



AIRBUS

42nd VFS Annual Student Design Competition Pioneering Hydrogen-Electric VTOL

Proposed by Team HOPPER

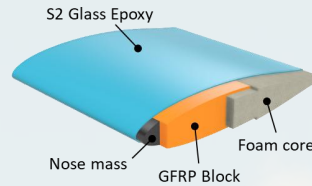
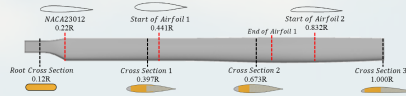
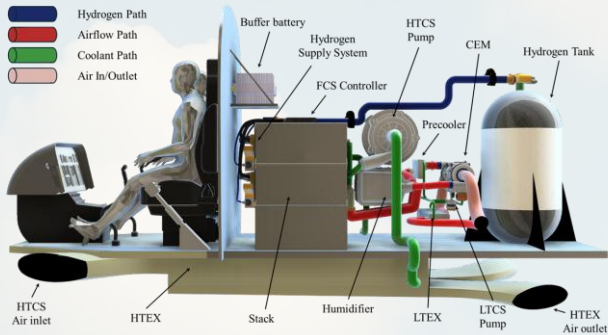


Executive Summary

SNU Graduate Design Team

Team HOPPER at Seoul National University

Design Summary

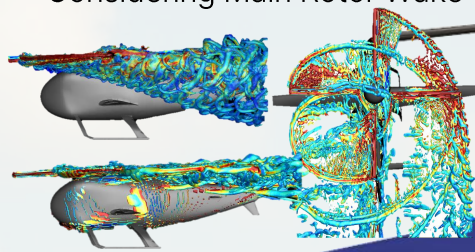


Optimized Fuel Cell System

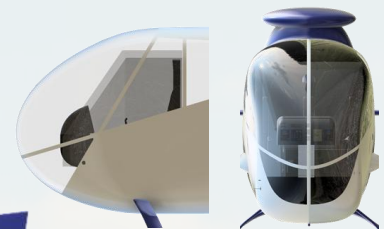
Hingeless Hub & Optimized Rotor

Wing Positioning

Considering Main Rotor Wake



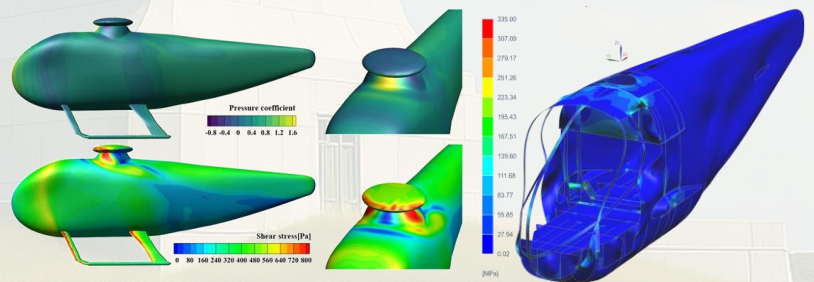
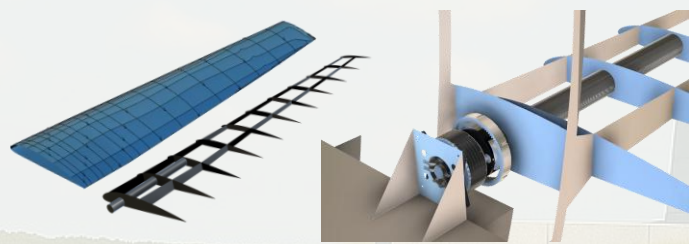
Cabin Design for Sightseeing



Fuselage Design

Aerodynamic and Structure Design
Under CG and Internal Volume Constraint

Variable incidence wing & tail
For maximized loiter performance



Specifications

Weights		Value		Velocity		Value		Performance		Value	
Gross Weight	2,000 kg	4,409 lb	V_{climb}	26.13 m/s	50.79 knots	Loitering Mission Time		39.34 min			
Empty Weight	1,804 kg	3,976 lb	V_{br} (Cruise)	52.22 m/s	101.51 knots	Maximum Speed		70.5 m/s	137 knots		
Fuel Weight	11 kg	24 lb	$V_{descent}$	25.00 m/s	48.60 knots	Maximum Ceiling Altitude @ 0°C		4,300 m	14,100 ft		
Payload	185 kg	408 lb	V_{be} (Loiter)	41.65 m/s	80.96 knots						



HydrOgen ProPulsion for long-Endurance Rotorcraft

HOPPER – HydrOgen ProPulsion for long-Endurance Rotorcraft – is a **Slowed-Rotor Compound Helicopter with Variable-Incidence Wing and Tail** developed by the SNU Graduate Student Design Team.



Powered by PEMFC, HOPPER 'redefines' endurance and sustainability in the rotorcraft domain.

HOPPER, at a gross weight of 2,000 kg (4,409 lb), completes a **69.25-minute** mission—**39.34 minutes of immersive sightseeing loiter** over the Alligator River—using just **11 kg of hydrogen fuel** while carrying a 185 kg payload.

This achievement was possible by constructing a physics-based fuel cell system design optimization considering thermal demands, and hover-optimum rotor with slowed down forward flight capability. By adopting the variable incidence wing & tail mechanism, HOPPER maximizes lifting force in every forward flight mission segment. Its fuselage was designed while accounting for internal components volume constraints, aerodynamic & structural efficiency, and target CG location.

HOPPER is not a mere technical leap—it is a symbolic hop toward sustainable aviation. It fulfills all mission requirements while offering an uncompromised eco-tourism experience.

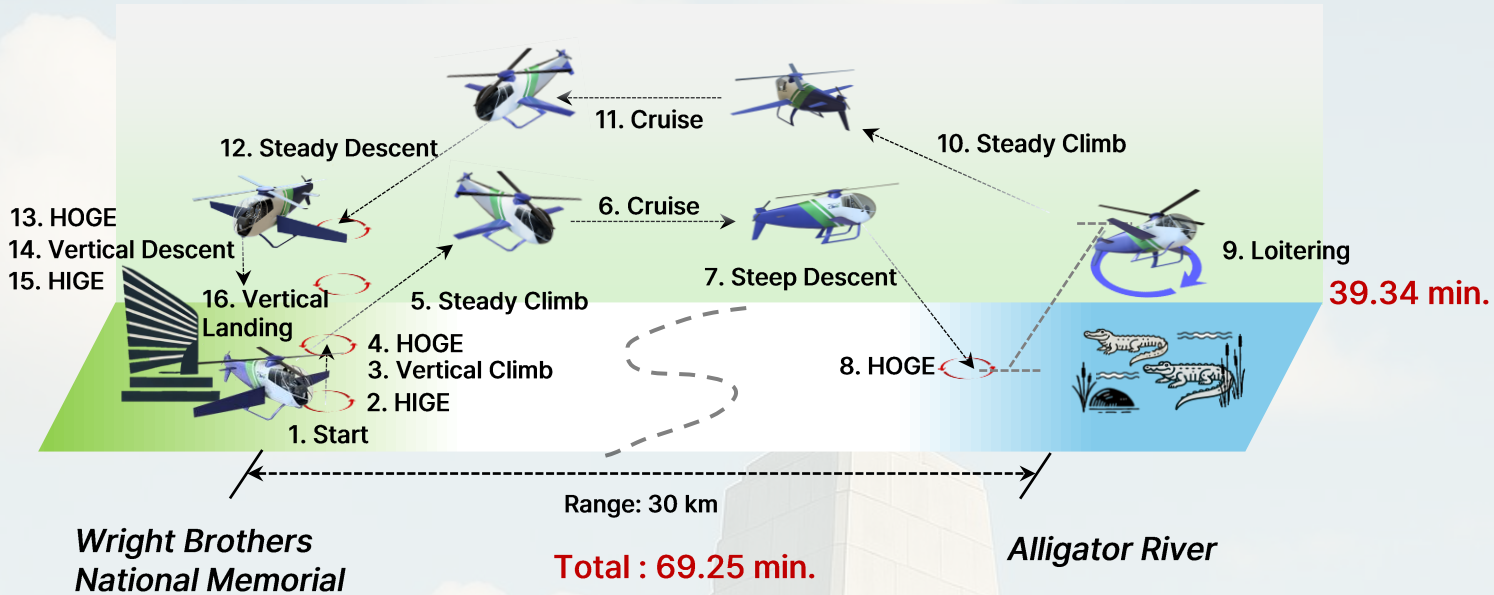
Let's hop for hope with HOPPER.



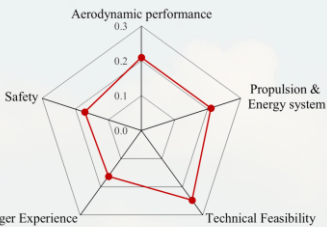
Mission Requirements Analysis

Values shown in red were designed by TEAM HOPPER

 Hover (OGE/IGE)



Aircraft Configuration Selection

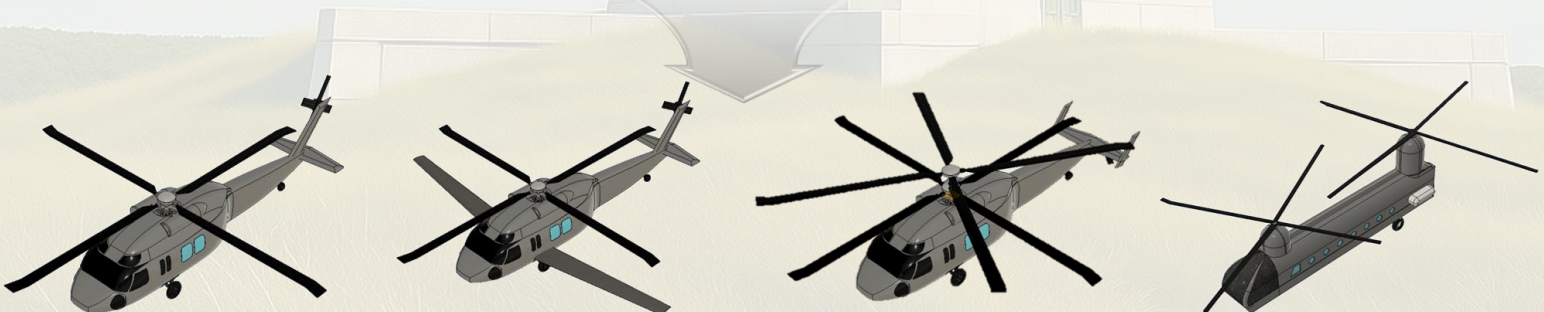


Configuration	Weight	Power	Range	Time	Altitude	Speed	Maneuverability	Stability	Control	Reliability	Maintainability	Cost
Single helicopter	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Compound Single helicopter	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Coaxial rotor helicopter	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Compound coaxial rotor helicopter	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Multicopter	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Lift+Cruise	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Tandem rotor helicopter	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Tailsitter	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Vectored thrust	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Single helicopter	Compound Single helicopter	Coaxial rotor helicopter
Compound coaxial rotor helicopter	Multicopter	Lift+Cruise
Vectored thrust	Tailsitter	Tandem rotor helicopter

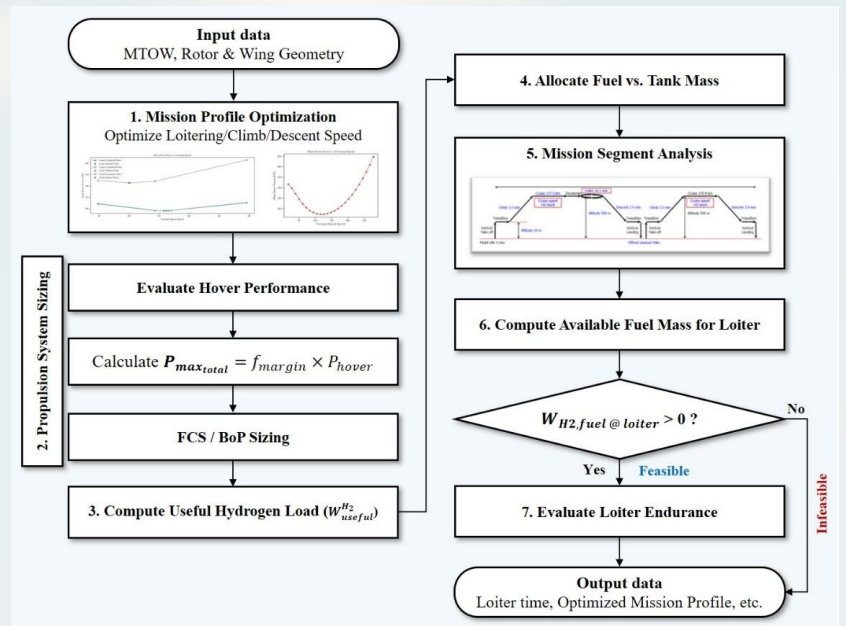
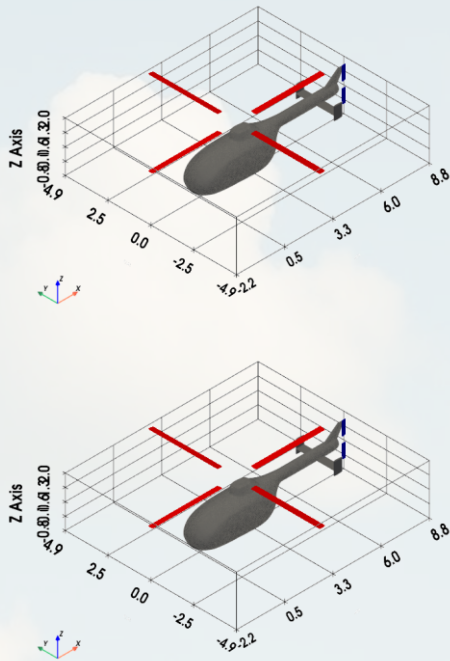
Mission Analysis (AHP & HOQ)

Configuration Candidates

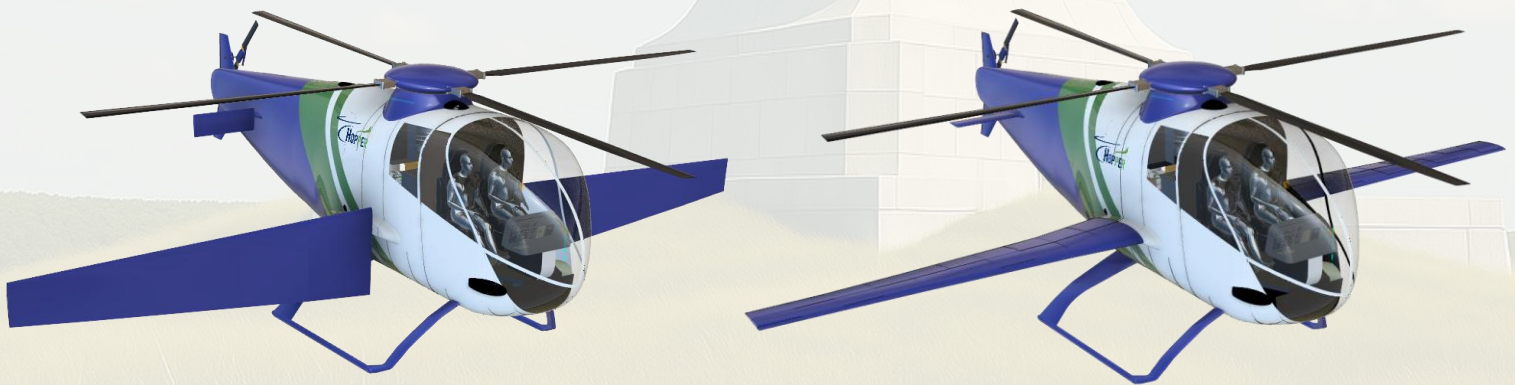


Filtered Configuration Candidates

From Initial Sizing & Trade-Off Study



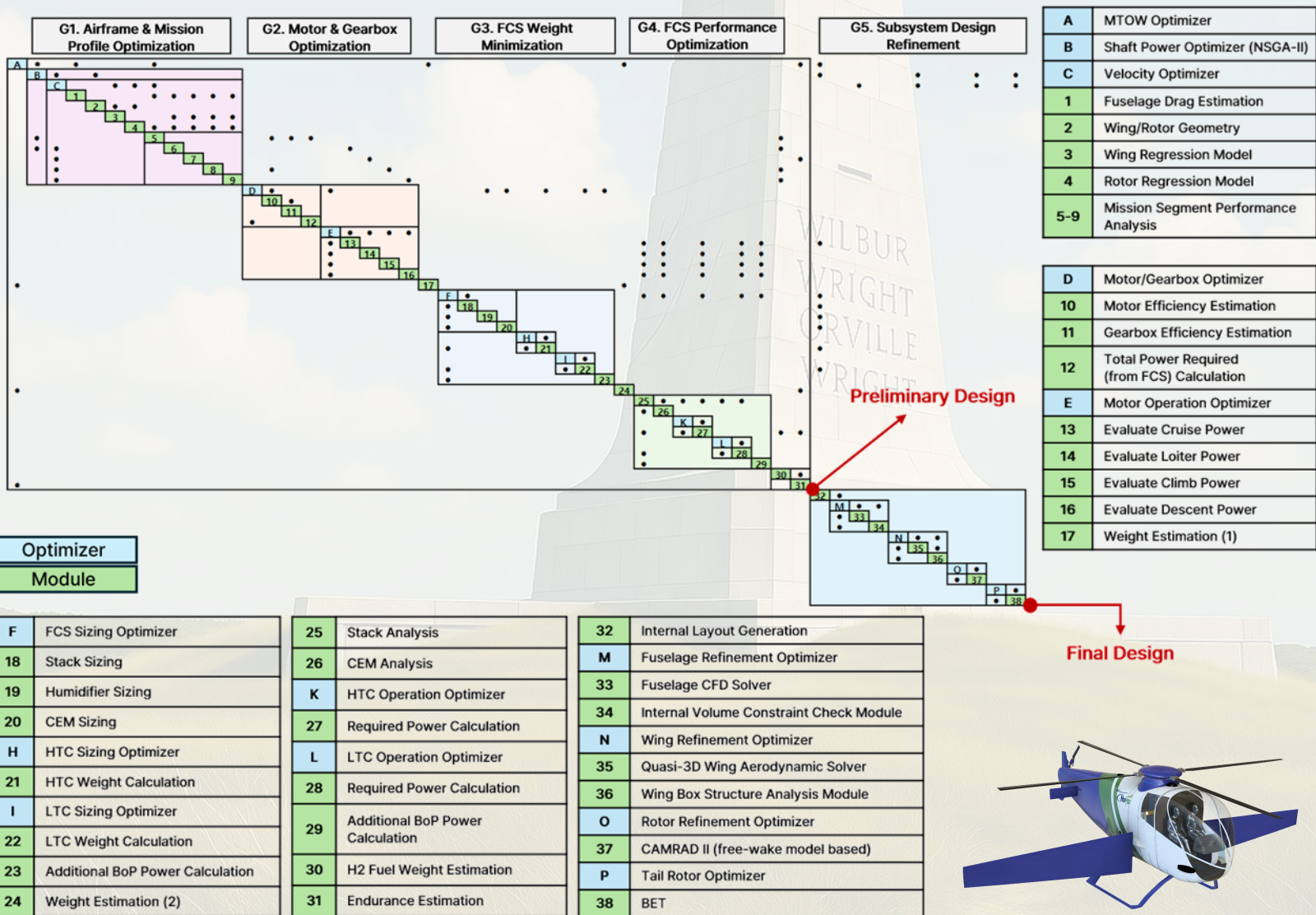
“Variable incidence wing” concept was selected through the customized sizing framework



An Innovative Multidisciplinary Design Optimization Framework Was Adopted

Our **Multidisciplinary Design Optimization (MDO)** framework efficiently generates a preliminary design for a hydrogen fuel-cell-powered compound helicopter with a focus on **maximizing loiter endurance**.

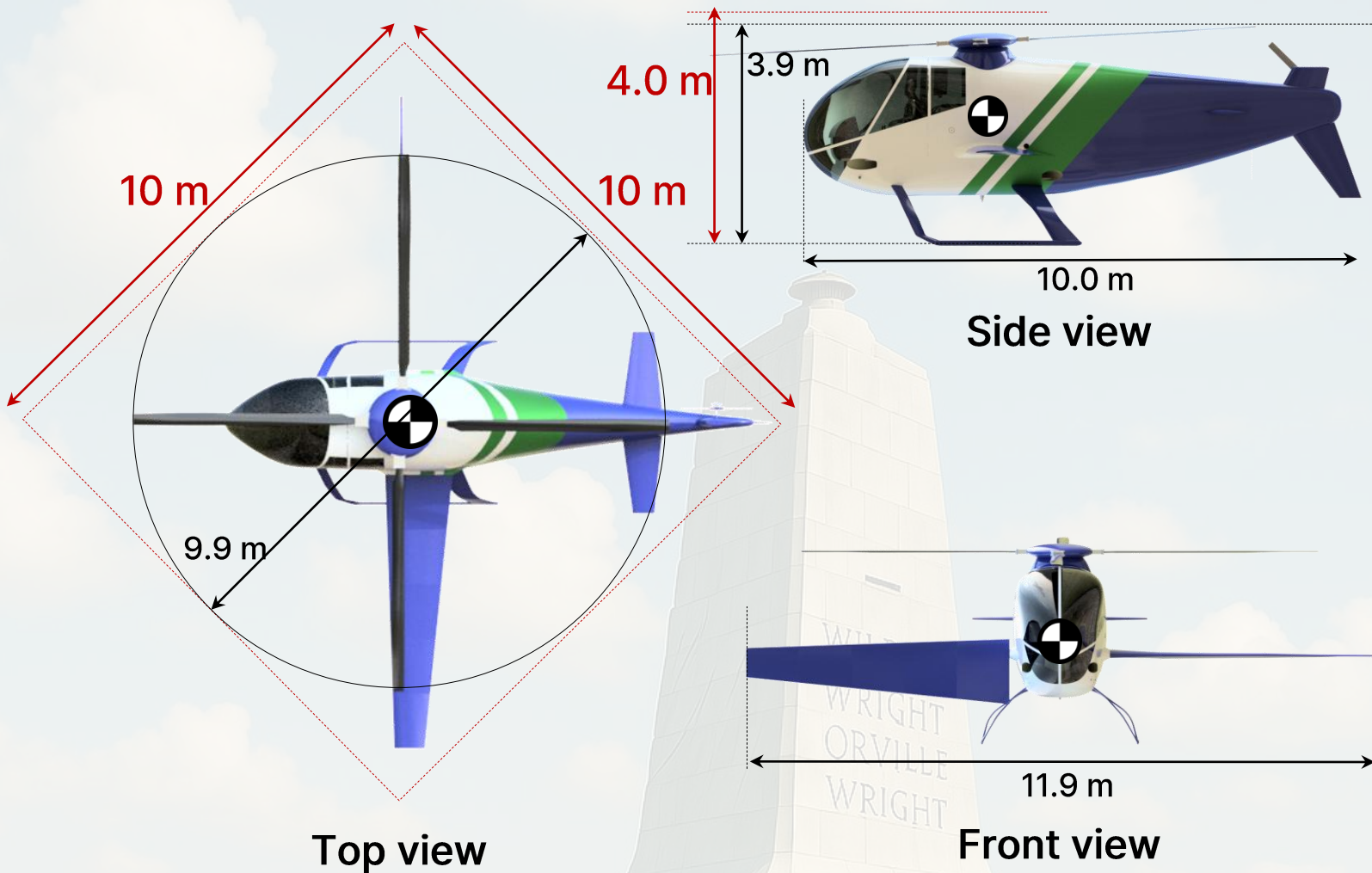
By structuring the process into **five coordinated modules with minimal feedback loops**, the framework expands design flexibility, reduces computational cost, and **quickly identifies endurance-optimized configurations within defined constraints**.



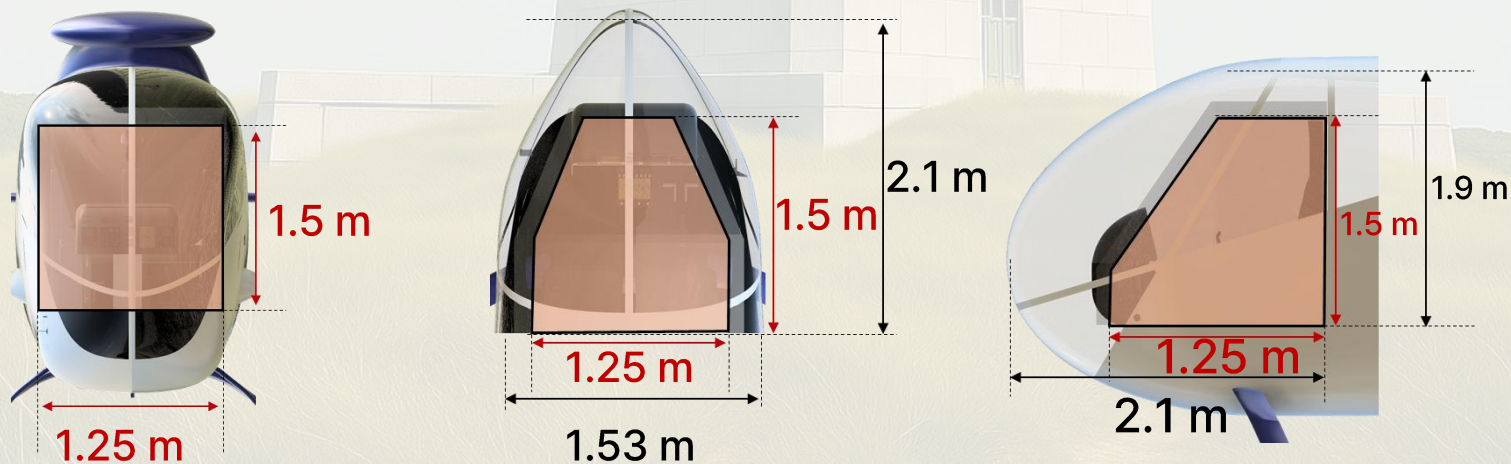
Final Design Results

Aircraft and Cabin Dimensions

Aircraft Dimension Constraints (10 m × 10 m × 4 m)

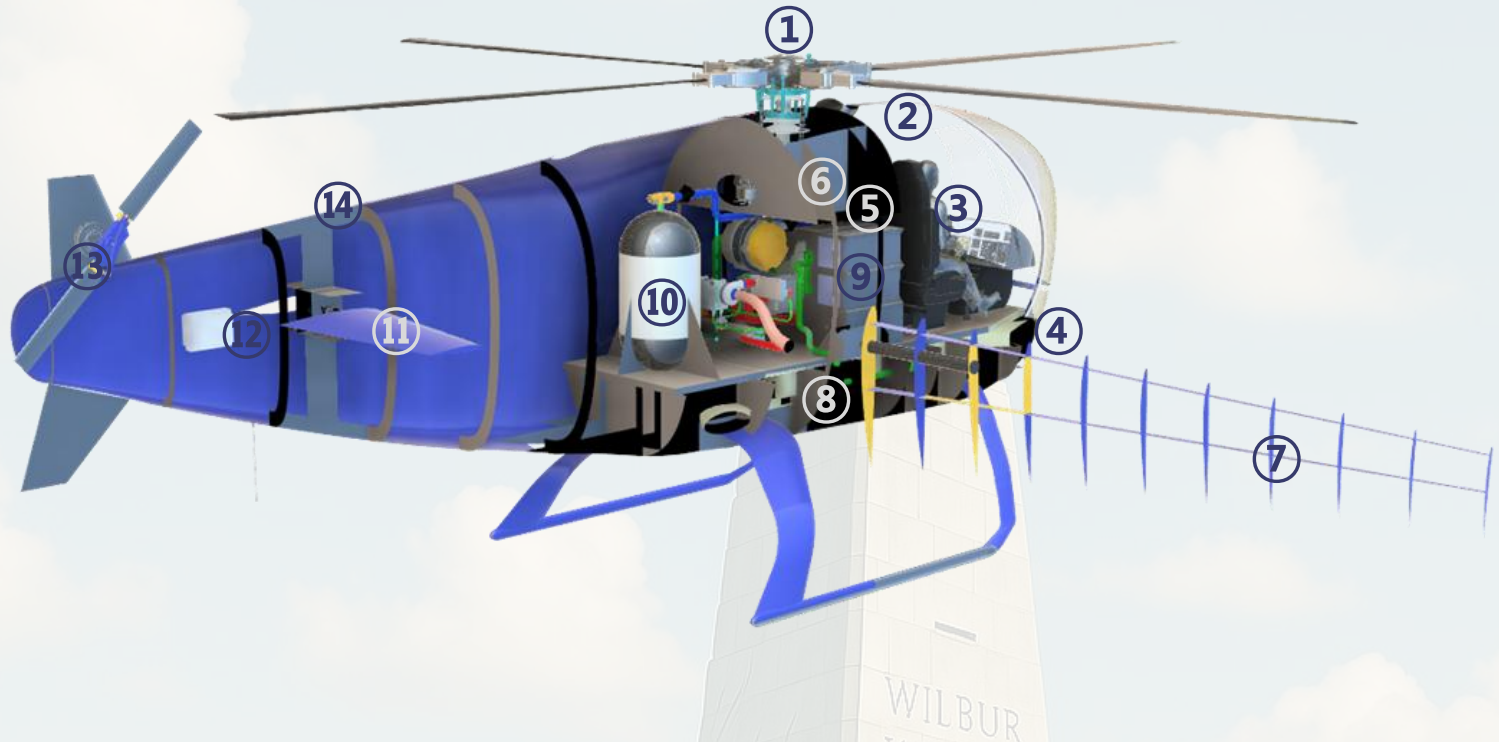


Cabin Minimum Dimension Constraints (1.25 m × 1.5 m × 1.5 m)



Final Design Results

Internal Components and Layout



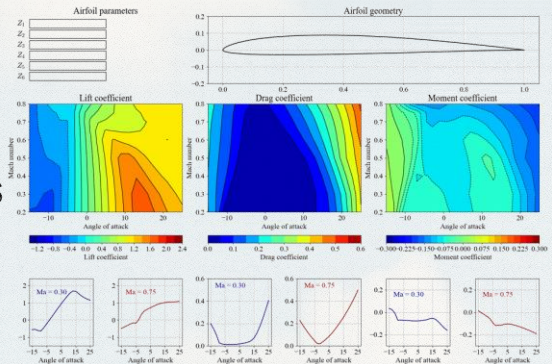
No.	Component	No.	Component
1.	Hingeless rotor hub	8.	Heat exchanger
2.	Gearbox airintake	9.	Fuel cell stack
3.	Digital instrument	10.	Hydrogen tank
4.	FCS air intake	11.	Tail wing with tilt mechanism
5.	Firewall	12.	Auxiliary battery source for tail rotor
6.	Gearbox	13.	Tail rotor
7.	Wing structure	14.	Fuselage structure

Integrated Aero-structural Blade Design

Airfoil Brain

2D Aerodynamic Performance Predictor

- ✓ Using only 6 parameters to generate airfoils
- ✓ Trained by 2D URANS CFD data
- ✓ Fast and accurate prediction of C81 tables



X-ray image

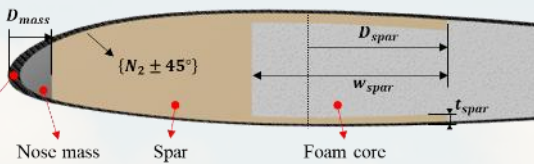


Parameterization

C-beam Generator

2D Structural Performance Predictor

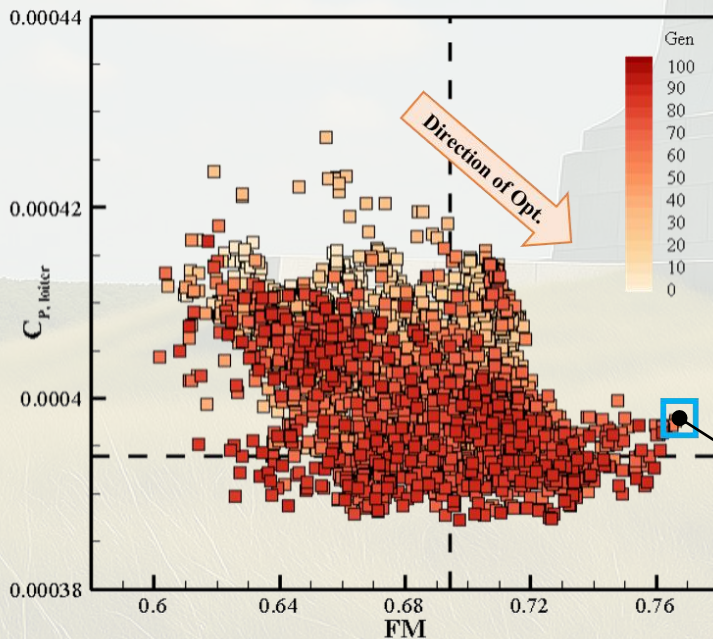
- ✓ Parameterization based on X-ray scan data
- ✓ Trained by 2D cross section solver KESC2D-AE
- ✓ Fast and accurate prediction of beam properties



CAMRAD II

Comprehensive solver for aeroelastic analysis

- ✓ Multi-disciplinary Design Space using 40 design variables
- ✓ Realistic design consideration with 22 design constraints

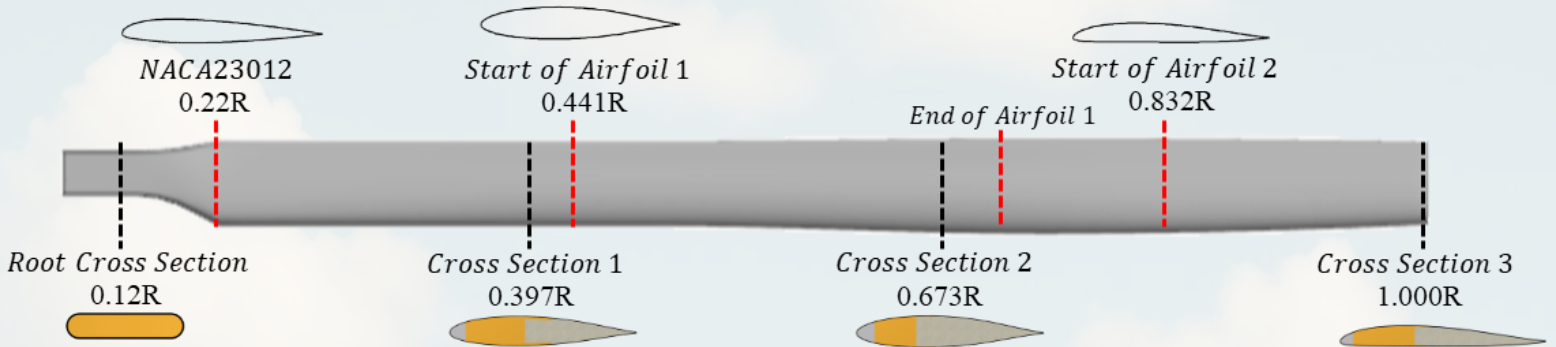


Main Rotor Blade Performance

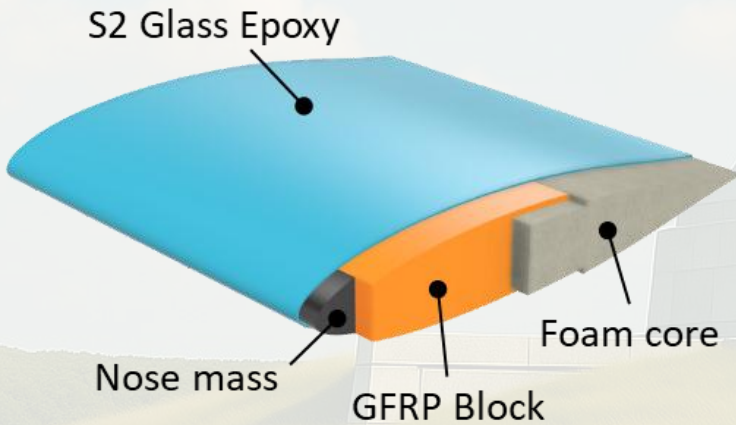
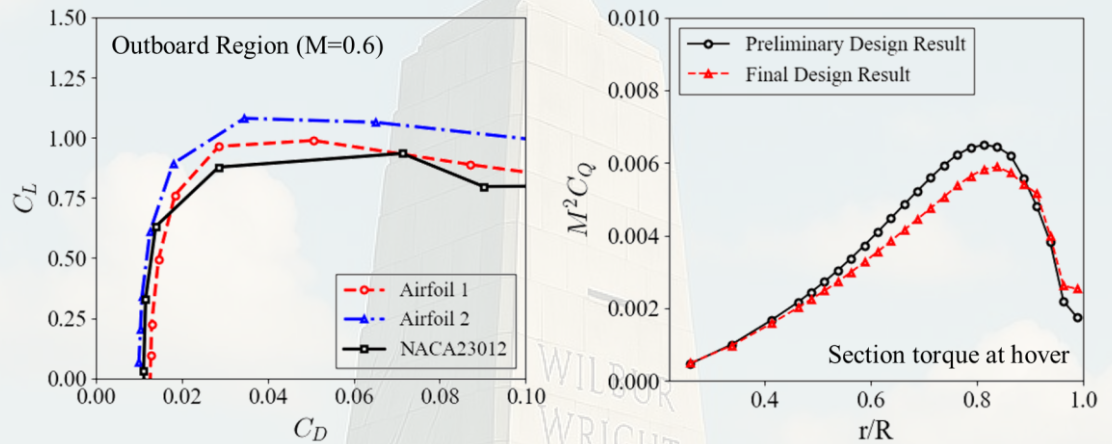
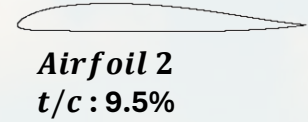
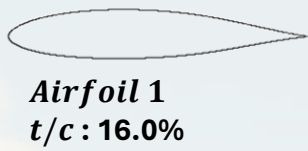
FM	0.7661
$C_{p,cruise}$	0.0003977
VI	0.02231
Blade Mass	24.92 kg

Best design out of 6400 design candidates

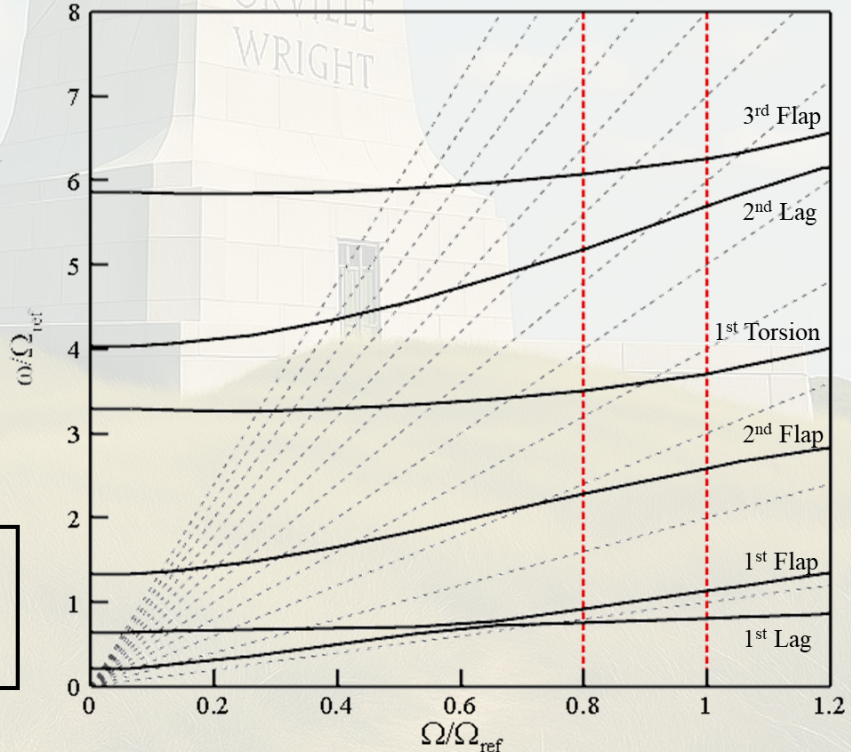
Main Rotor Blade Design Results



Aerodynamically Efficient and Manufacturable Rotor Blade Design



Loiter Hover



Hover
 Flap : 1.13/rev
 Lag : 0.81/rev

Loiter
 Flap : 1.15/rev
 Lag : 0.95/rev

Variable Incidence Wing Design

✓ Advantages: Variable Incidence Wing

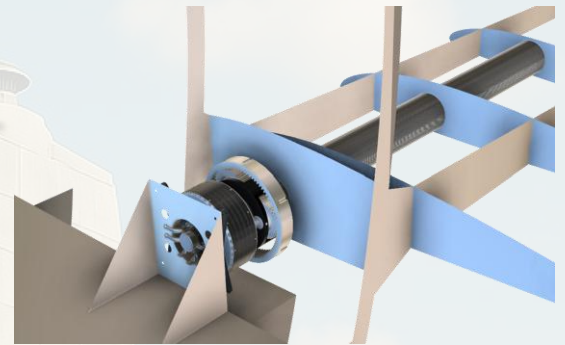
- Maximum lift sharing ratio during the whole flight
- Controlling wing incidence C_L to be 0.8 (Lift sharing constraint up to 50%)
- Minimize the interaction between rotor wake and wing



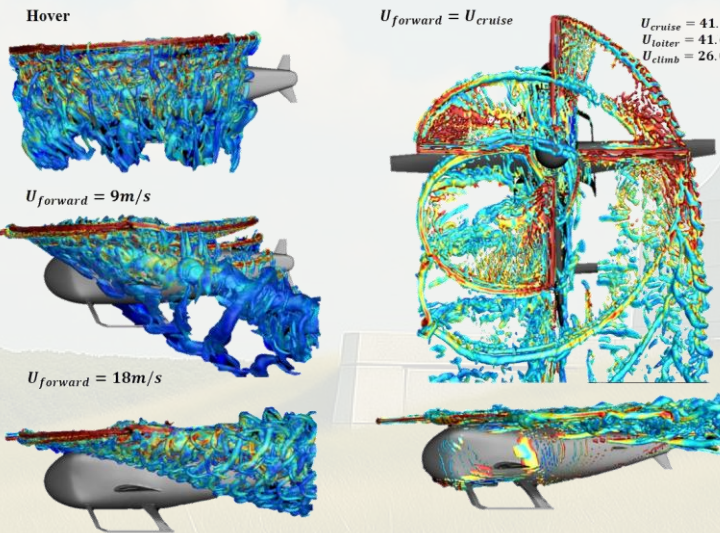
Hover flight
(90 deg tilted wing)



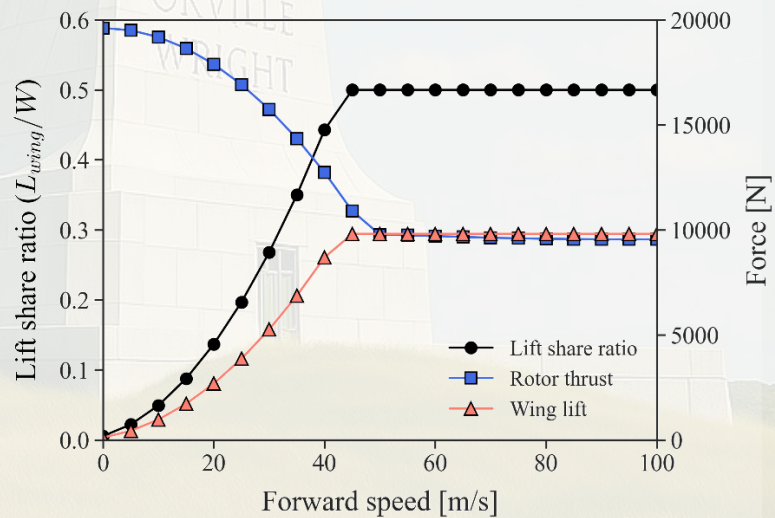
Forward flight
(variable tilt)



Wing tilting mechanism



Consideration on Main Rotor Wake



Lift share ratio with forward speed

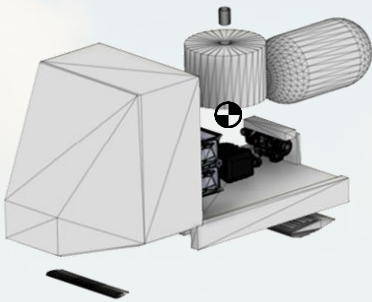
Integrated Fuselage Design:

Center of gravity, Internal volume, Structure, and Aerodynamics

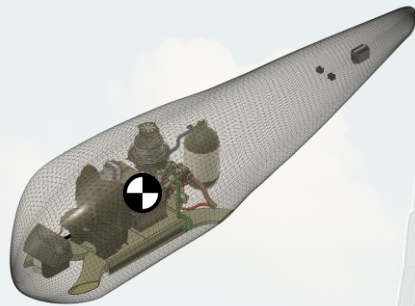
✓ Fuselage design considering:

- Target CG (desired CG)
- Fuselage structural constraints
- Internal component volume
- Low drag coefficient

Targeted Center of Gravity
with internal component volume

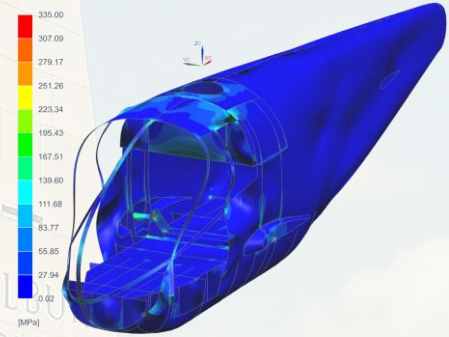


Internal component volume



Optimized fuselage configuration

Fuselage structural analysis

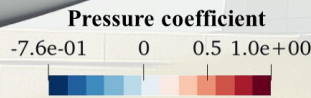


von-Mises equivalent stress (MPa)

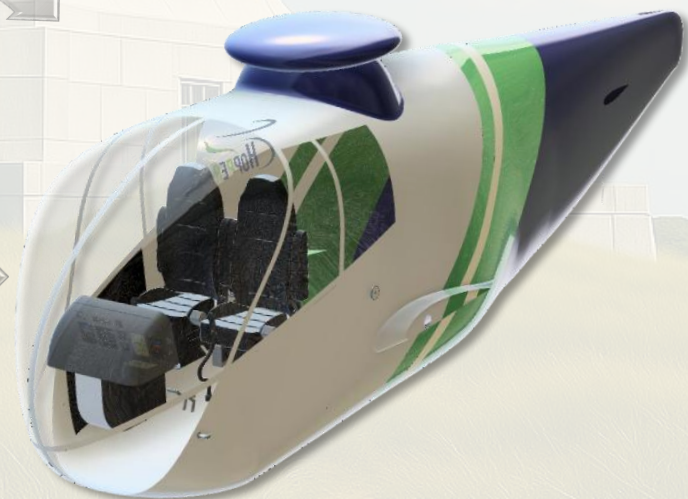
Fuselage aerodynamic analysis



Pressure coefficient variation

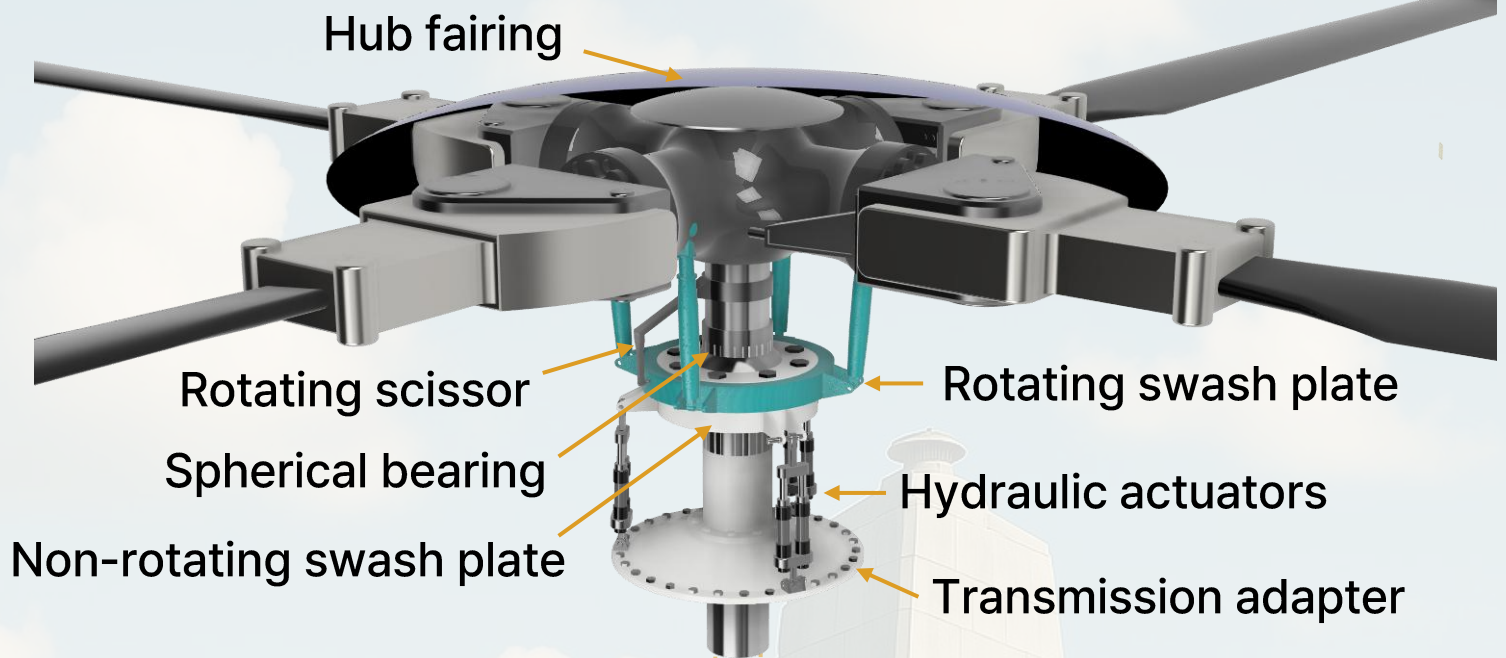


Skin friction coefficient variation



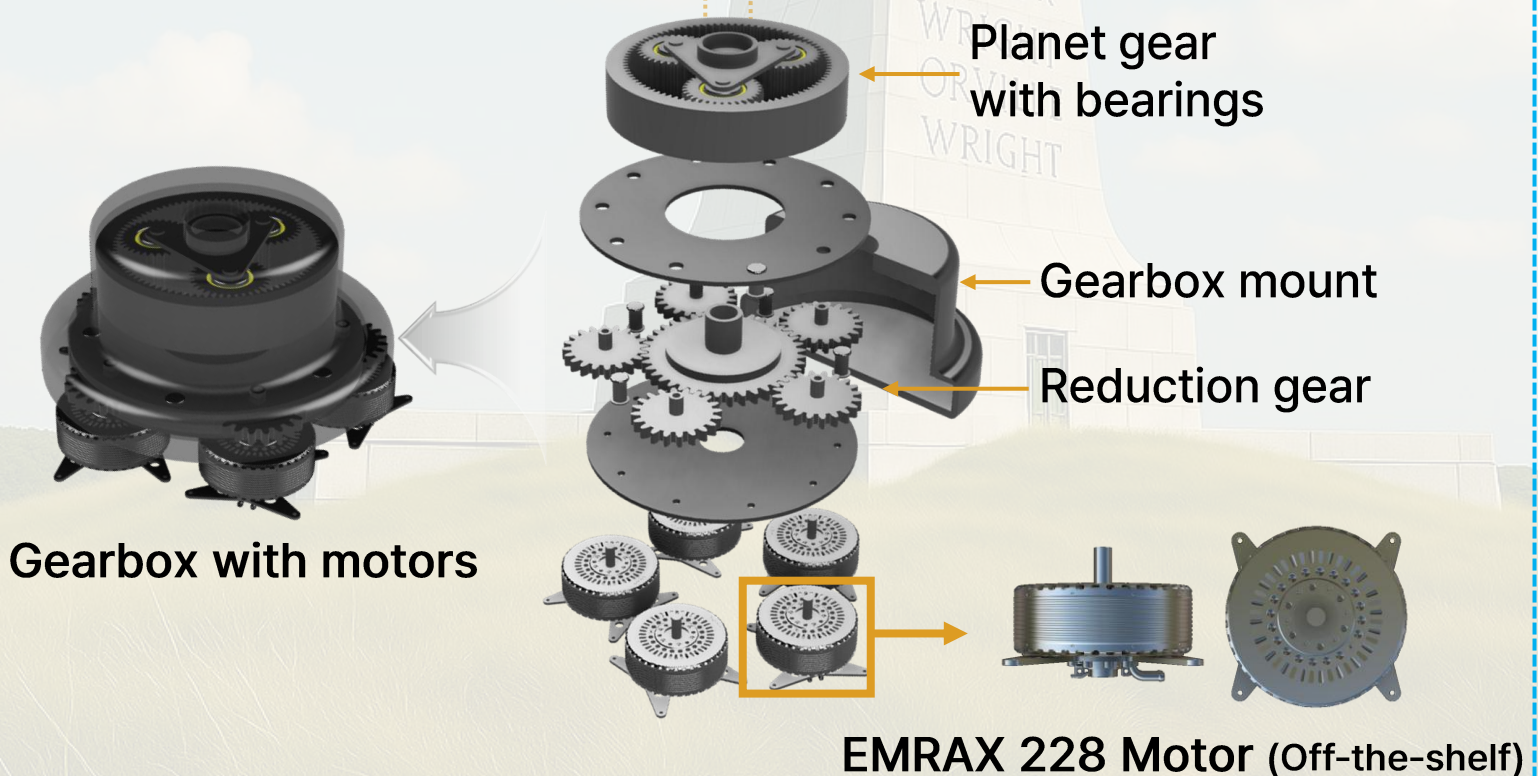
Final design of HOPPER's fuselage

Rotor Hub and Transmission



**Compact and Efficient
Transmission System**

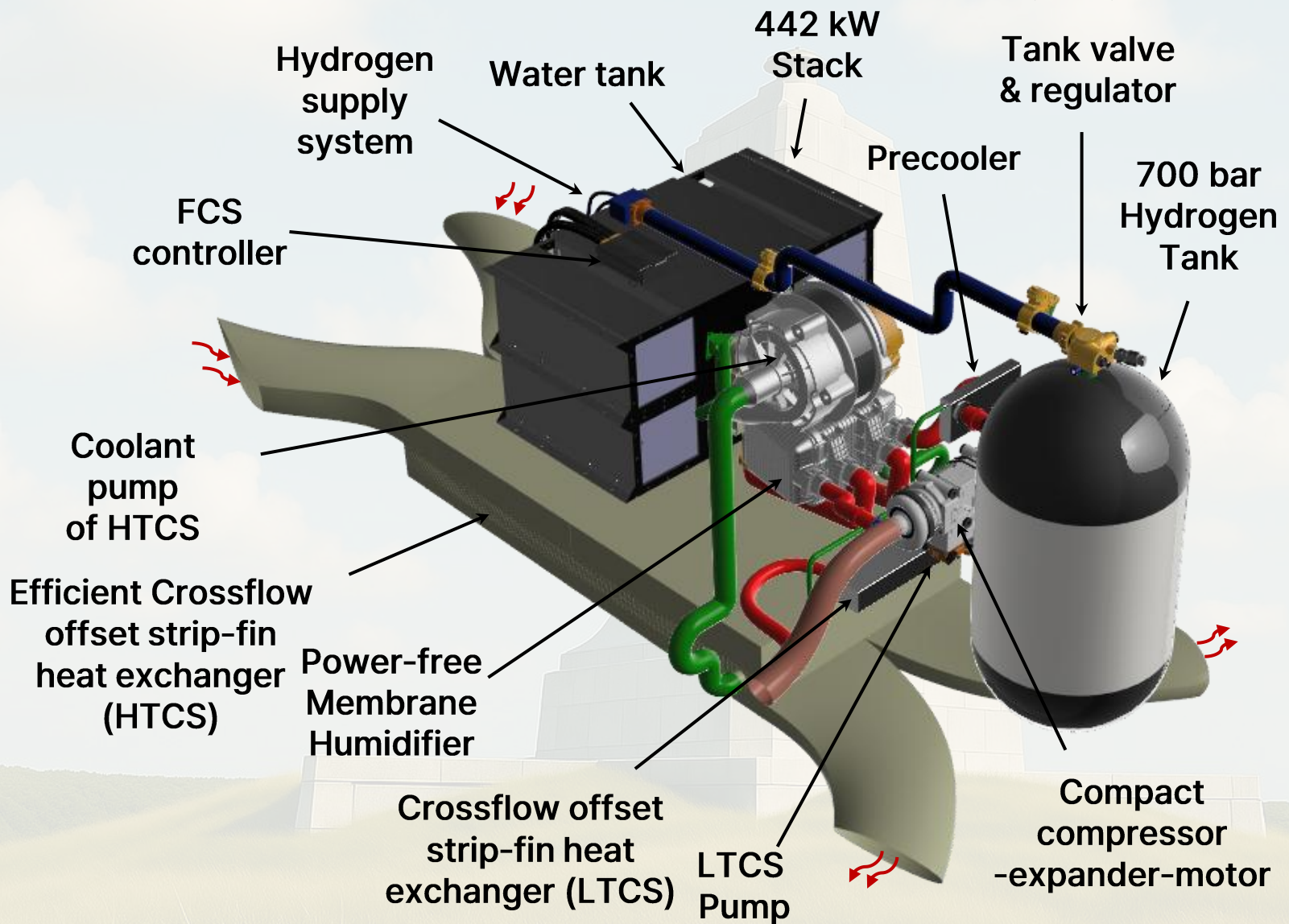
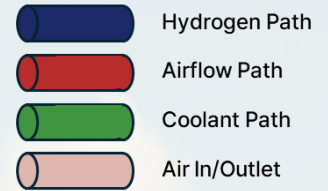
**Robust and Simple
Hingeless Hub System**



Fuel Cell System Layout

✓ Advantages of HOPPER's Fuel Cell System

- Designed to be low-powered, lightweight and compact system
- Realistic integration among the components
- Added expander to maximize energy recovery

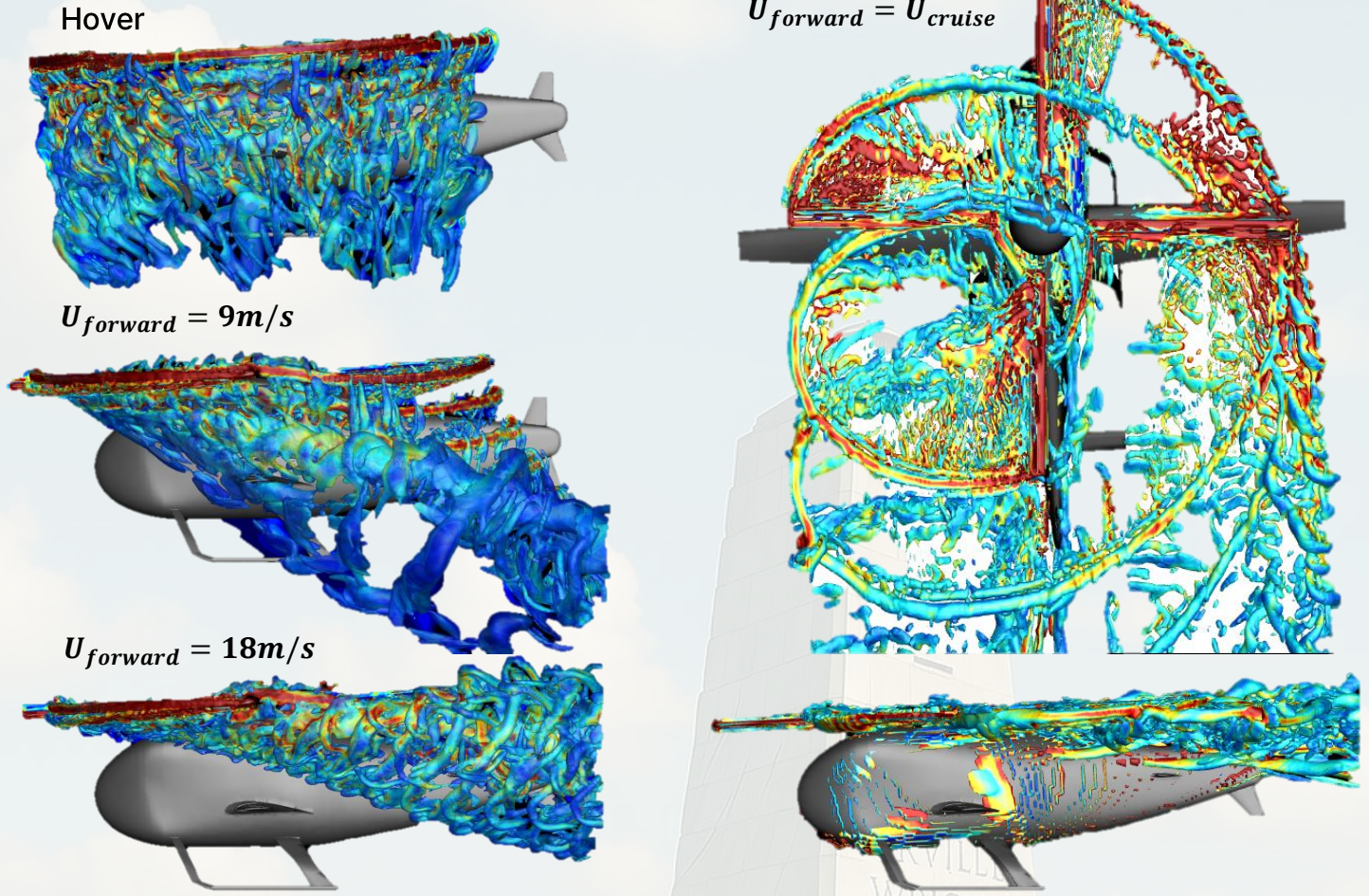


*HTCS : High Temperature Cooling System

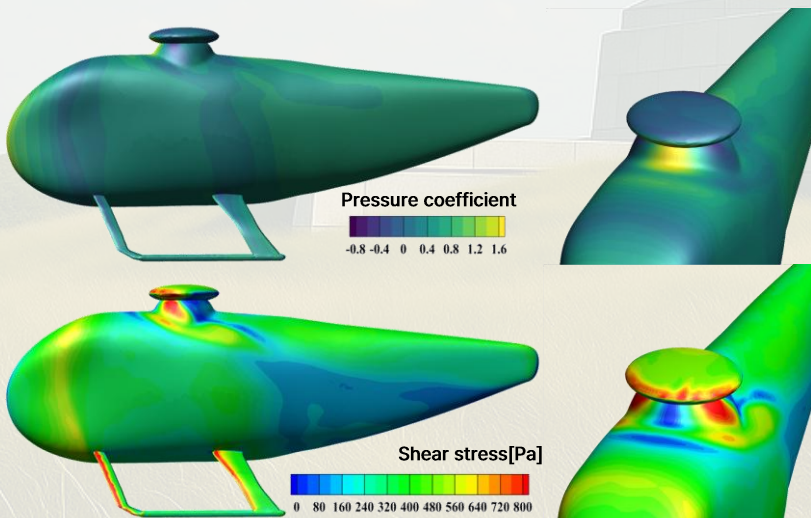
**LTCS : Low Temperature Cooling System

RANS/URANS CFD aerodynamic analysis

Rotor wake interaction analysis



- Low enough position of main wing to avoid rotor wake at all mission speeds
- At low speed, wing pitch angle is adjusted to match wake angle (ex. 90° @ Hover)



Airframe aerodynamic metric

- Streamlined designed airframe
- $D/q = 0.539 m^2$
- $M/q = 3.757 m^3$

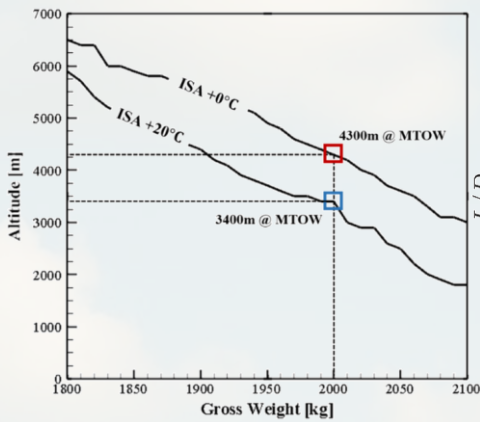
Performance analysis



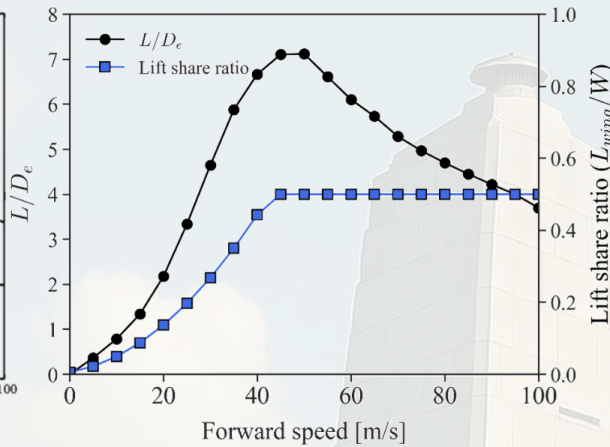
Total 69.25 minutes flight
(39.34 min loitering capability)

4300 m Hover ceiling

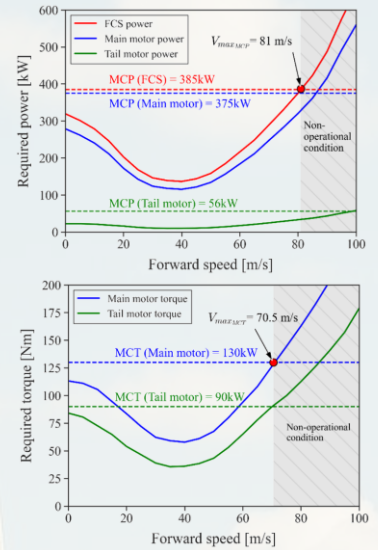
4300 m (ISA +0°C)
3400 m (ISA +20°C)



High Maximum $L/D_e > 7$
With up to 0.5 lift sharing ratio

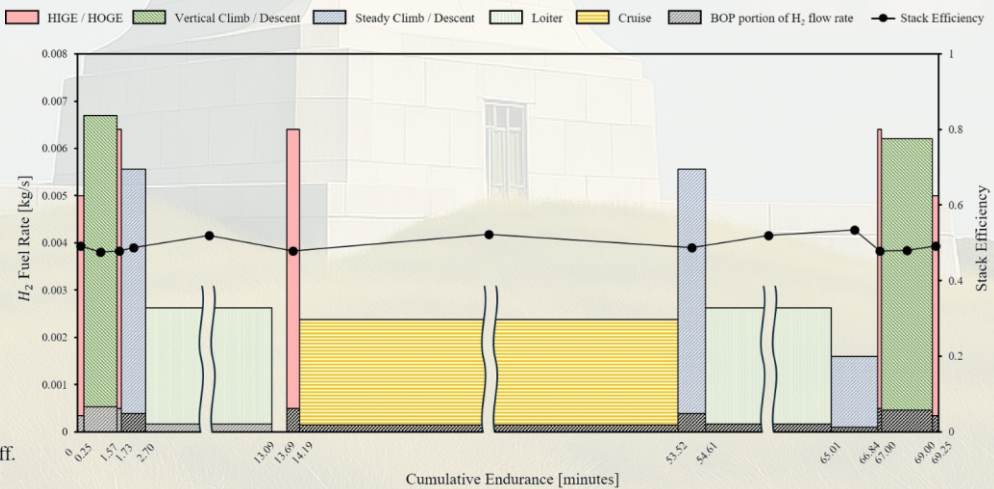
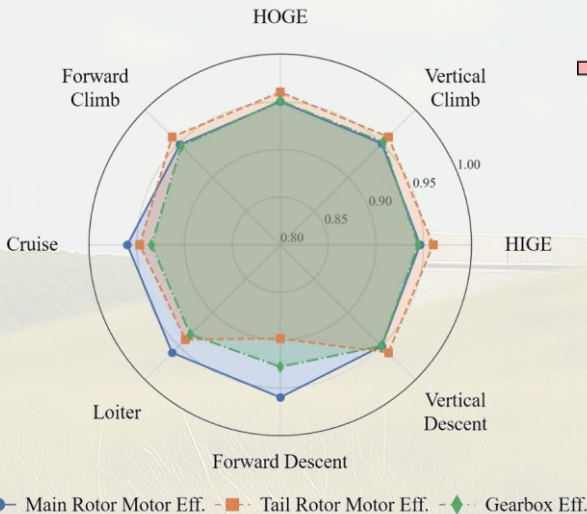


70.5 m/s (137 knots) Max Speed



Higher & Robust
Drivetrain Efficiencies
across all mission segments

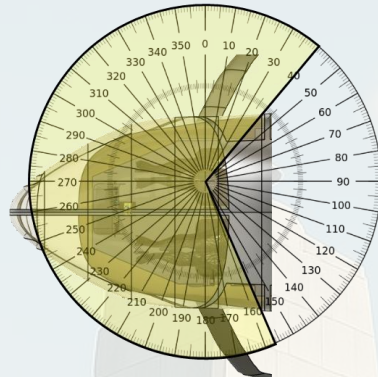
Lower H2 Fuel Consumption
across all mission segments
Optimal Fuel Cell System



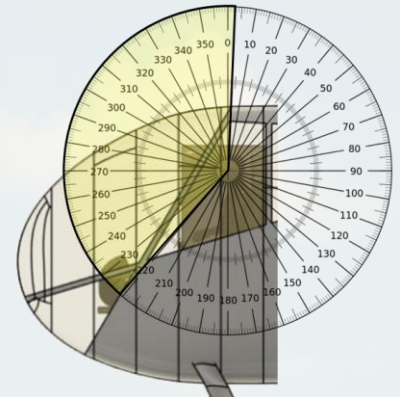
Operation and Safety

Pilot's Field of View

- A panoramic 243° horizontal and 140° vertical view for immersive experience with secured safety for the pilot



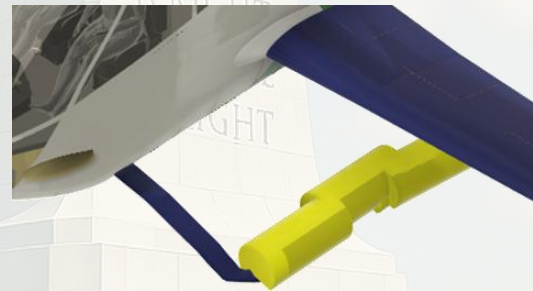
(a) Side view



(b) Top view

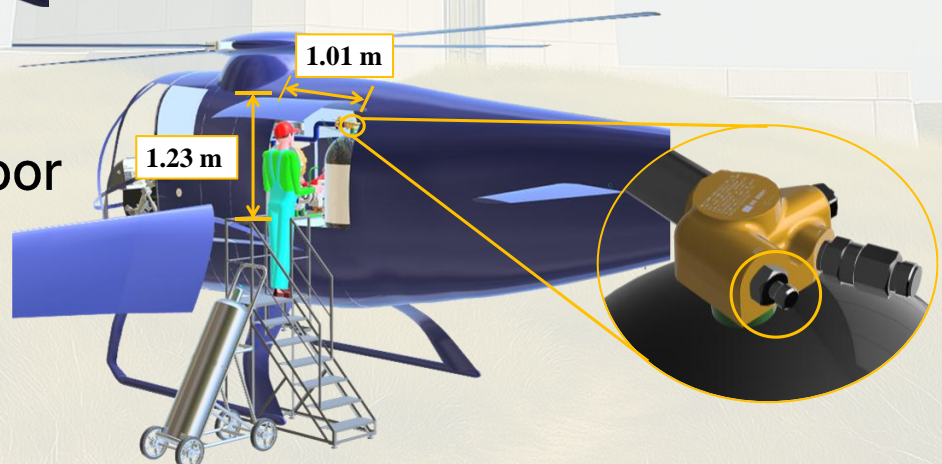
Safety measures

- Safety floats activated upon water landing
- Foldable ladder located at the seat sides



Maintenance

- Wide Maintenance door for repair & refuel





*HydrOgen ProPulsion
for long-Endurance Rotorcraft*

HOPPER: From Mission to Vision

The HOPPER proposed in this RFP can carry a pilot and a passenger (185 kg payload) and achieve up to 69.25 minutes of flight on just 11 kg of hydrogen fuel, including 39.34 minutes allocated for sightseeing over the Alligator River.

But the HOPPER is not only for flights over the Alligator River, but also for flexible operation in diverse environments, enabled by clean hydrogen fuel and long-endurance capability.



HOPE. 1 for urban areas

- ✓ Allowing safe operation in densely populated areas due to zero emissions
- ✓ Can be utilized for tourism and commuter transport in densely populated urban areas

HOPE. 2 for agricultural areas

- ✓ Enhanced aerodynamic efficiency with the variable incidence wing enables longer endurance and reduced fuel consumption
- ✓ The aircraft can perform seeding to spraying operations over larger farmland areas without frequent refueling

