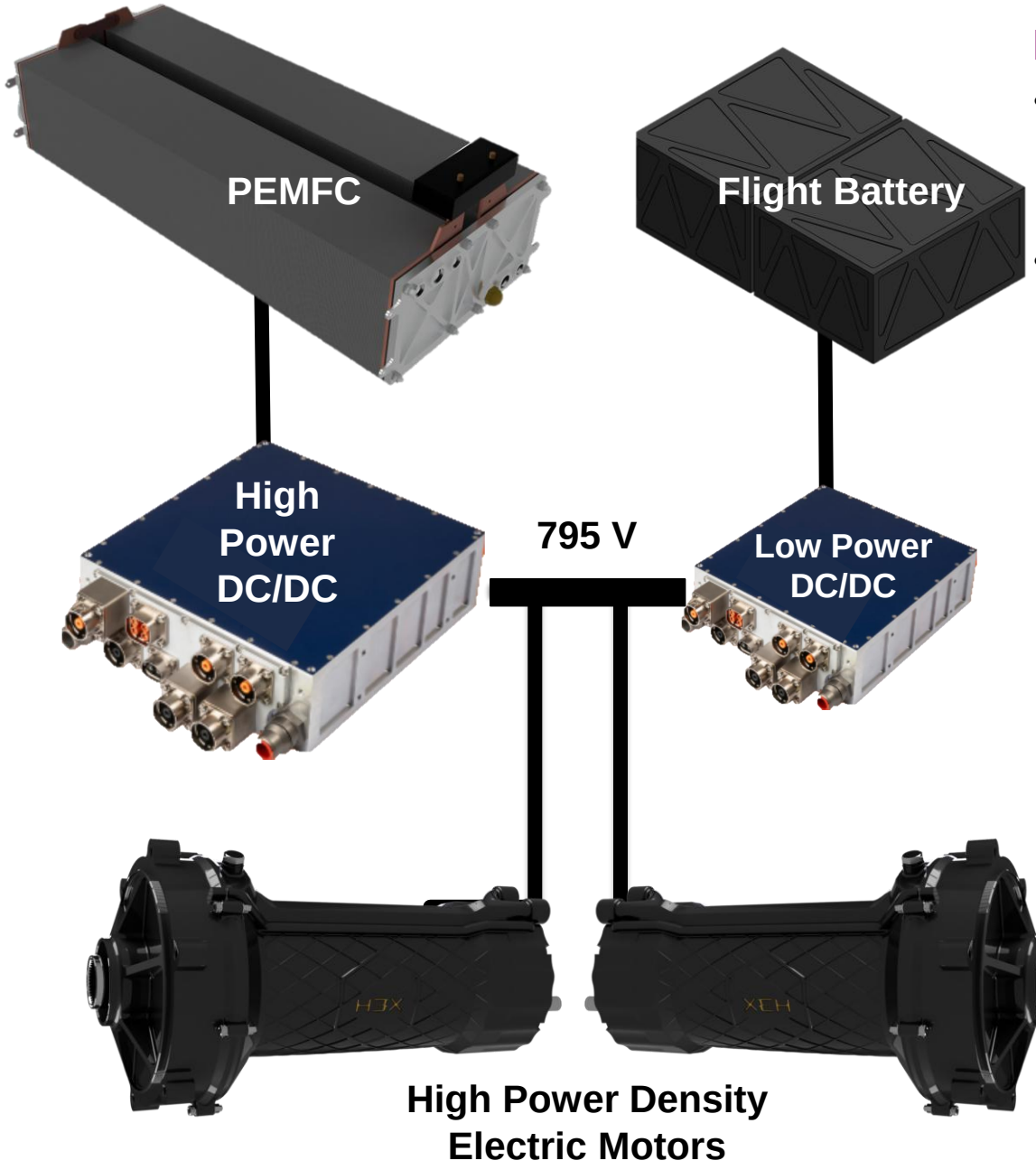
- MCP of 210 kW
- Mass of 127 kg
- 824 Cells
- 1 atm stack pressure eliminates need for air compressor
- Vibration isolating mounts



Safe and Compact Hydrogen Storage

- 2x Type IV, 700 bar tanks with 24.8 kg of storage
- Tanks equipped with pressure release valve, hydrogen detector, and energy absorbing honeycomb

Endurance Boosting Plug-In Hybrid Architecture

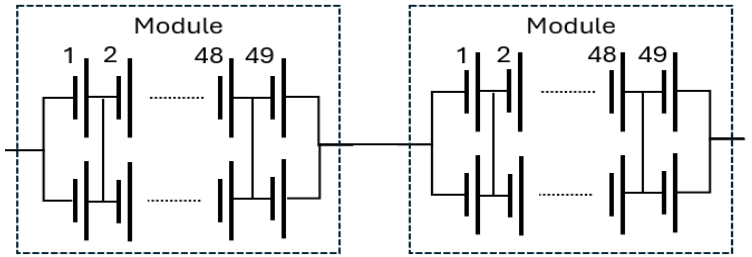


Hover Enhancing Parallel Propulsion

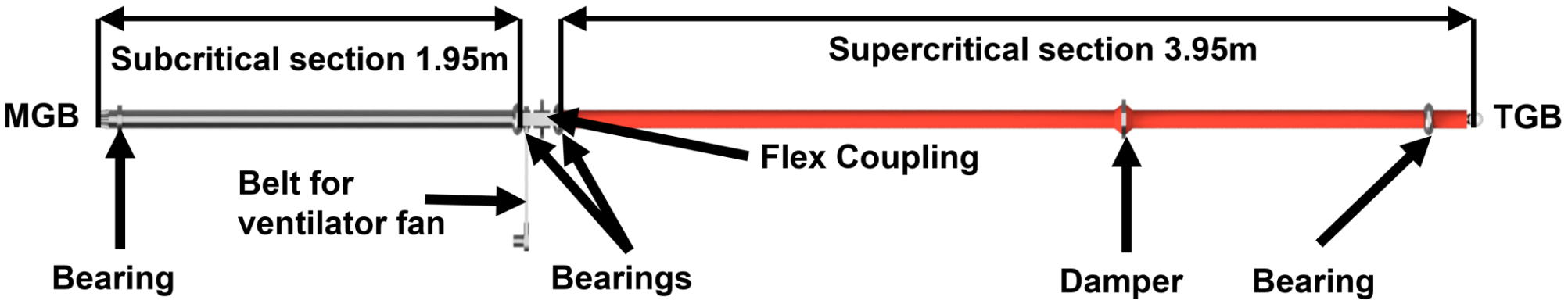
- Battery provides ~25% of power during hover, allowing reduction of PEMFC and cooling system weight
- Powerplant redundancy allows power-assisted autorotation

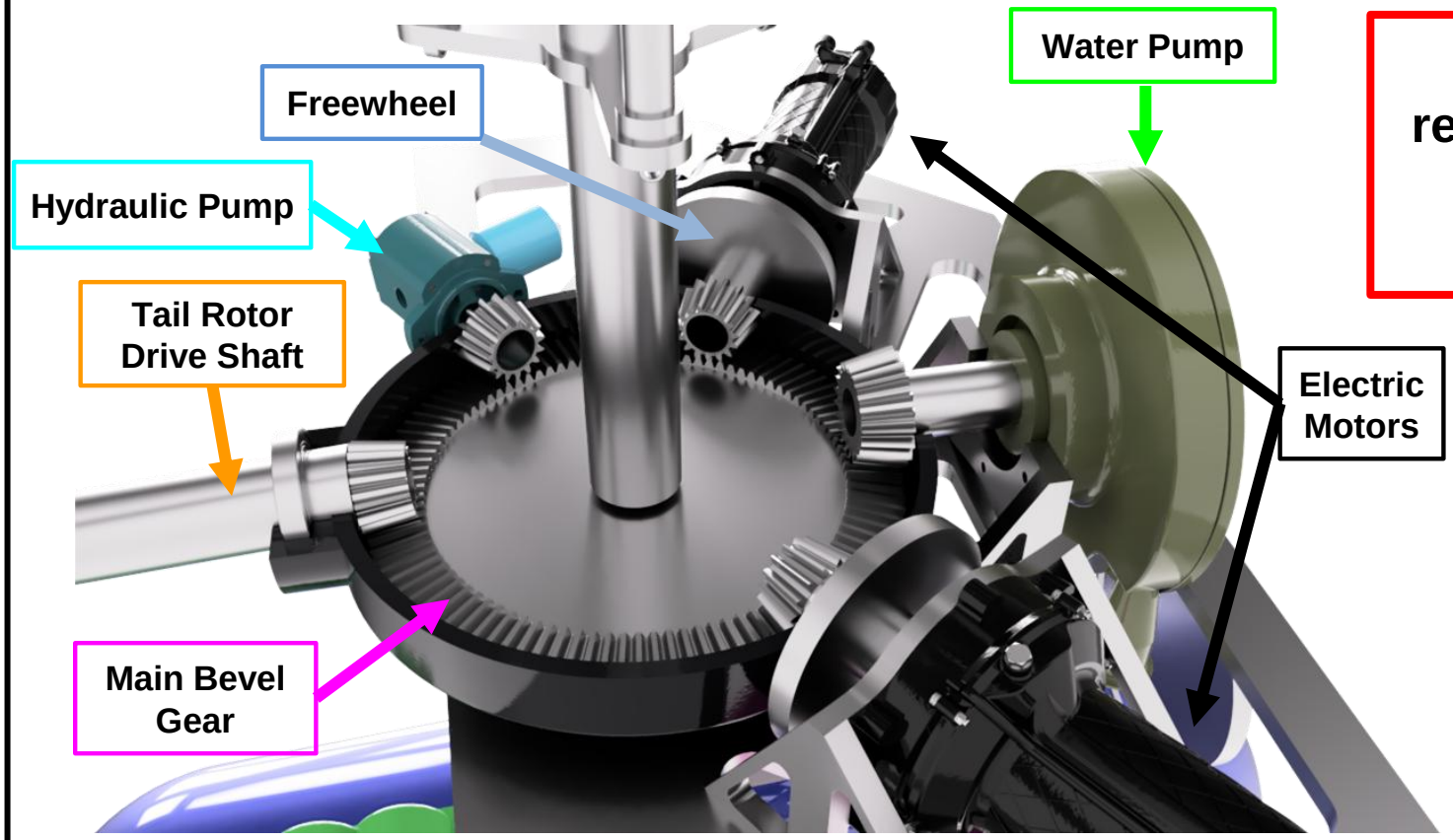
High Power Flight Battery

- 10C Silicon Anode Cells allow 223 Wh/kg and 2.23 kW/kg on pack level
- 67 kW Nominal, 100 kW Burst
- 20 Ahr capacity
- Pack has two 49S2P modules



Supercritical Electromechanical Drive

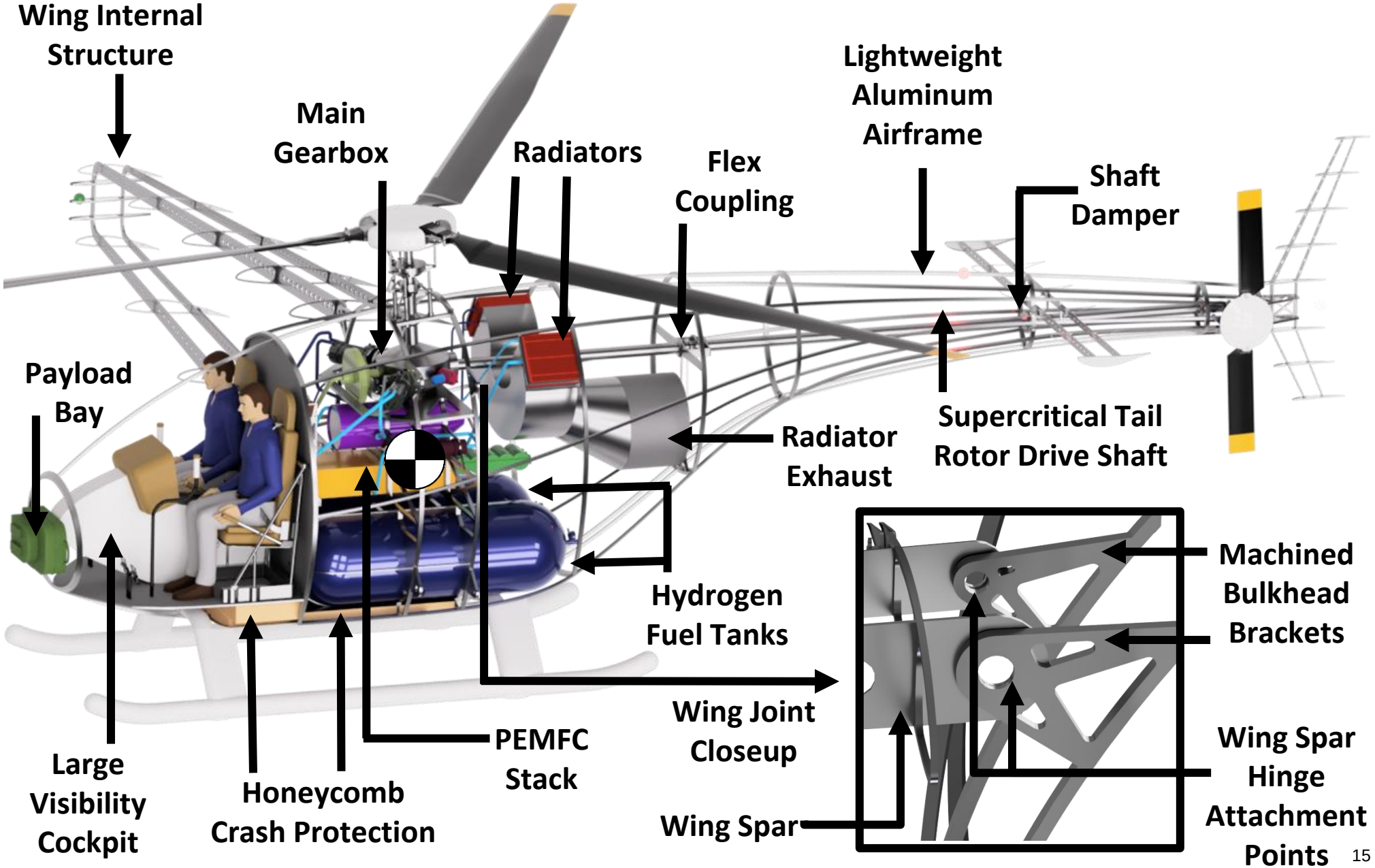




Supercritical shaft reduces weight by 50% compared to a subcritical shaft

Single-stage gearbox reduces weight by 70% compared to a two-stage reduction

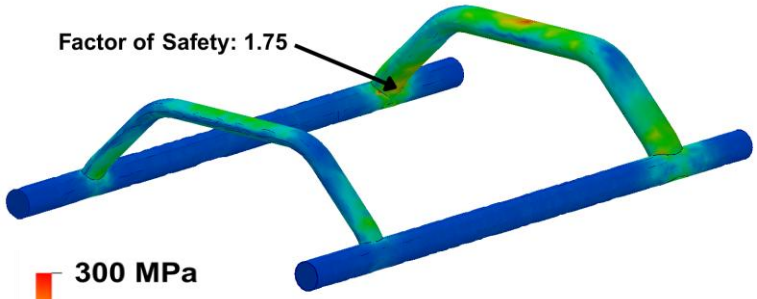
Wyvern Cutaway

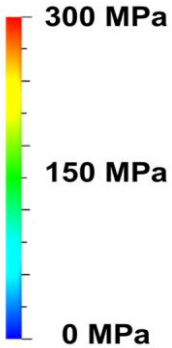


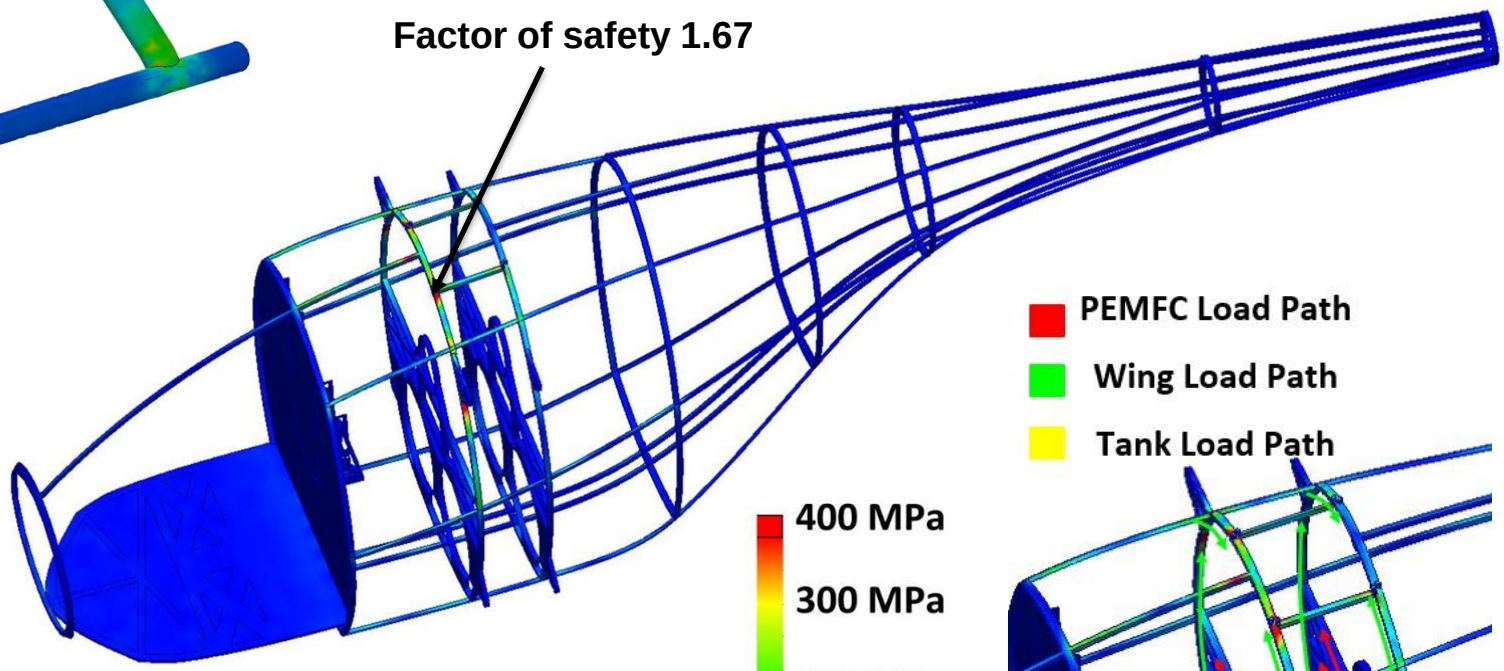
Roll-Over and Resonance-Free Airframe

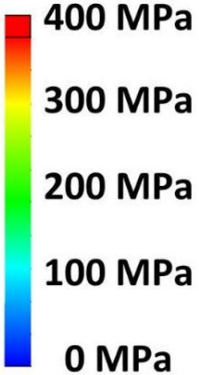
WYVERN

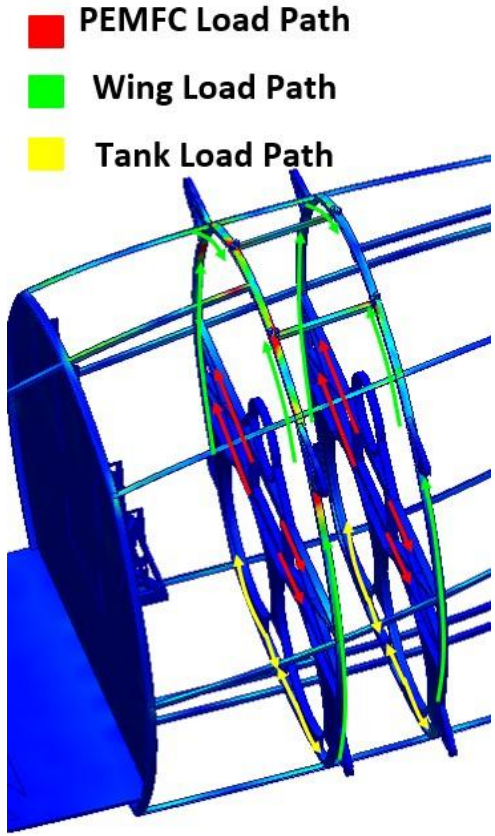
FEA simulation under 3.5g loads









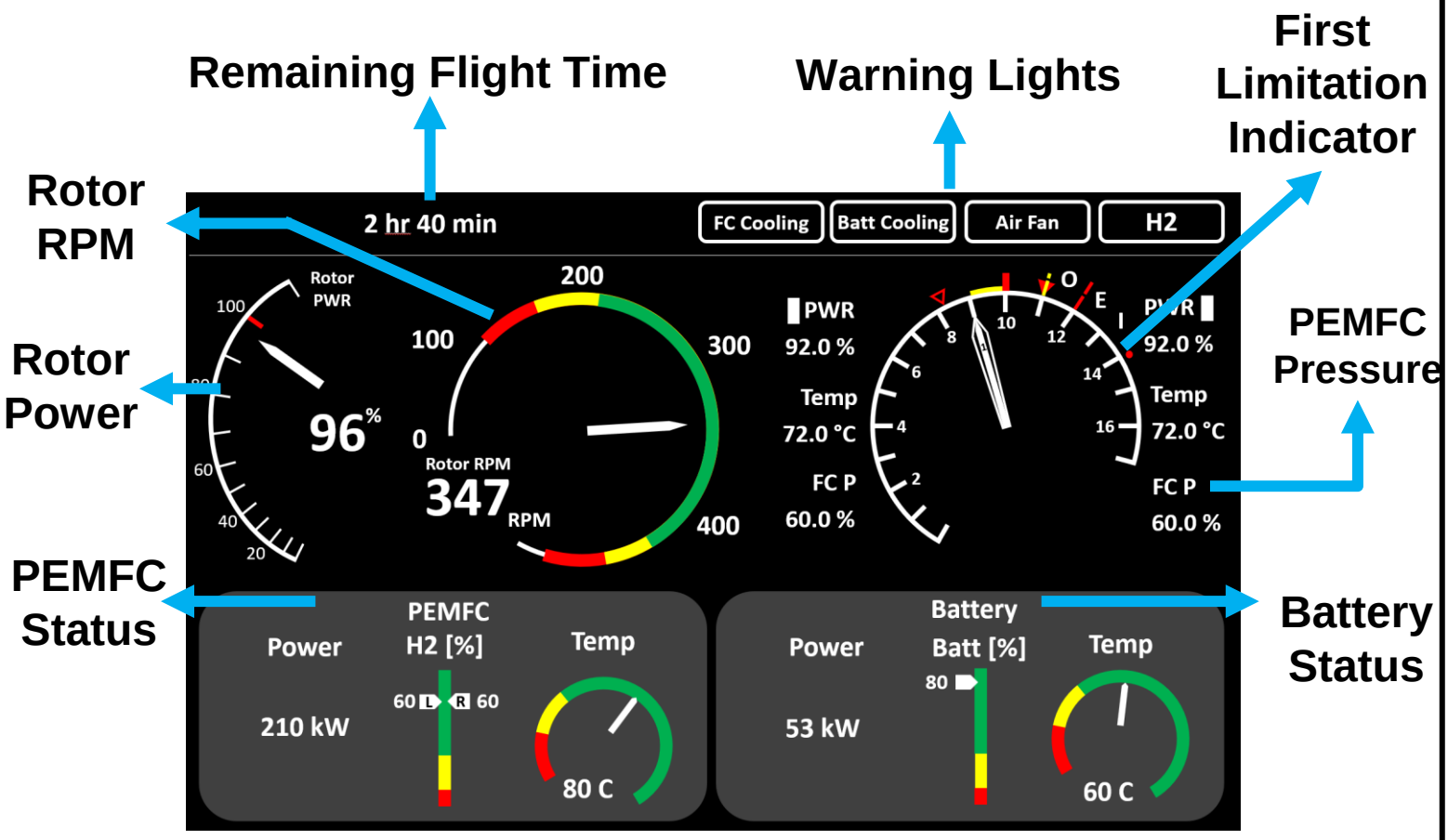


Tip-over angle

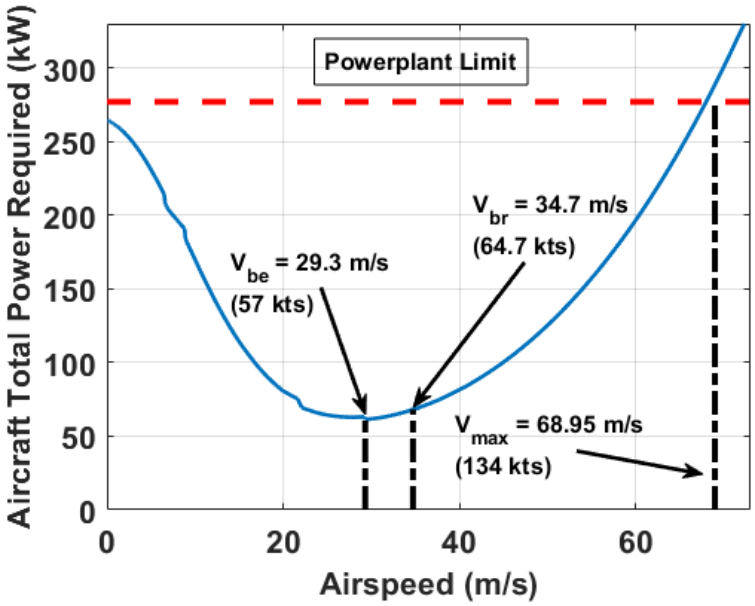
Pitch angle

Cockpit Avionics & Advanced Pilot Interface

Engine Monitoring System for PEMFC



Unprecedented Loiter, Uncompromised Hover

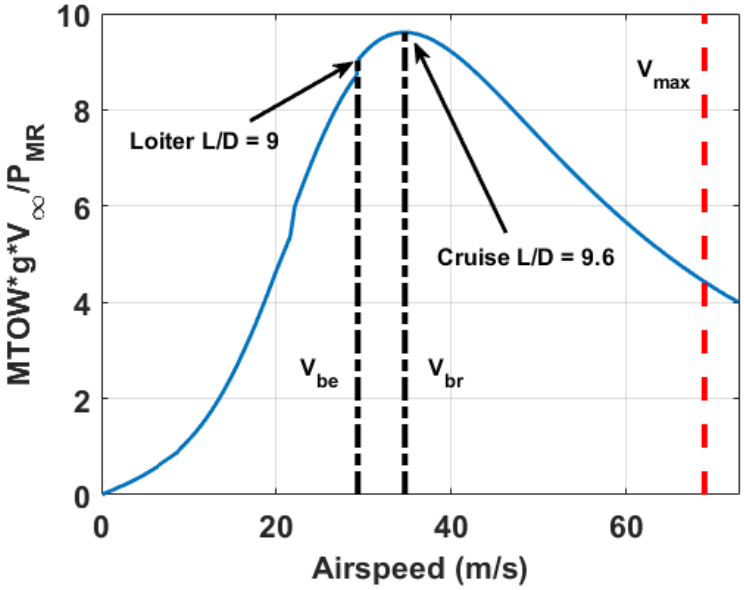


- Highly efficient box wing
- Optimal lift share through slowed rotor
- Streamlined airframe produced:

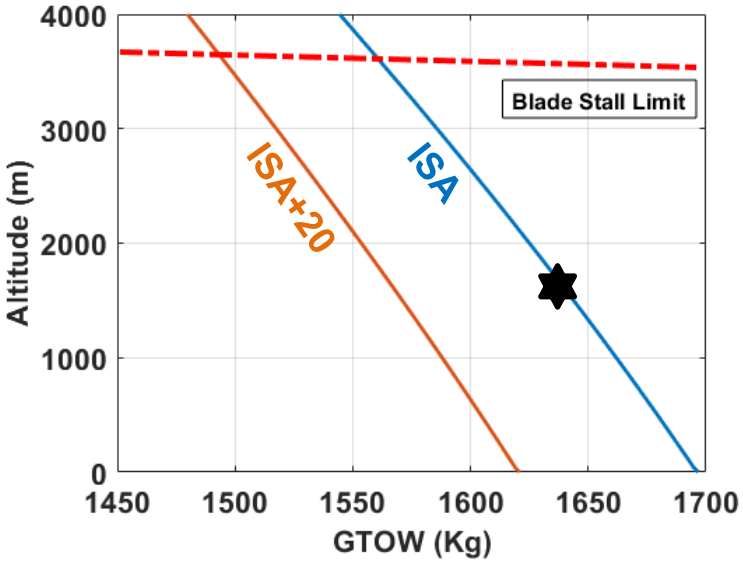
$(L/D)_e = 9$ in Loiter

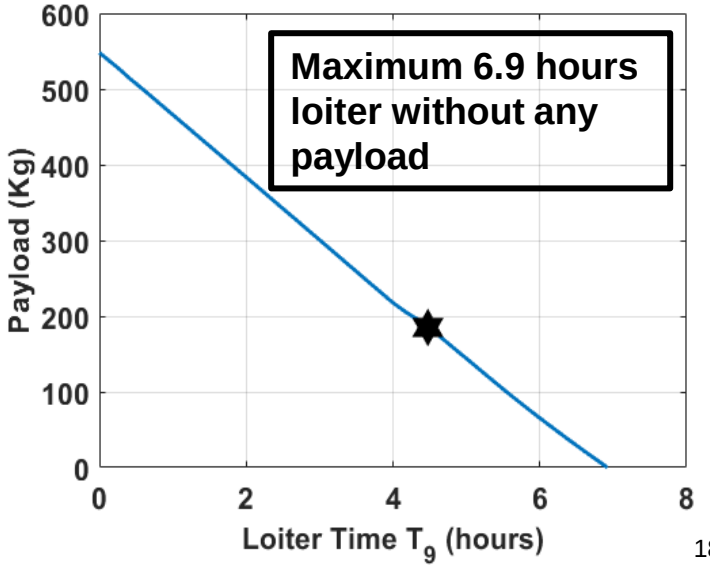
Enabling 4.5 hours of Endurance

FM prioritized rotor optimization for low specific power stack, ensured exceptional loiter as well as hover performance.

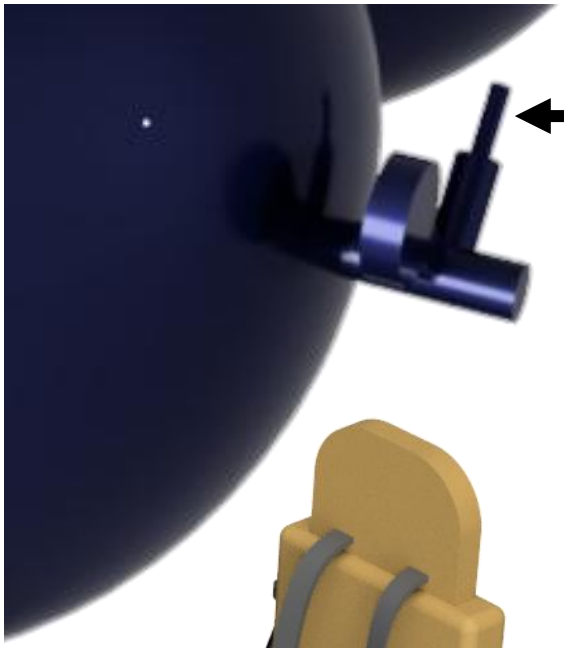


★ **HOGE Ceiling at GTOW = 1390 m**





Safety Features

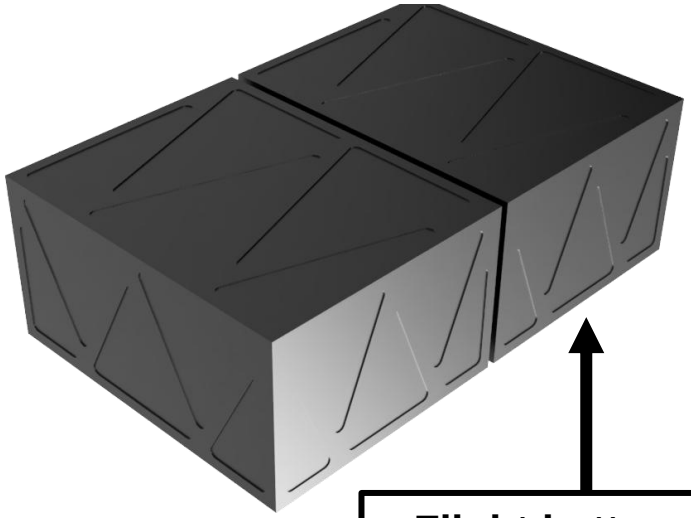


Hydrogen Relief Valves

Aluminum Hydrogen Tank Cage

Nomex/Kevlar Honeycomb Mesh

Inversion Tube VLEA systems installed to provide tuned energy absorption over a wide range of occupant profiles



Flight battery enables power-assisted autorotation

Summary

Wyvern is a hydrogen-powered lift-compound SMR designed for long endurance missions**.**

Long endurance capability

- Maximum endurance: 4.5 hours
- Maximum range: 562 km
- Total H2 required: 24.8kg

Affordability

- 1,193,000 USD
- 734 USD per flight hour

Wyvern's capability for additional missions

Aerial Survey

Firefighter Command and Control

Crop-dusting