

Samppaati

Executive Summary

Team Thapar

Thapar Institute of Engineering and Technology, India



**42nd Annual Vertical Flight Society
Student Design Competition**

Sponsored by Airbus



**THAPAR INSTITUTE
OF ENGINEERING & TECHNOLOGY**
(Deemed to be University)

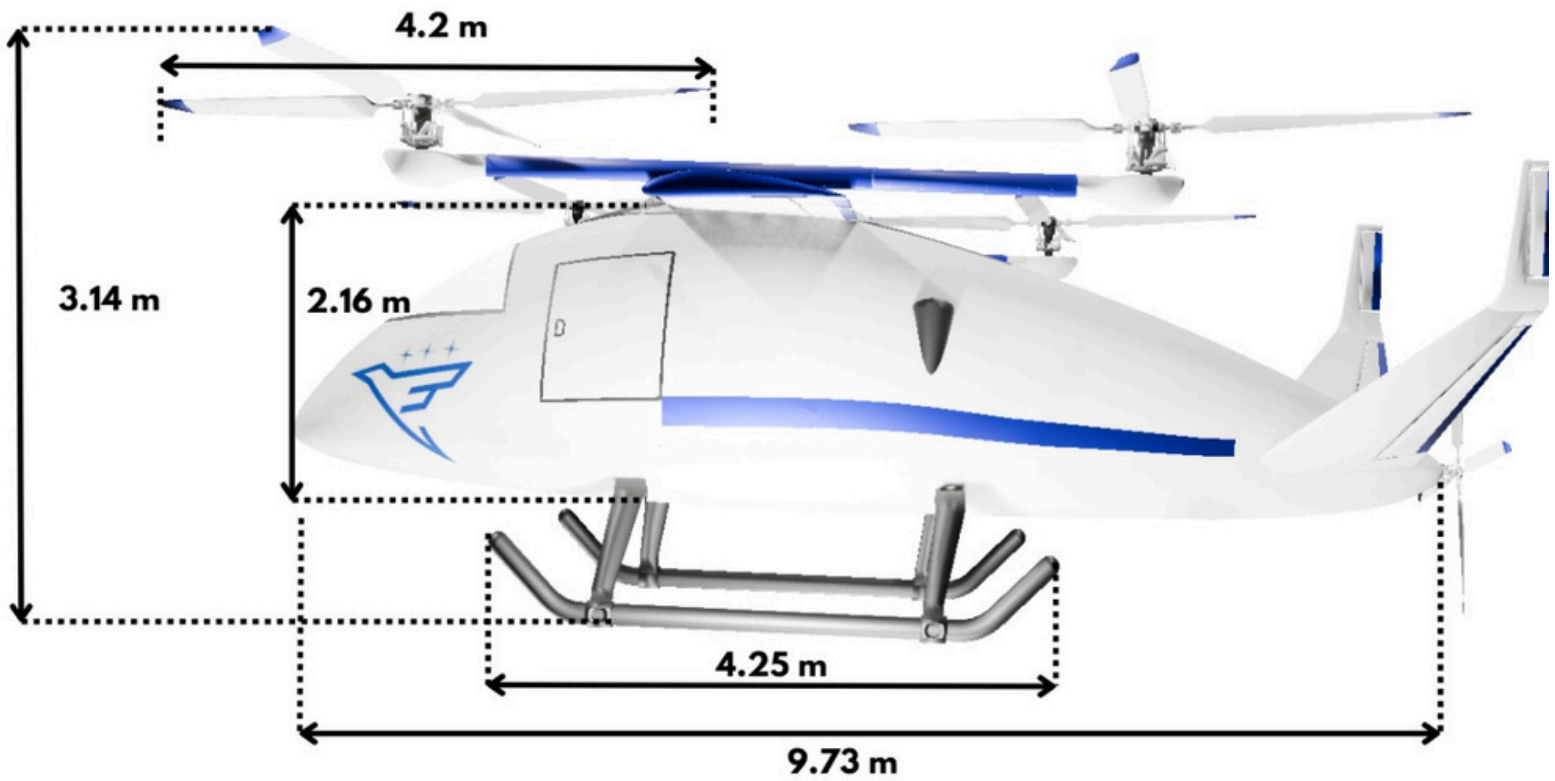
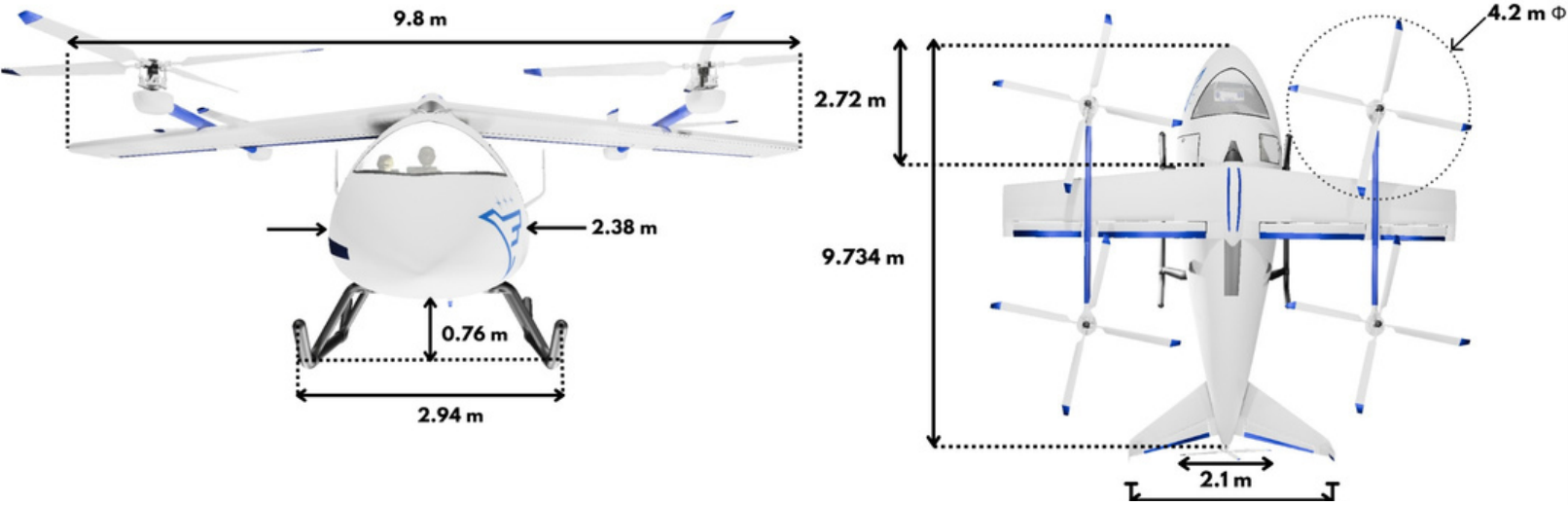


AIRBUS



SAMMPAATI

External Dimensions



Introduction

Team Thapar, an undergraduate team of Thapar Institute of Engineering & Technology, presents Sammpaati as its solution to the Vertical Flight Society's 42nd Annual Student Design Competition Request for Proposal (RFP). The team was asked to conceptually design a passenger-carrying hydrogen-powered VTOL aircraft that specifically uses Proton Exchange Membrane Fuel Cells (PEMFC) to loiter over Alligator River.

The name 'Sammpaati' comes from the ancient Hindu scripture 'Ramayana'. Sammpaati was a bird and the elder brother of 'Jatayu'. Sammpaati is known for its courage and bravery in the epic of 'Ramayana'.



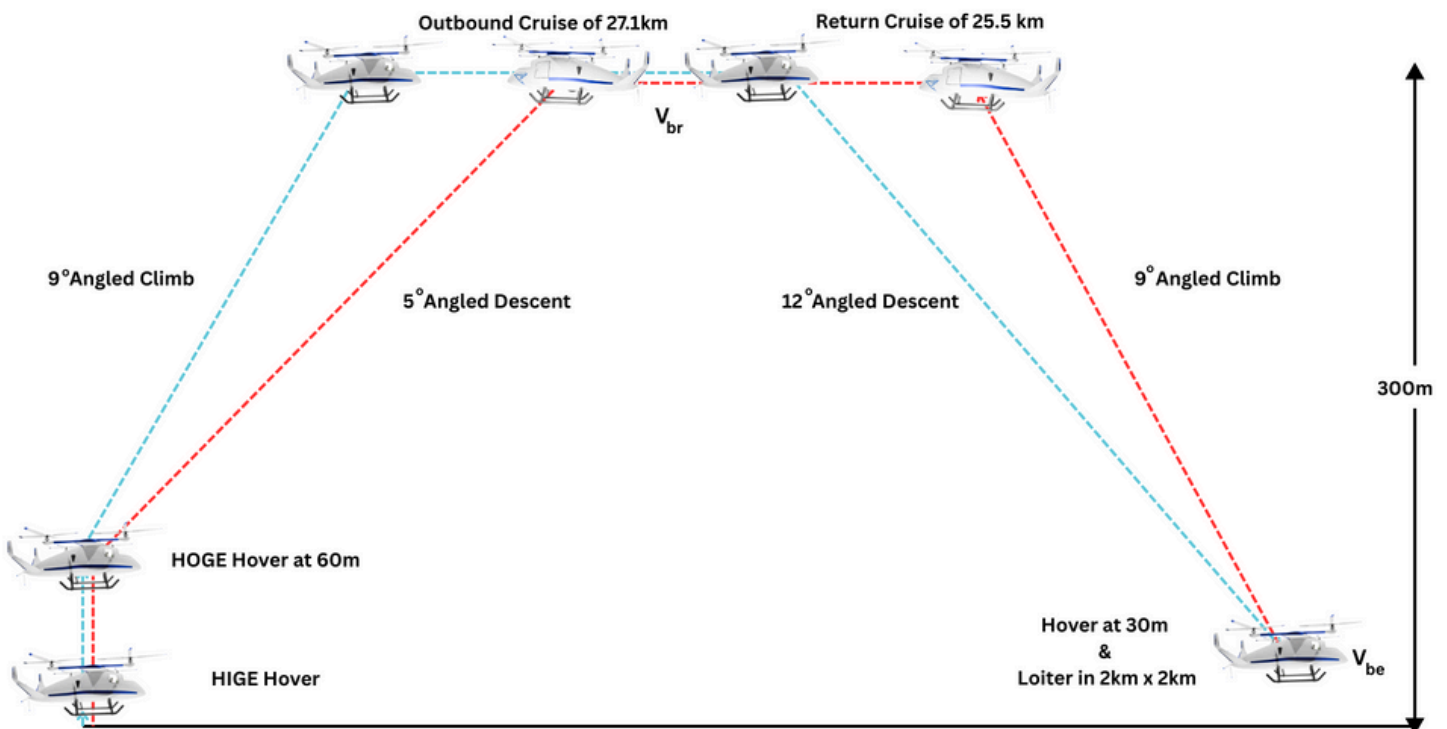
Vehicle Overview

GTOW	1250 kg
Payload	185 kg
Best Range Speed (V_{br})	34.66 m/s
Best Endurance Speed (V_{be})	31.3 m/s
Loiter Time	79 min 40 s

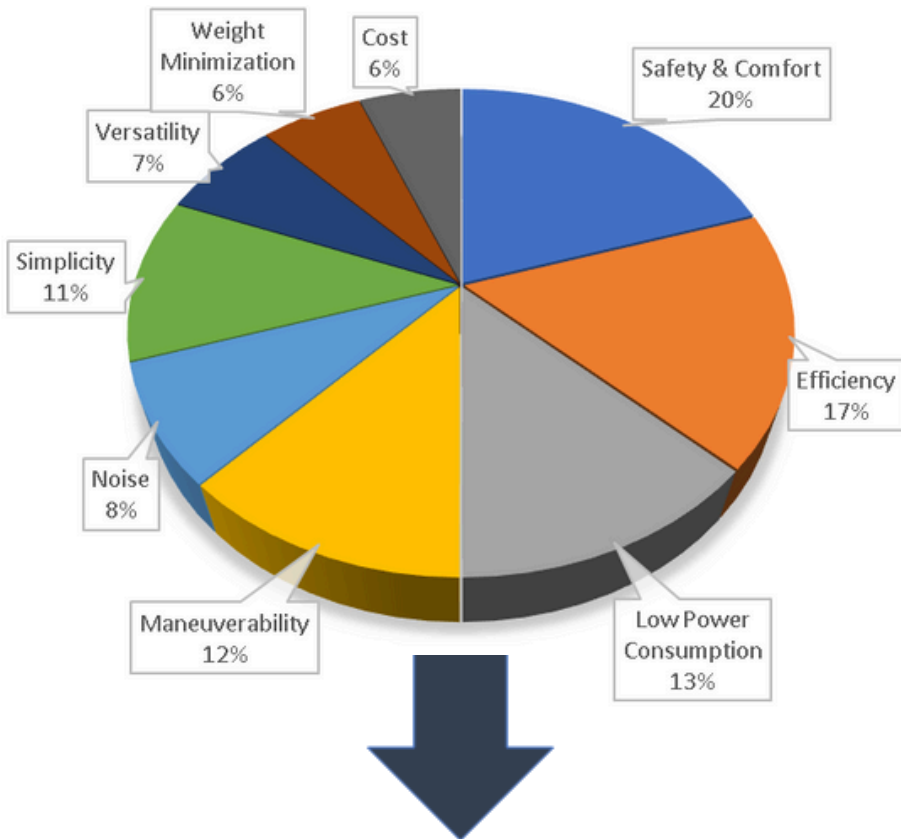
Mission Profile



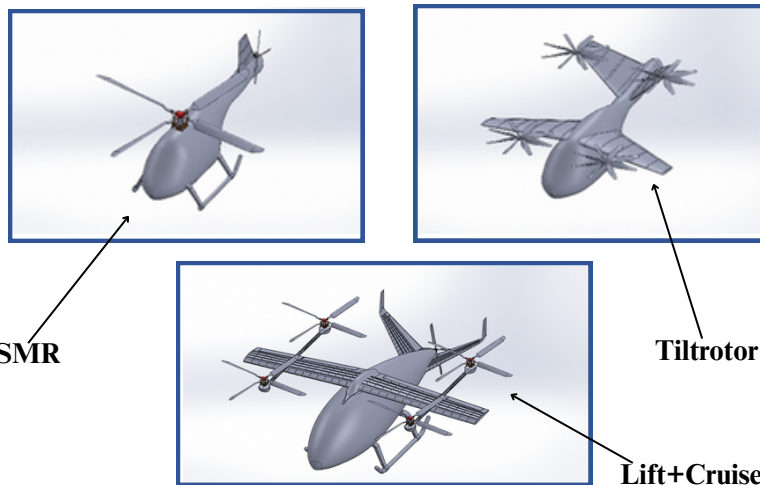
Sammpaati can loiter for 79 minutes 40 seconds over the Alligator River carrying a payload of 185 kg or 1 pilot, 1 passenger and luggage. Its mission profile is illustrated below.



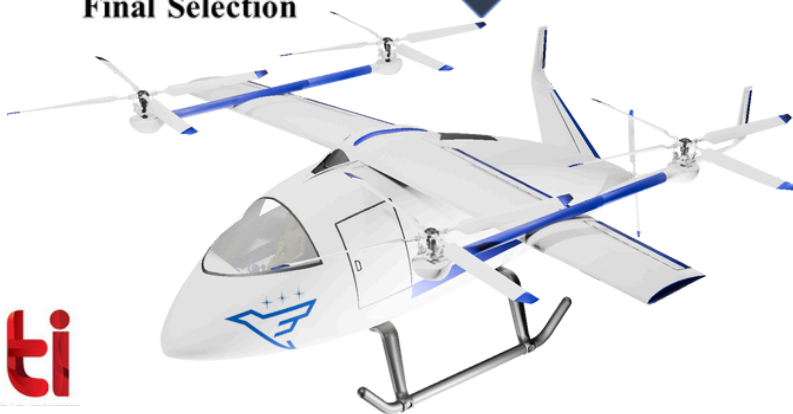
Vehicle Configuration



Configuration Selection



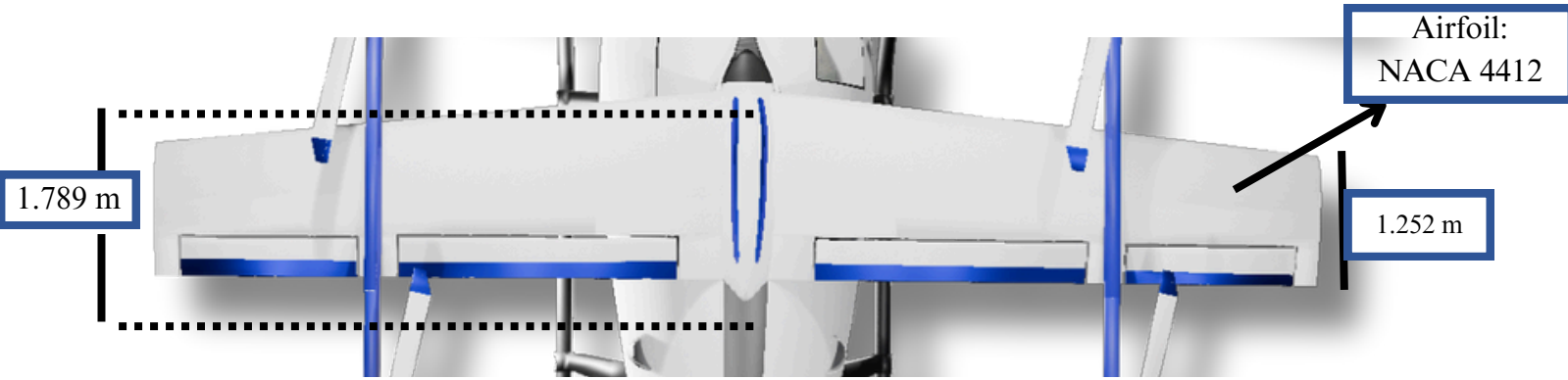
Final Selection



LIFT + CRUISE

1. Lift + cruise design separates vertical lift and forward propulsion systems.
2. Optimizes both VTOL efficiency (vertical takeoff/landing) and cruise efficiency.
3. Fixed wings enhance range with lower power consumption.
4. Justifies added complexity for battery missions requiring extended range.

Wing Design

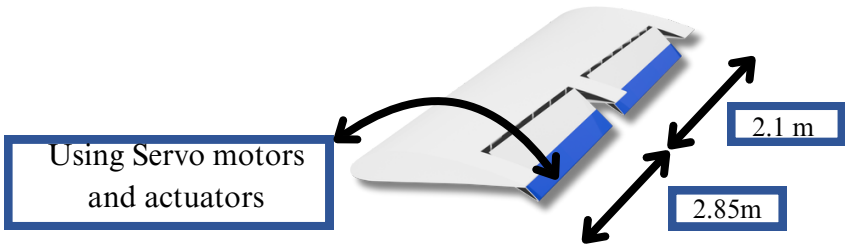


Airfoil:
NACA 4412

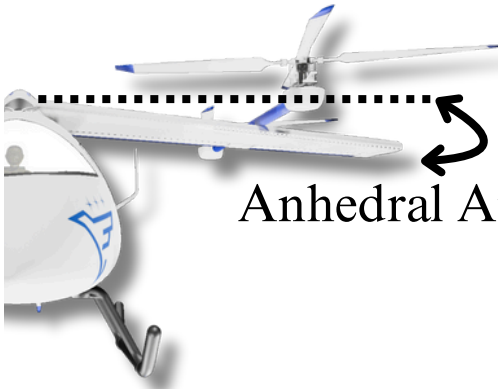
1.789 m

1.252 m

9.8 m



$C_l = 1.4$
 $C_{l\ max} = 1.6$
 $C_d = 0.09$
 $C_{d0} = 0.012$
Aspect Ratio = 6
Mean Chord Length = 1.52 m
MAC = 1.536 m

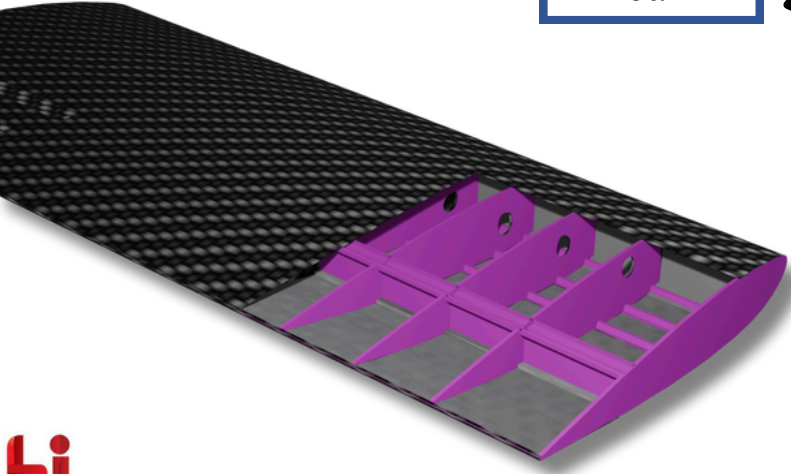
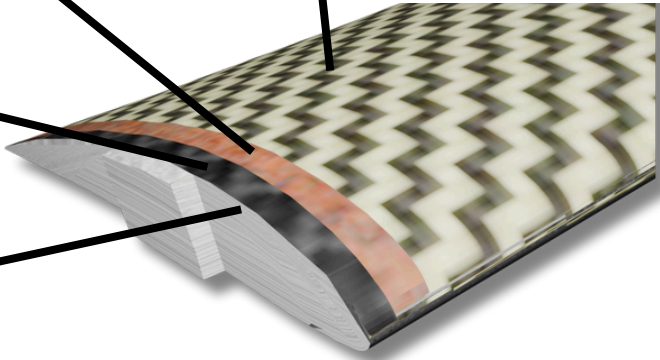


Copper

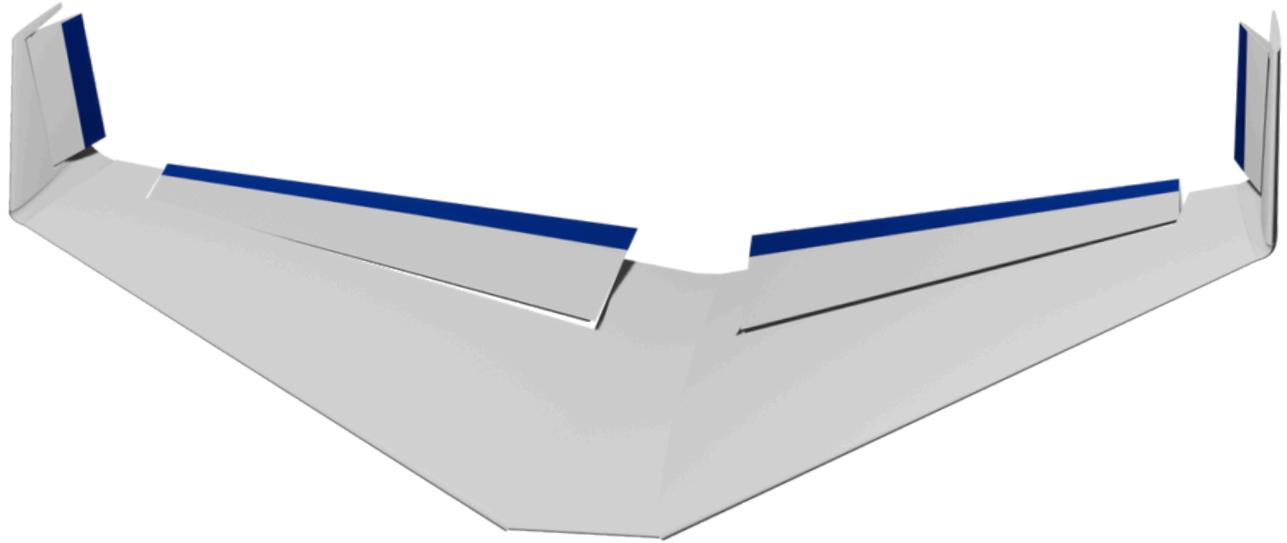
Kevlar

Kevlar

Foam



Tail Wing Design

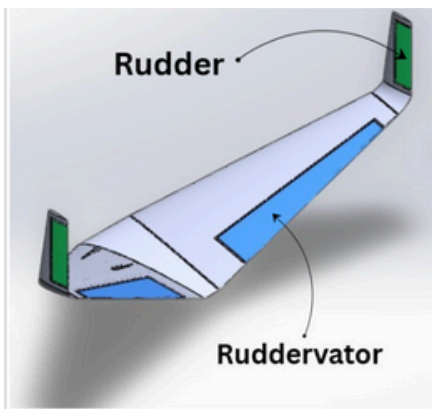


Why this design of tail-wing?

- Minimized Weight
- Redundant Yaw Controls
- Separate Control Mixing

Pure V Tail Challenges

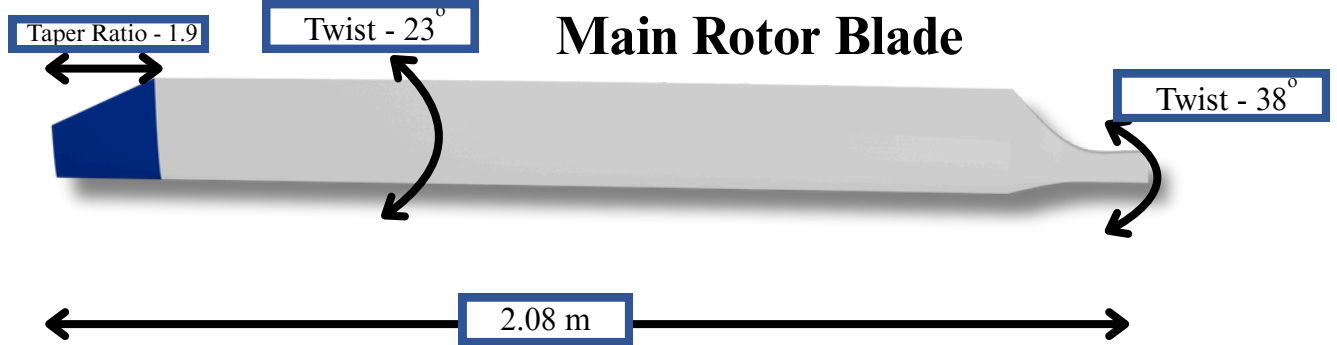
- Adverse roll and yaw coupling
- Complex controls (yaw and pitch mixed)
- No redundancy in controls



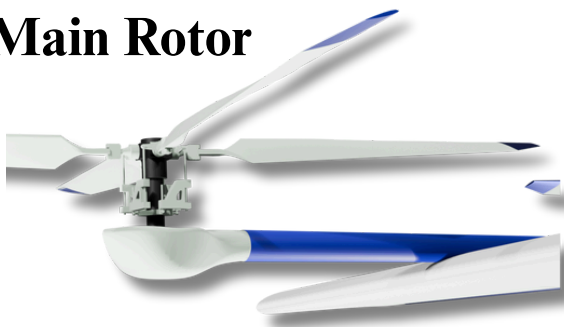
Airfoil	NACA 0012
L/D	13.3
C_T / σ (V tail)	0.14
Ruddervator Effectiveness Factor	0.6
Static Margin	15%



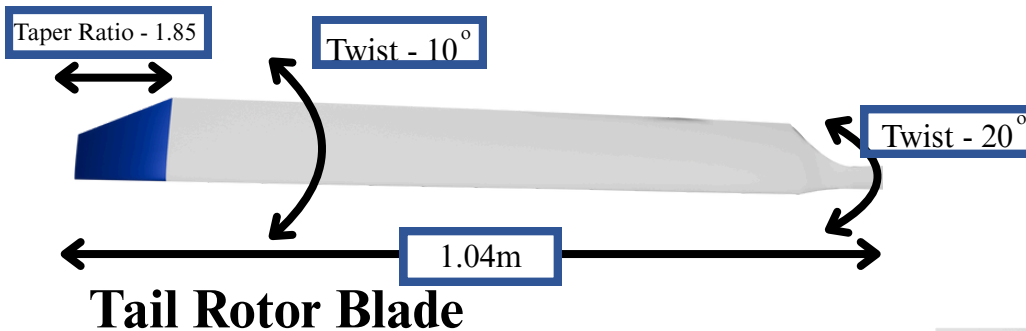
Rotor Design



Main Rotor



Solidity - 0.116
Cl - 1.2
Cd - 0.09
Cl max - 1.4
Mean Chord Length - 0.19 m
Swept Area - 13.58 m²
No. of Blade per Rotor - 4

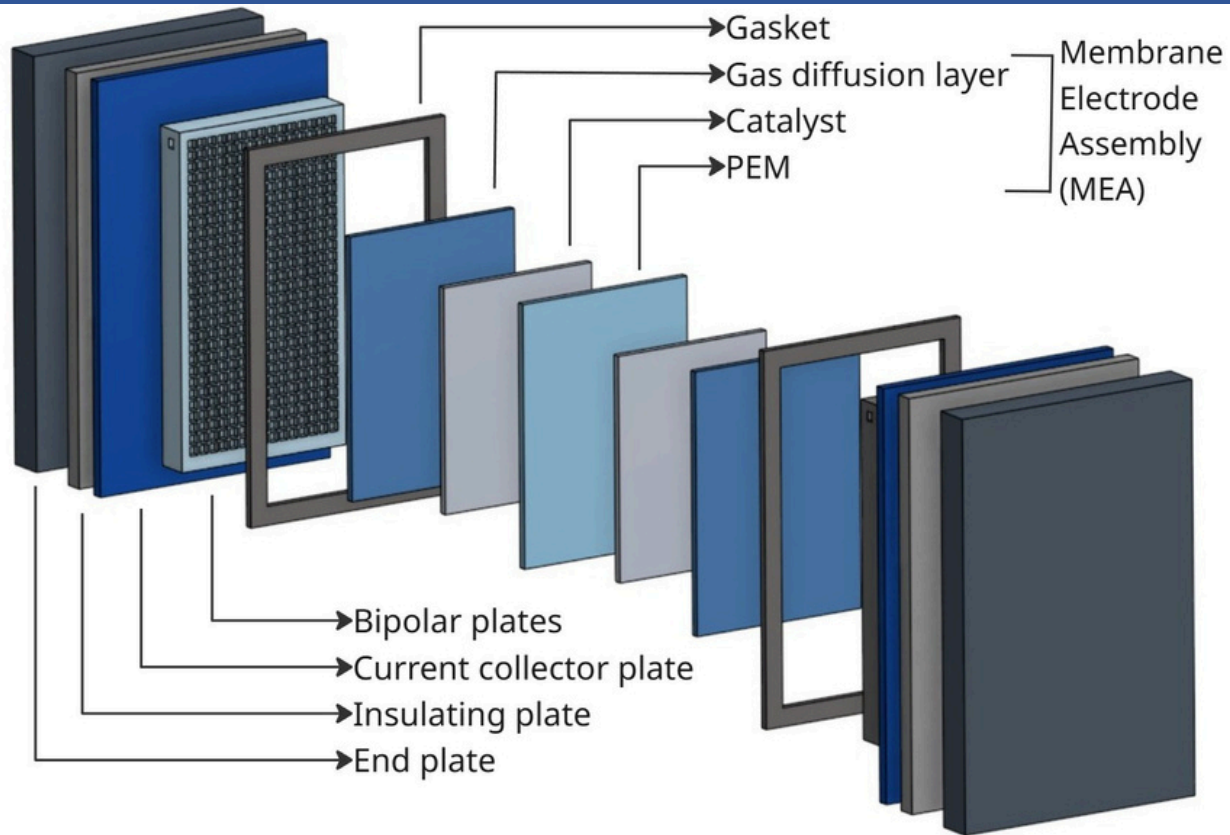


Tail Rotor



Solidity - 0.208
Cl - 1.2
Cd - 0.09
Cl max - 1.4
Mean Chord Length - 0.17 m
Swept Area - 3.39 m²
No. of Blade per Rotor - 4

PEM Fuel Stack



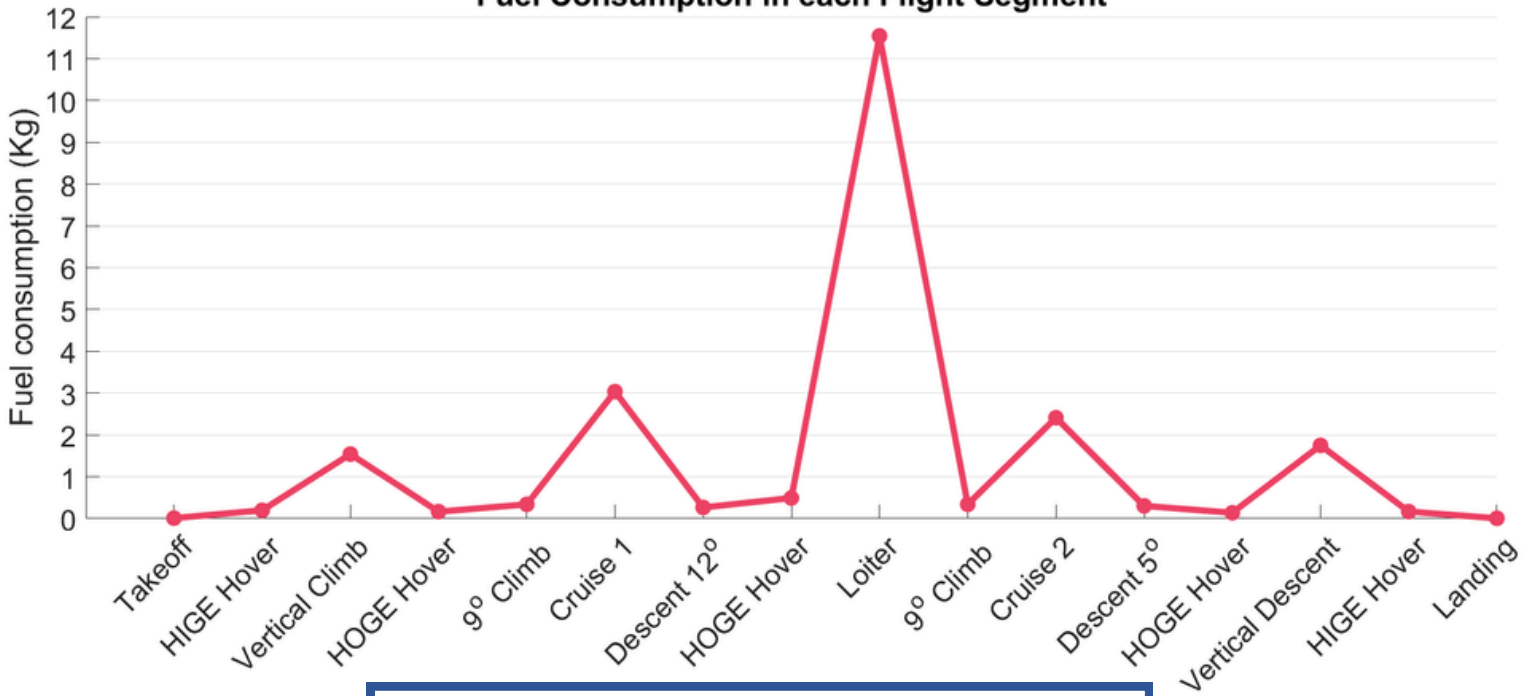
Max net power	292kW
Weight	191.146 Kgs
Operating Temperature	80°C
Pressure	1 atm
Voltage	300 V
Number of Cells	447

Stack Dimensions:
1.223m × 0.076m ×
1.224m

The stack was sized based on a net maximum power of 292 kW, though the actual operational peak of 218 kW remained within the cooling system's capacity, avoiding continuous load design constraints.

Hydrogen Tank & Fuel Consumption

Fuel Consumption in each Flight Segment



Total Hydrogen used: 22.698kgs

Total Flight Duration: 113 min 23 s

Loiter Time: 79 min 40 s

1.5m

Type 4 Tank with carbon fiber material

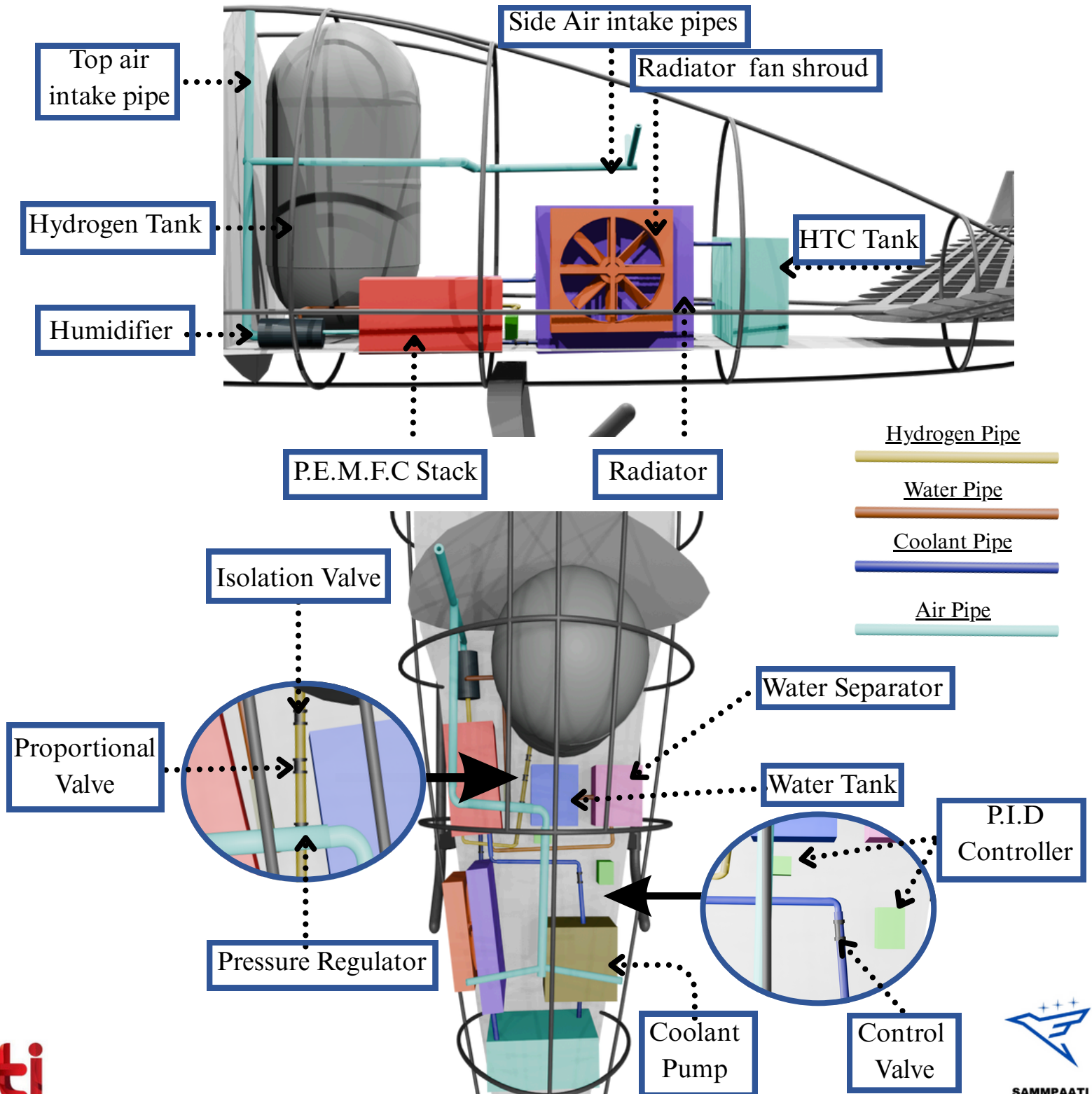
Radius: 0.625m

H₂ Tank Pressure: 700 bar

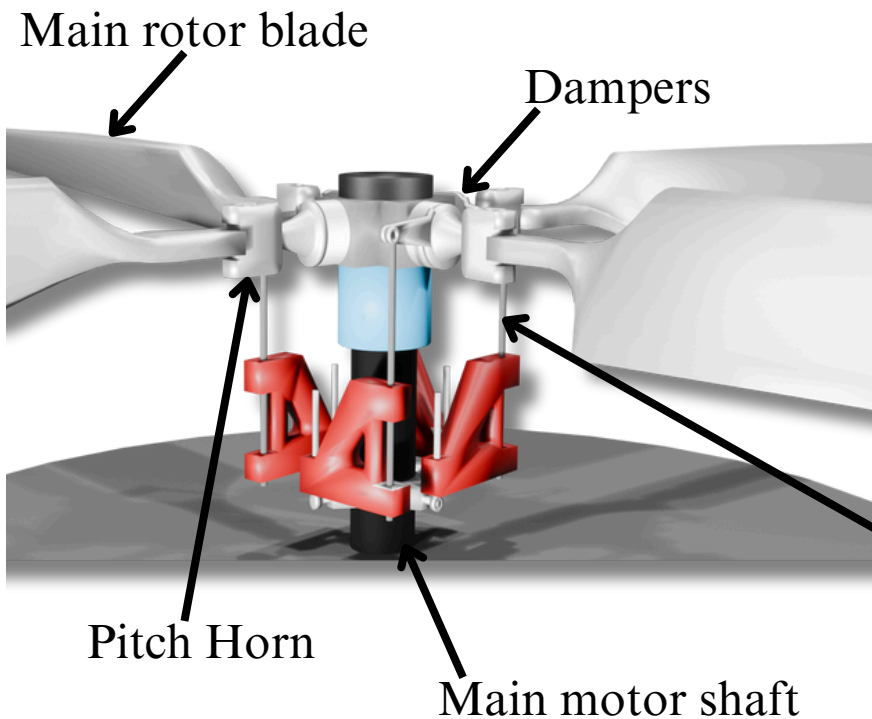
Tank Weight: 301kgs

Internal Placement of PEMFC System

The sizing and placement of all PEMFC system components, down to the smallest details like piping and valves, have been conducted using rigorous analytical methods in accordance with the EASA CS-27 small rotorcraft safety standards.

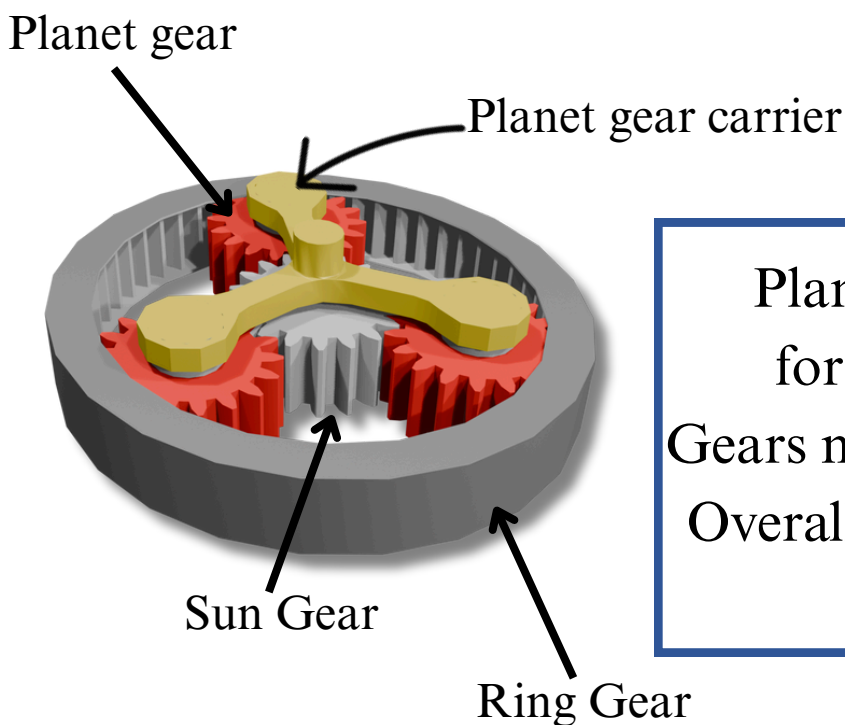


Gearbox & Hub Design



Semi-articulated Hub

- 1) High stability
- 2) Less weight
- 3) Simpler mechanics due to fewer moving parts
- 4) Low vibration



Planetary Gear set is used for lift+cruise operation. Gears made with AISI 9310 Steel. Overall Gear Reduction Ratio :- (3:1)

Drive Systems

Continuous Power : 121.5 kW

Continuous Torque : 207.5 kW

Weight (Lift Motors): 33.2kg
Weight (Cruise Motors): 8.3kg

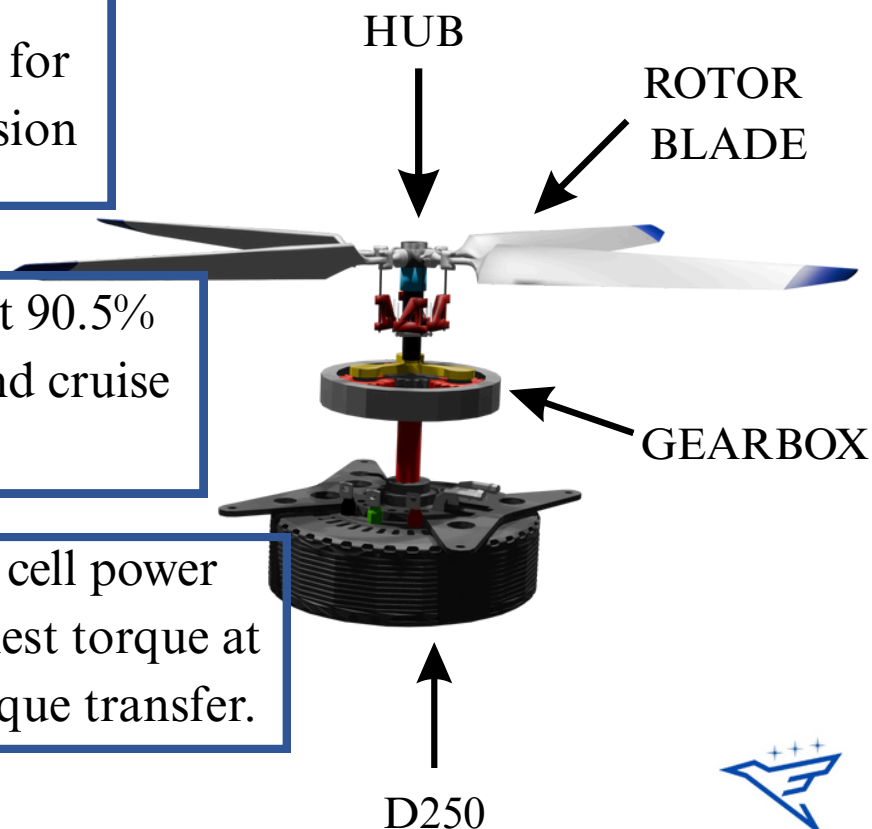
RPM : 2500

D250

Evolito D 250 motor is selected for both lifting and cruising propulsion

The motor efficiency is rated at 90.5% which is suitable for both lift and cruise operation.

The system efficiently turns fuel cell power from a PEM fuel cell into the highest torque at the rotor hub using controlled torque transfer.



Buffer Battery

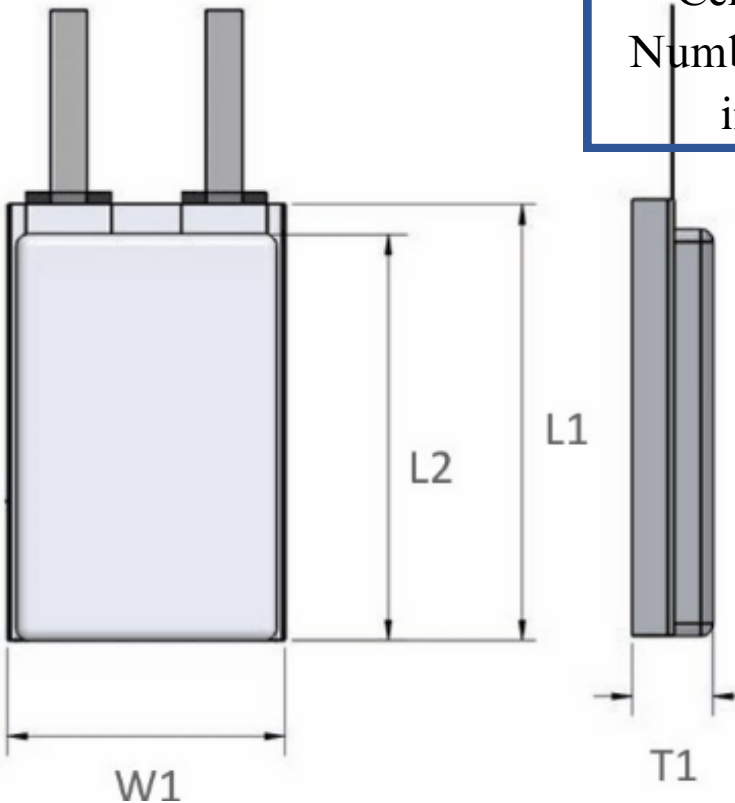
Buffer battery in Sammpaati will be used only for emergency landing. If there is drastic change in voltage supply for more than 3 seconds, buffer battery will be used.

Battery weight: **29.25 Kg**

Energy density:
395 Wh/Kg

Battery size:
14.504 m³

Cells in series: 100
Number of series stack
in: 25 parallel

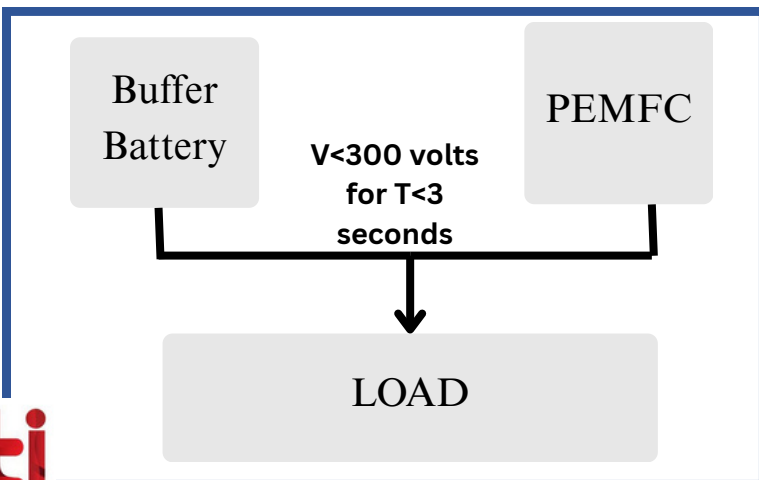


L1	37.0 ±1.0mm
L2	33.5 ±0.55mm
W1	22.4 ±0.5mm
T1 (@ 30% SOC)	7.0 ±0.4mm

Li-ion (silicon nanowire anode technology)

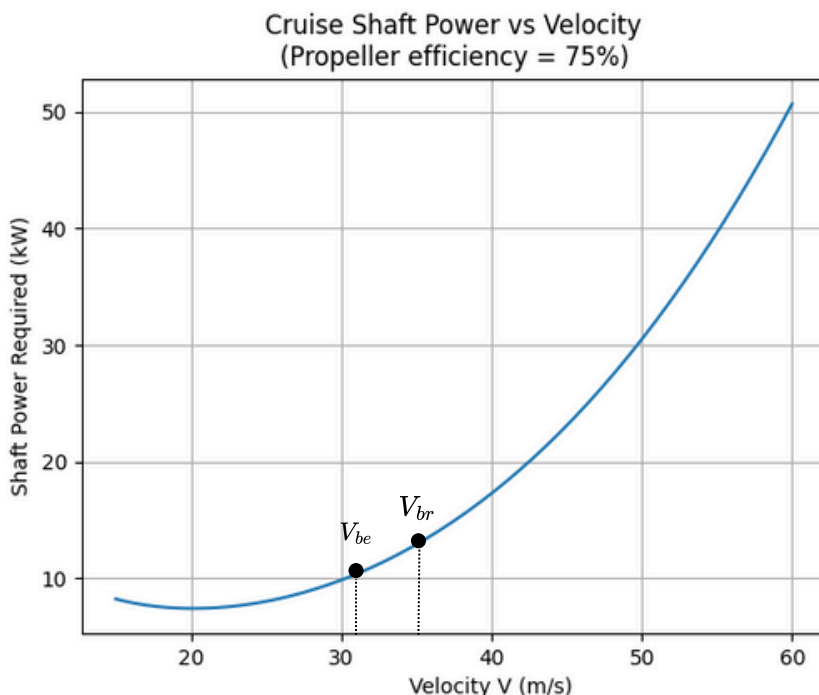
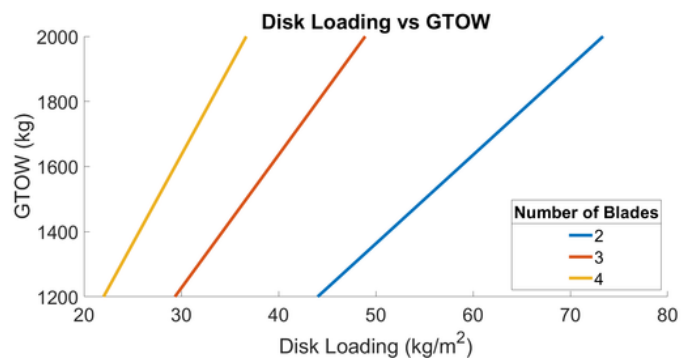
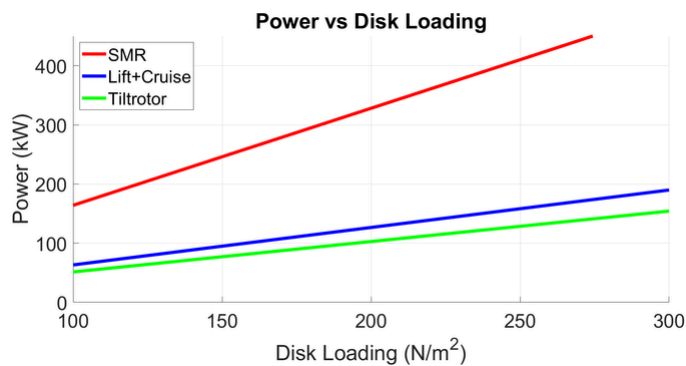
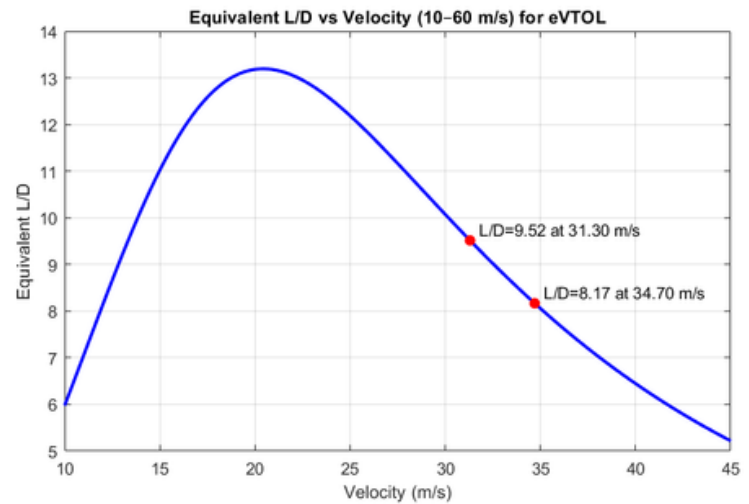
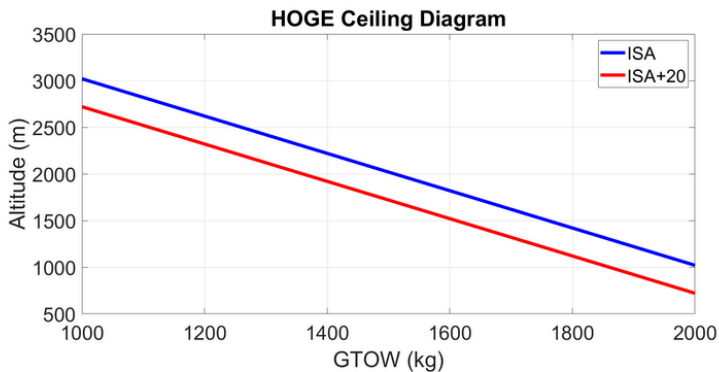
cell

- SiMaxx 1.34 Ah Balanced Power+ Energy cell
- High energy density
- Longer endurance
- Safe to use over other chemistries
- Pouch configuration of cells



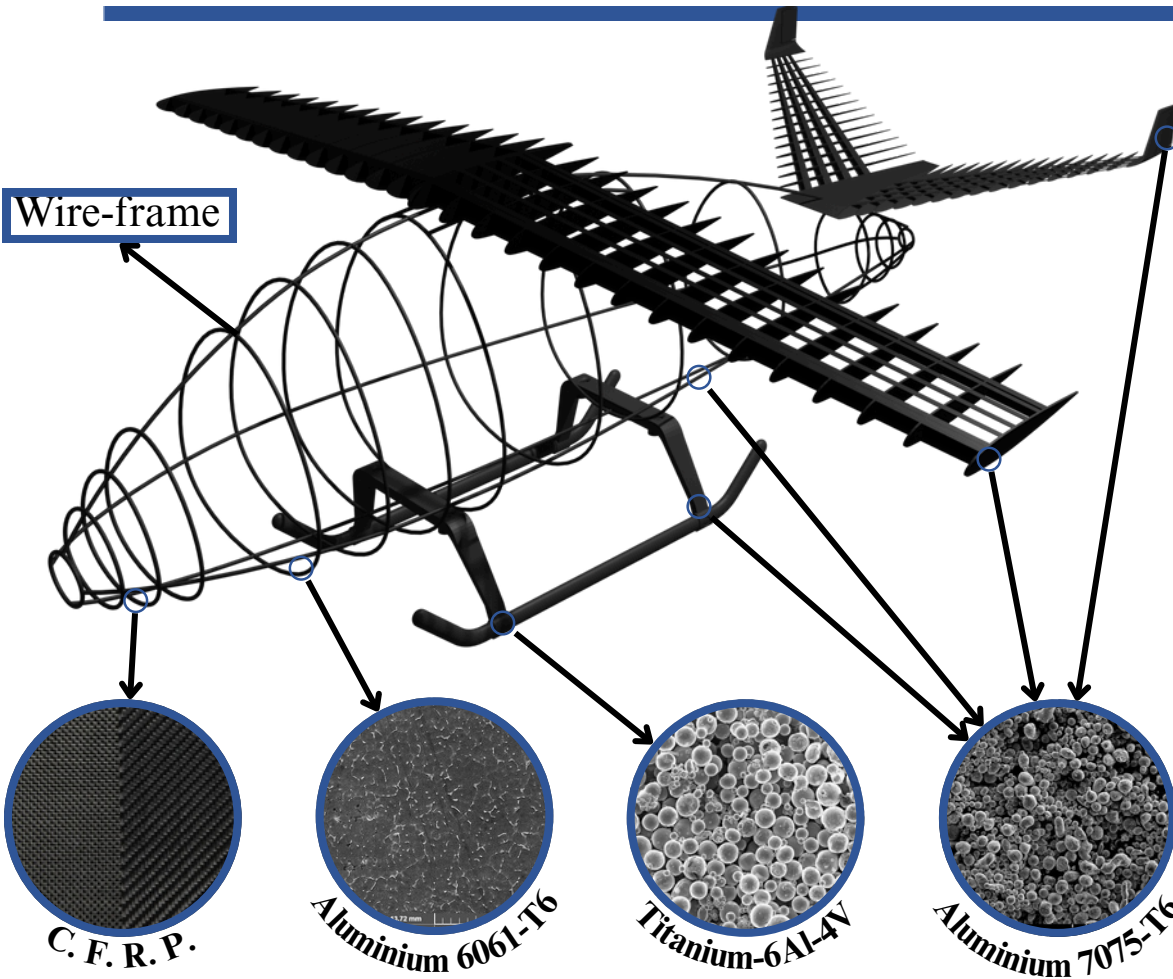
Vehicle Performance

Best Endurance Velocity (V_{be}) - 31.33 m/s
 Best Range Velocity (V_{br}) - 34.66 m/s
 Stall Velocity - 31 m/s



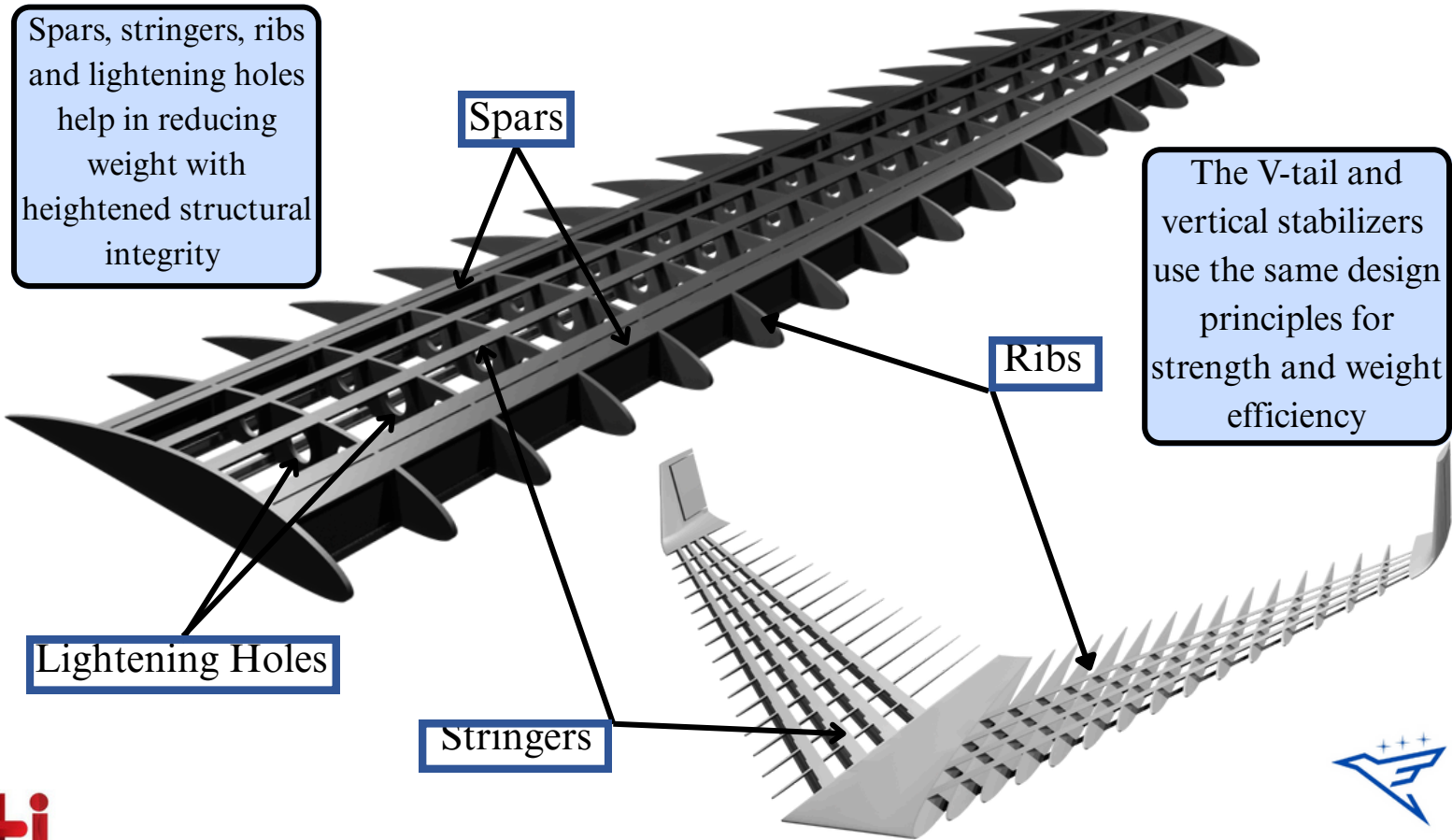
Peak L/D - 13.3
 HOGE Ceiling at 1250kg -
 2600m(ISA) & 2300m
 (ISA+20)
 Disk Loading at 1250 kg -
 225 N/m^2
 Wing Loading - 893 N/m^2

Airframe



Wireframe fuselage with 15 mm tube diameter is used to be lighter, more cost-effective, and easier to manufacture, repair and inspect. Overall improving flexibility, material use efficiency, and simpler assembly. The material used are corrosion resistant and light-weight while maintaining high strength

Spars, stringers, ribs and lightening holes help in reducing weight with heightened structural integrity

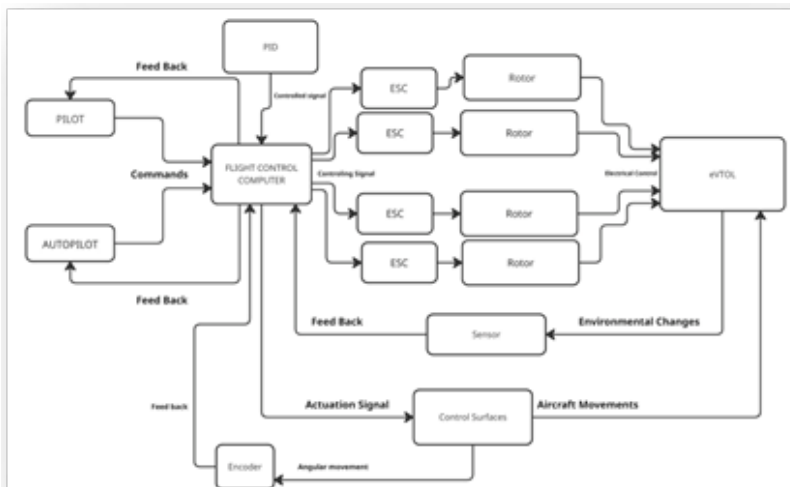


The V-tail and vertical stabilizers use the same design principles for strength and weight efficiency

Flight Control & Avionics



Navigation: GNSS + custom INS for precise tracking
FCS: FCC, IMU, and autopilot for stable control
Communication: Radio, telemetry, and satellite links
HMI: Display and joystick for intuitive control
Energy Monitoring: Tracks PEM fuel cell performance



Fly-by-Wire: FCC and sensors enable manual and automatic control
Autopilot: Manages altitude, attitude, speed, and flight transitions.
Control Scheme: Lift-plus-cruise with redundancy for stability and rotor failure safety.
PID Control: Ensures precise flight dynamics.
Hover & Attitude: FCC and IMU maintain orientation and stable hover.

Cost & Weight Breakdown

Components	Cost
PEMFC	246899.18
WINGS	75770.50761
ROTORS	197931.1219
FUSELAGE	892095.4926
DRIVE SYSTEMS	77316.8445
AVIONICS	23850
Environmental Group (cabin, thermal mgmt)	32474
Aircraft Manufacturing Cost	1546336.89

Category	Component	Weight (kg)	Weight (lb)
Structure	Fuselage Internals	44.000	97.02
	Fuselage Skin	100.000	220.05
	Main Wing Internals	45.000	99.21
	Main Wing Skin	61.000	134.48
	Empennage Tail	20.700	45.64
	Landing Gear	38.300	84.45
	Booms Internals	30.000	66.14
	Booms Skin	20.000	44.10
	Foam, Fasteners, Fittings	12.500	18.64
	Propeller Blade	7.500	16.53
	Propeller Hub	17.000	37.49
	Propeller Windshield	12.500	27.49
	Cabin Chair	7.500	15.43
	Cabin Avionics Housing	1.500	3.31
Hydrogen Tank	278.540	614.18	
Propulsion	Motor	15.500	34.17
	Controller	13.500	29.76
	Gearbox	11.000	24.25
	Electrical + Shaft	4.131	9.11
Avionics	Servo	4.100	9.04
	FCC	1.800	3.97
	Autopilot	1.800	3.97
	Display	2.000	4.41
	Control Suite	2.000	4.41
	GPS	1.000	2.21
	LTC System	8.000	17.64
	Water	0.350	0.77
PEMFC	Stack	98.700	217.85
	HTC System	78.851	173.85
	Pump (Primary)	3.000	6.61
	LTC System	5.000	11.02
	Water Tank	0.350	0.77
	Pump (Auxiliary)	1.000	2.21
	Radiator Fan	4.000	8.82
	Humidifier	1.350	2.98
	Electrical	13.000	28.67
	HTC Tank	3.000	6.61
Battery	–	29.850	64.50
Payload	–	185.000	407.99
Fuel	–	22.780	50.23
Total	–	1250.000	2756.25

