
42nd Annual Student Design Competition

2024-2025

# THE HAWKS

Pioneering Hydrogen Electric VTOL

Sponsored By AIRBUS

Vertical Flight Society

# Signature Page:


MD Khalid Hasan Nabil (Team Lead)
The Hawks Team (Best New Entrant)
Faculty of Science and Technology
Bangladesh University of Professionals (BUP)
nabilhasan01541work@gmail.com

Rasel Khan
Undergrad Student
rasel.khan.ryo@gmail.com

Abu Salehin Ahmed
Undergrad Student
salehin.0987ahmed@gmail.com

Maruf Ahmed
Undergrad Student
marufaerospace@gmail.com

Jubayer Ahmed Sajid
Undergrad Student
sajid.jubayet@gmail.com

Ashab Farhan Anon
Undergrad Student
farhananan1512@gmail.com

Musayeb Hossain Usama
Undergrad Student
mhusama15@gmail.com

Dr. Mohammed Nasir Uddin (MNU)
Professor of Mathematics
Department. of Information and
Communication Technology (ICT)
Faculty of Science and Technology
Bangladesh University of Professionals (BUP)
nasiruddin@bup.edu.bd

**BANGLADESH UNIVERSITY OF PROFESSIONALS**
Department of Information Communication Technology
Mirpur Cantonment, Dhaka-1216, Bangladesh

# Permission for Publication:

To the Vertical Flight Society,

The members of the Bangladesh University of Professionals (BUP) Student Design Team in the best new entrant category hereby grant VFS full permission to distribute the enclosed Executive Summary and Final Proposal for the 42nd Annual Student Design Competition 2024–2025 as they see fit.

Thank you,

Khalid

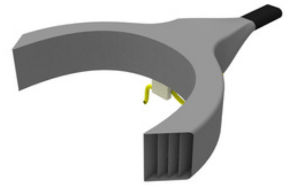
MD Khalid Hasan Nabil (Team Lead)
The Hawks Team (Best New Entrant)
Faculty of Science and Technology
Bangladesh University of Professionals (BUP)

Vertical Flight Society

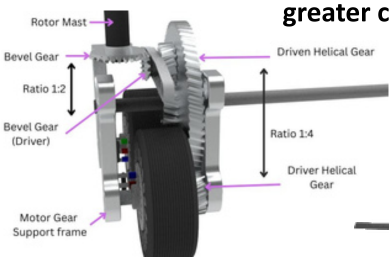
# AIRCRAFT DESIGN

Fully Articulated Main Rotor System enabling each blade to flap, lead-lag, and pitch individually, providing greater control and flexibility in flight.

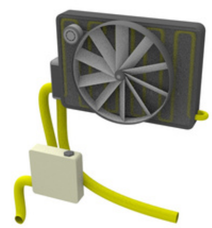
U Shaped Air Inlet for maximum volume of air intake . Inlet fins for smooth laminar air flow through the intake.



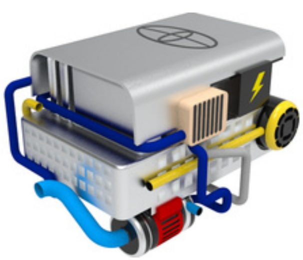
Cooling system located behind the cabin for uninterrupted airflow.




Efficient Reduction Gear assembly consisting of bevel and helical gear.

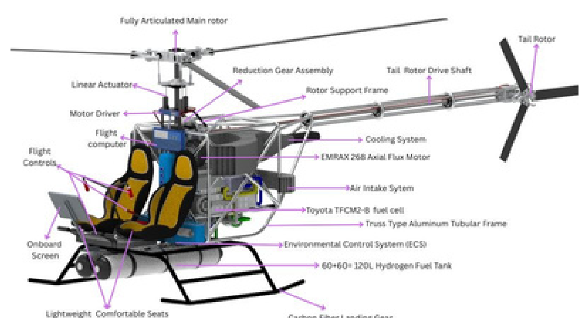



Lightweight aluminium finned cross-flow radiator.



Toyota TFCM2-B fuel cell , power output, weight size fulfill design requirements.

Ultra Comfort Interior Design with advanced control system and luggage space for passengers.




Lightweight truss type aluminum tubular frame , offering strong structure and bearing weight of every components including fuel cell stack ,LG, motor & cabin.

Fig - 1:Features of The Hawk

# INTRODUCTION

Based on the Robinson R22 and Cabri G2, the Hawk is a conceptual helicopter that runs on hydrogen-electric power. It features an 85 kW Toyota PEM fuel cell, a 30 kg battery, and our own rotor system, capable of completing missions stated in the RFP with a significant margin.


Fig - 2:Bottom Isometric View

## Key Design Features:

- **Structure:** Has our own design frame, 6.78 m rotor, supports 624kg MTOW, fits within 10m X 10m X 4m VFS limit and has built in LTC cooling.
- **Power System:** Power is shared efficiently between a 700 bar H2 TFCM2-B and a 30 kg lithium-ion battery. About 60% fuel efficiency was achieved and no extra water storage was needed.
- **Performance:** Covers about 100 km, capable of autorotation and can carry 185 kg payload. Designed to complete the VFS requirements stated by the RFP.
- **Modeling:** Ansys was used to simulate and study blade stress and airflow, simulated mission needs and fuel efficiency using MATLAB and created 3D models and finalized structure using SolidWorks and rendered via Keyshot.

# MISSION SEGMENT

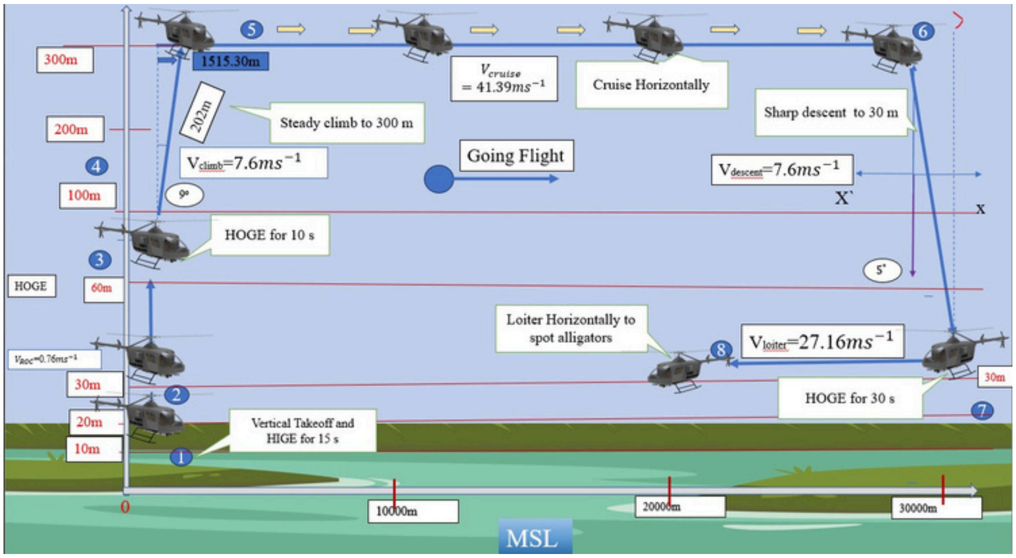



Fig -3: Going Flight

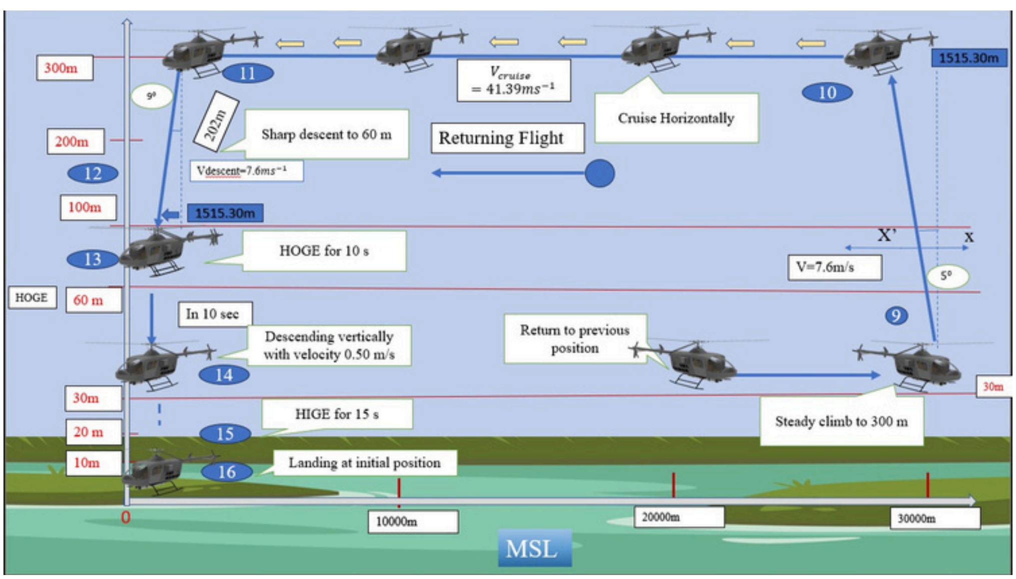



Fig - 4: Returning Flight

**The aircraft performs these operations based on the mission segments provided in [RFP] for going flight: [ Fig:3 ]**

1. **Vertical Takeoff**: Launch from Wright Brothers Memorial with standard HIGE at 10m MSL for 15 seconds.
2. **Initial Climb**: Ascend 60m vertically at 0.76 m/s, followed by 30-second HOGE hover at 60m altitude.
3. **Transit Climb**: 9° angle climb to 300m operational altitude covering 1,515m horizontal distance.
4. **Cruise Phase**: Level flight at 300m covering 26,969m to target area at optimal cruise velocity.
5. **Descent & Positioning**: Autorotation descent at 5° angle to 30m altitude using -7.6m/s descent rate.
6. **Target Acquisition**: 10-second loiter at 30m for alligator spotting and surveillance operations.
7. **Return Transit**: Reverse flight profile back to base following identical performance parameters.

**Returning to Wright Brothers National Memorial: [ Fig: 4 ]**

1. **Transit Climb**: 5° angle climb from 30m to 300m cruise altitude with horizontal velocity Vclimb
2. **Return Cruise**: Level flight at 300m back to base area at cruise velocity Vbe=41.39m/s
3. **Approach Descent**: Controlled descent from 300m to 60m altitude using descent velocity Vdescent
4. **Contingency Hold**: 10-second HOGE at 60m altitude for final approach planning and safety checks
5. **Final Descent**: Vertical descent from 60m to 10m MSL at controlled 0.75 m/s rate
6. **Landing Preparation**: 15-second HIGE hover at 10m MSL for final positioning and clearance
7. **Mission Complete**: Precision landing at Wright Brothers Memorial at original departure point

# CONFIGURATION SELECTION

## 8 Configurations Considered

## Preliminary Analysis

Distributed Propulsion ?

Yes → Configuration dropped: high weight, volume, and complexity

No ↓

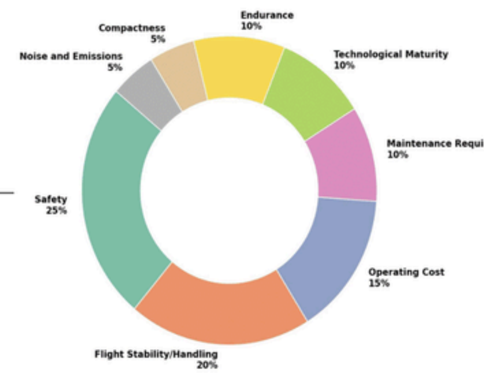
## Qualitative Downselection for Detailed Analysis

Robinson R22

*Simple, affordable maintenance*

Cabri G2

*3-blade composite, fully articulated main rotor*




## Comprehensive Trade Studies

Superior autorotation characteristics

- Modern, modular design
- Enhanced flight stability for training
- EASA-certified with advanced safety systems
- Lower noise and emissions footprint

## COMPREHENSIVE TRADE STUDY RESULT

- **3-DOF Fully Articulated Rotor System**
- **High-Volume U-Shaped Air Inlet with Fins**
- **Rear U-Shaped Cooling System**
- **Toyota TFCM2-B Fuel Cell Integration**
- **Panoramic Glass Canopy for Visual Detection**


Fig - 5: Trade Study

# THE HAWK : SIZE AND CHARACTERISTICS

ALL DIMENSIONS ARE IN METRE

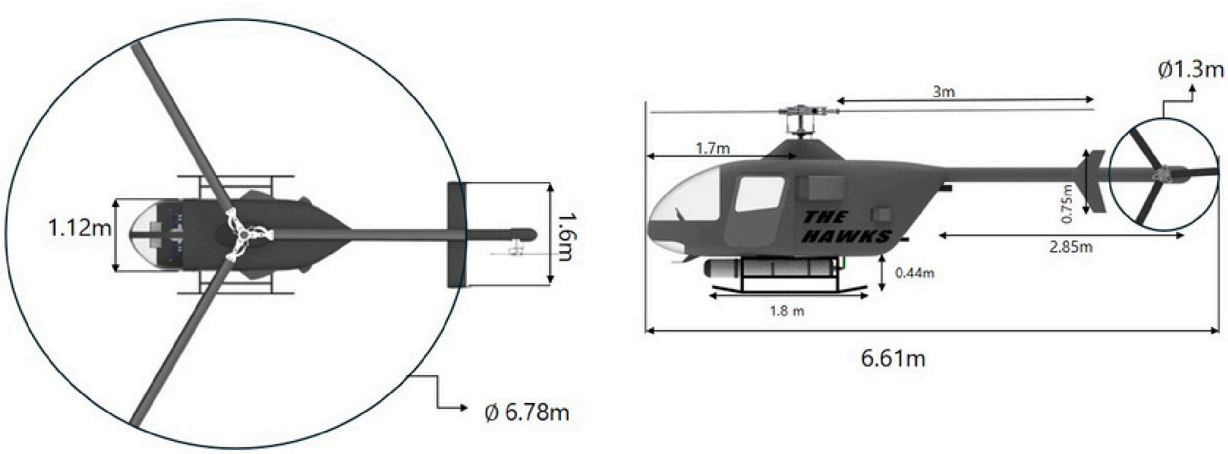



Fig - 6: Top View and Right View Dimensions

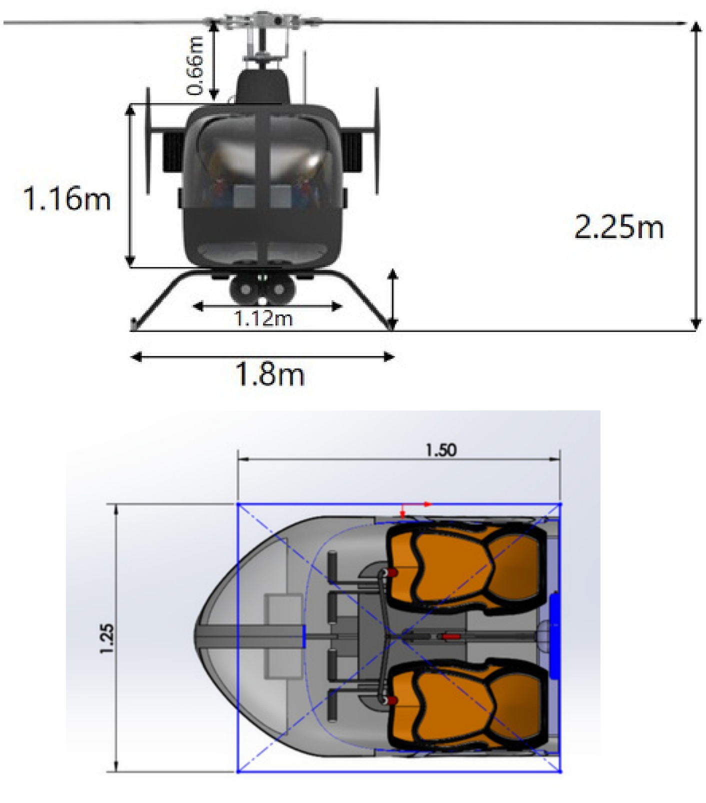



Fig - 7: Front View and Cabin Dimensions

| | |
|---|---|
| **MTOW** | 624 Kg |
| **INSTALLED POWER** | 2*100= 200kW |
| **PAYLOAD** | ( 1 pilot + 1 passenger + luggage space) **185kg** |
| **DISK LOADING** | 17.28 kg/m^2 |

Table -2:Characteristics Table

# THE HAWK INTERNAL LAYOUT

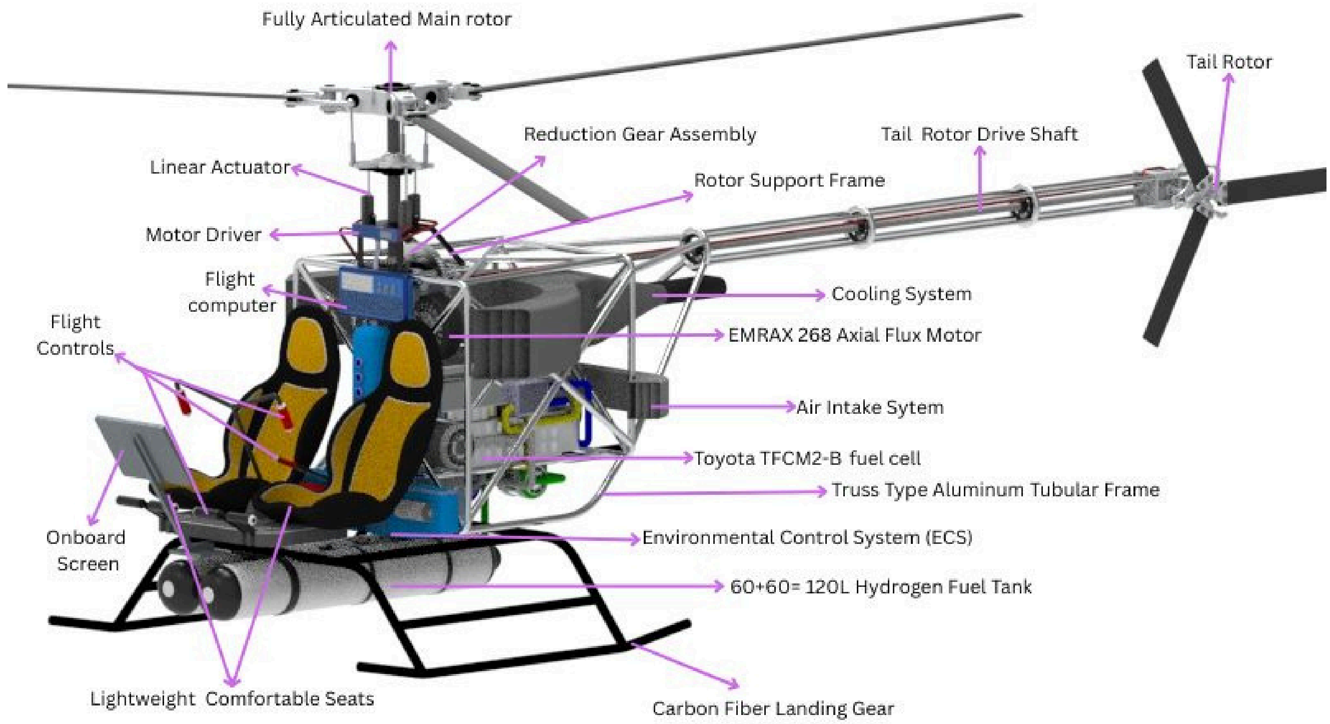



Fig - 8:Internal Layout

- **Zero-Emission Powerhouse**: Toyota fuel cell + 120L hydrogen tank for silent, clean flight is used.
- **Smart Flight Systems:** Advanced computer with integrated ECS and precision EMRAX motor control with an smart screen display for all around avionics control.
- **Aerospace Construction**: Aluminum truss frame with carbon fiber cabin - maximum strength, minimum weight. Makes it robust, lightweight and high endurance vehicle.
- **Mission-Ready Cockpit**: Dual racing seats with environmental control and tactical display along with movable functionality for keeping necessary baggage.
- **Precision Engineering**: Fully articulated rotor system with optimized cooling and drive systems, aiming at a sustainable and greener future.

# AVIONICS SYSTEM

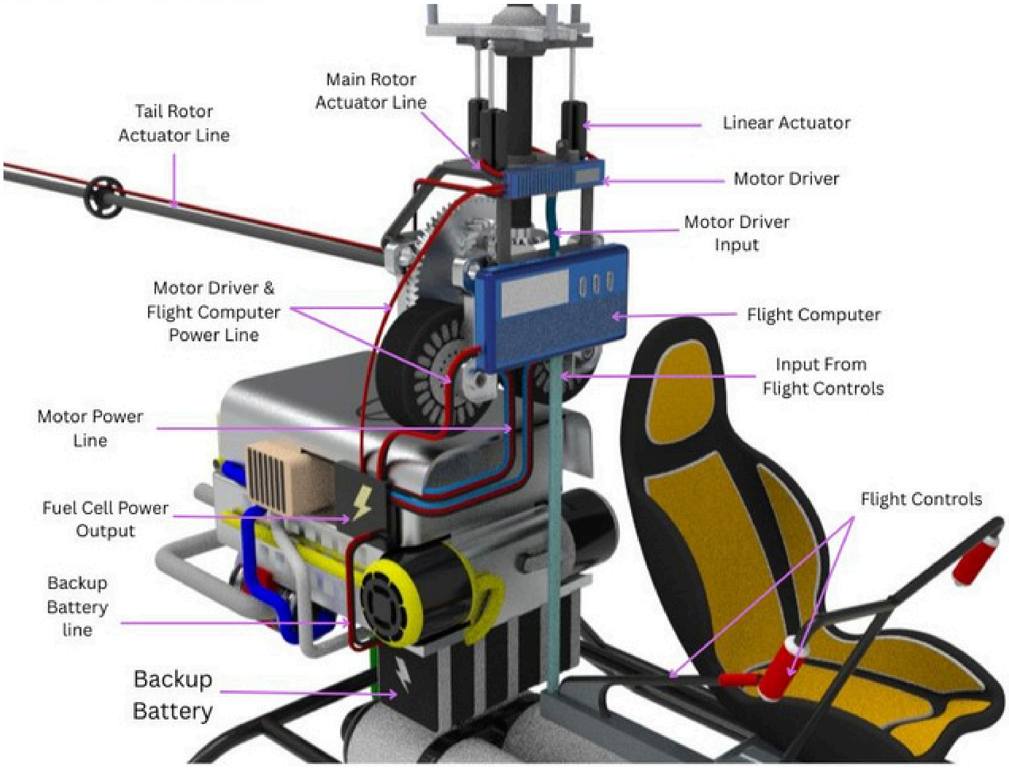



Fig - 9:Avionics System

## AVIONICS SYSTEM WORKING FLOW DIAGRAM

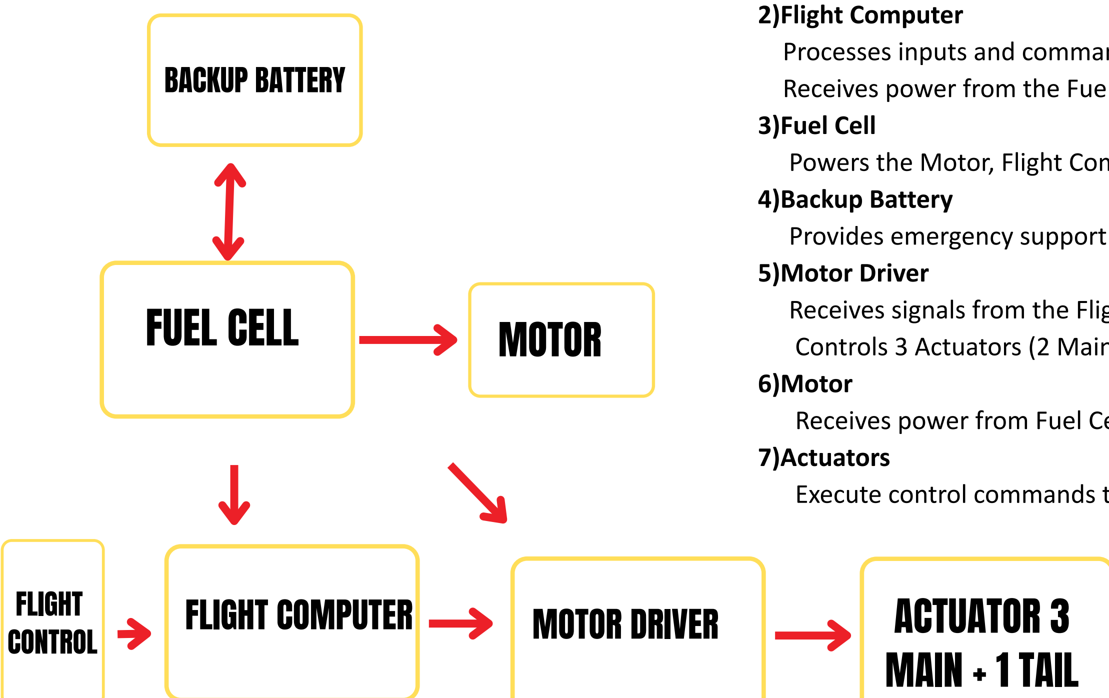



Fig - 10:Avionics System Flow Diagram

**AVIONICS SYSTEM WORKFLOW**

1)**Flight Control Input**

Sent to the Flight Computer.

**2)Flight Computer**

Processes inputs and commands the Motor Driver.

Receives power from the Fuel Cell and Backup Battery.

**3)Fuel Cell**

Powers the Motor, Flight Computer, and Motor Driver.

**4)Backup Battery**

Provides emergency support to the Fuel Cell and Flight Computer.

**5)Motor Driver**

Receives signals from the Flight Computer.

Controls 3 Actuators (2 Main Rotor + 1 Tail Rotor).

**6)Motor**

Receives power from Fuel Cell to rotate the rotor system.

**7)Actuators**

Execute control commands to manage aircraft motion.

# MAIN ROTOR SYSTEM

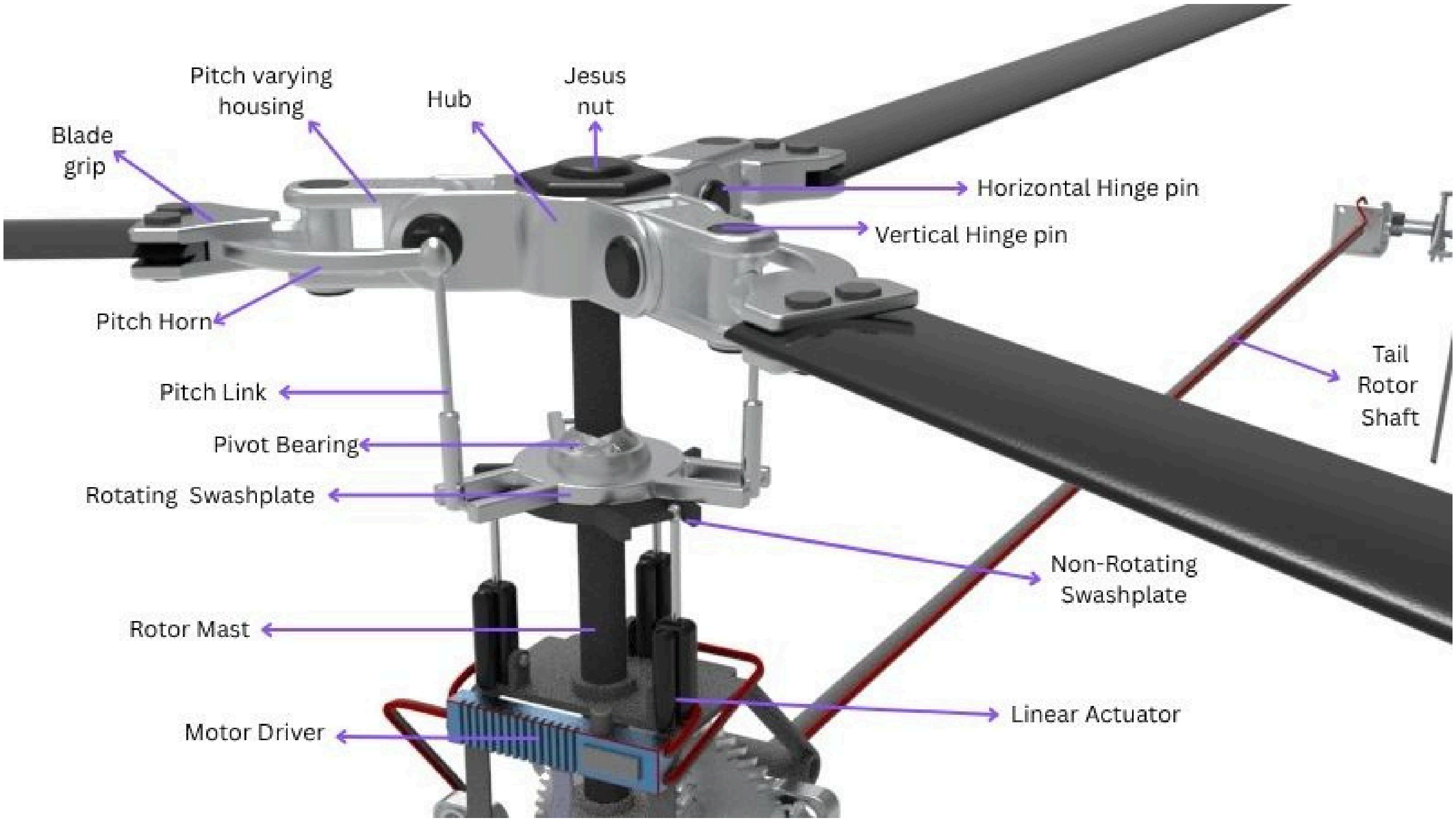



Fig - 11:Rotor System

## KEY FEATURES

- ***3-Axis Blade Motion***
  Enables flapping, lead lag, and pitching which ensures superior stability and maneuverability.
- ***Swashplate Control System***
  Dual (rotating and non rotating) swashplate enables real time blade pitch variation for precise lift.
- **Horizontal & Vertical Hinges**
  Allow dynamic flapping motion to balance lift during forward flight and reduce asymmetric lift.
- ***Lead-Lag Bearings***
  Absorb in plane aerodynamic stresses, minimizing fatigue and blade stress during high speed rotation.
- ***Pitch Horn + Link Assembly***
  Delivers accurate twist to rotor blades for efficient climb, descent, and yaw movements.
- ***Scalable & Reliable Design***
  Based on real world platforms (e.g., UH-60 Black Hawk), ensuring robustness and adaptability for UAV scale.
- ***Secure Central Hub (Jesus Nut)***
  Critical fail safe component locks rotor assembly to mast which ensures flight safety.
- ***Compact Linear Actuators***
  Precise swashplate motion control for automated or manual flight systems.

# TAIL ROTOR SYSTEM

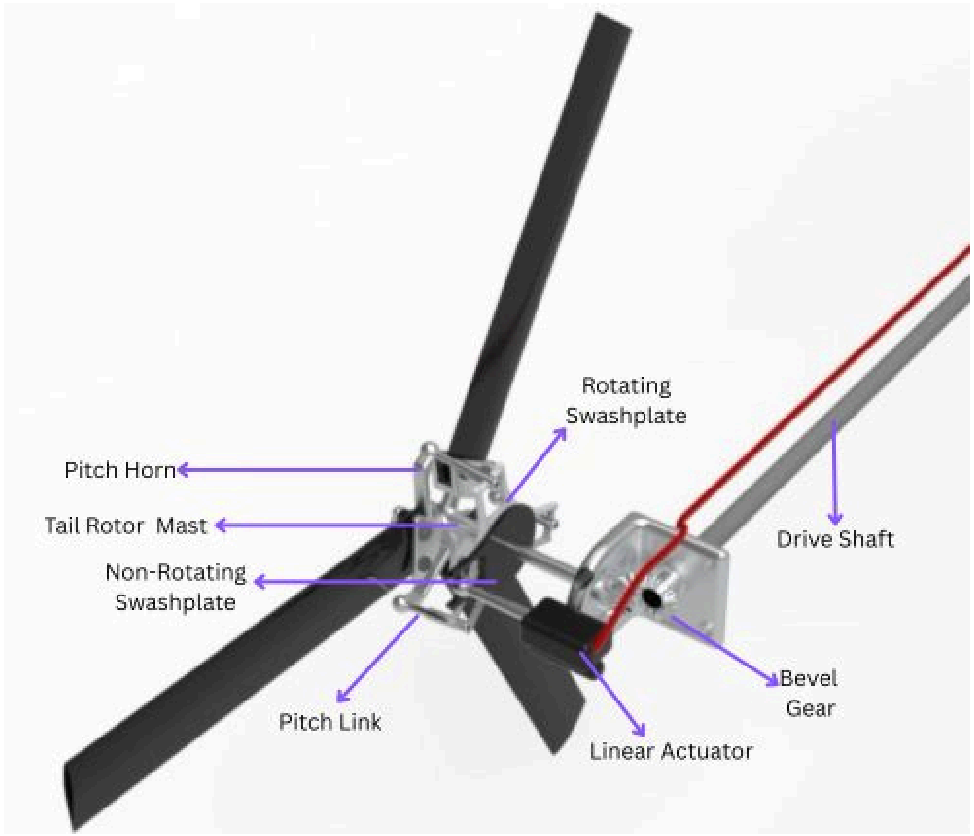



Fig - 12:Tail Rotor System

## KEY FEATURES

***THREE-BLADE CONFIGURATION***

Provides improved yaw authority and smoother anti-torque control.

***CARBON FIBER BLADES***

Each blade features carbon fiber skin with a reinforced carbon fiber spar lightweight yet highly durable.

***ALUMINUM ROTOR HUB & MAST***

Ensures structural strength with minimal weight, optimizing tail performance.

***PRECISION PITCH CONTROL***

Aluminum pitch horns, grips, and links adjust blade angle via a linear actuator for accurate yaw maneuvering.

***BEVEL GEAR MECHANISM***

Tail rotor is driven by a bevel gear connected to the drive shaft, powered directly from the main gearbox.

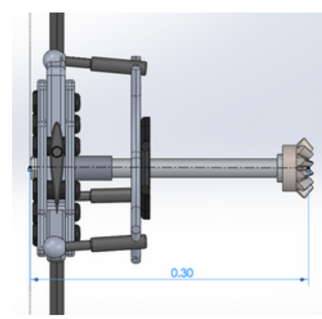


FIG - 13: Tail rotor front view

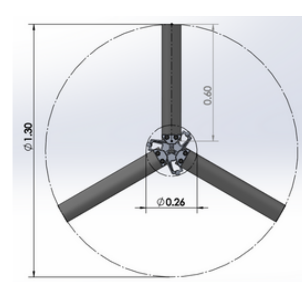


FIG - 14: Tail rotor TOP view

# U SHAPED AIR INTAKE

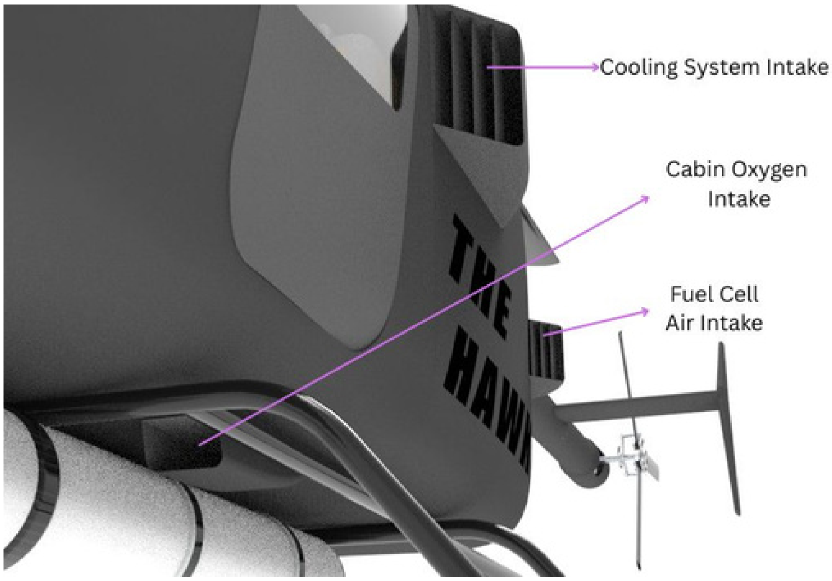



Fig - 15:Air Intake Close View

Fig - 16: Air Intake Isometric View

- **Strategic Rear Placement**: Intake valve is positioned behind cabin integrating seamlessly with vertical fin design for optimized airflow management.
- **Dual-Side Configuration**: Twin inlets mounted on fuselage sides maximize air intake volume while maintaining aerodynamic profile.
- **Enhanced Flow Efficiency**: Rear mounted design smoothens airflow over tail section reducing turbulence and drag which is crucial.
- **Aerodynamic Optimization**: Side mounted placement avoids upper/lower fuselage disruption, preserving clean aerodynamic lines.
- **Lightweight Integration**: Complex geometry seamlessly incorporated into airframe structure without weight penalties making it also robust.
- **Streamlined Design**: Intake system enhances overall rotorcraft efficiency through improved airflow management and reduced parasitic drag which improves efficiency and lessens fuel consumption.

# COOLING SYSTEM

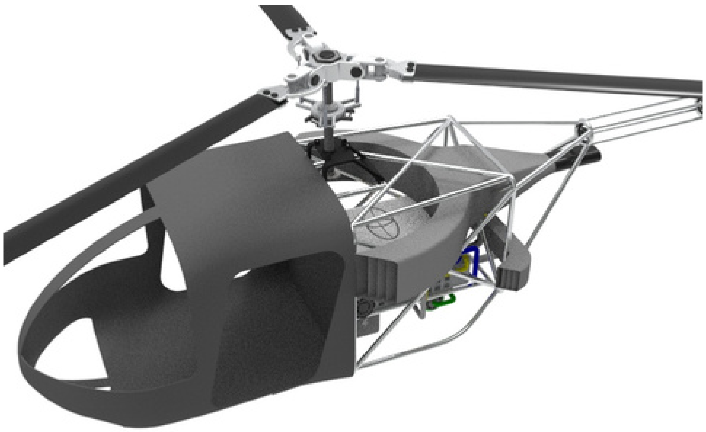


Fig - 17: Cooling and Air Intake Location

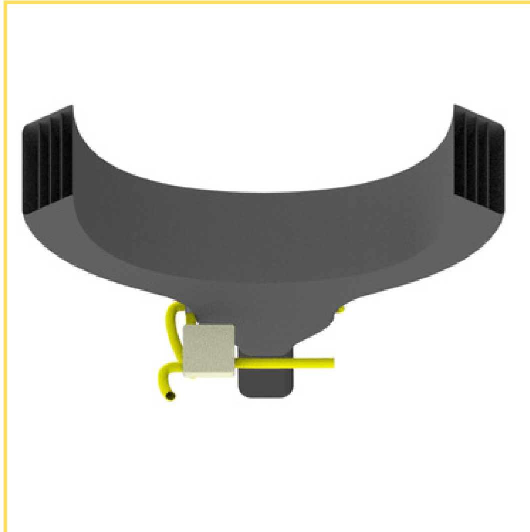


Fig - 18:Cooling System

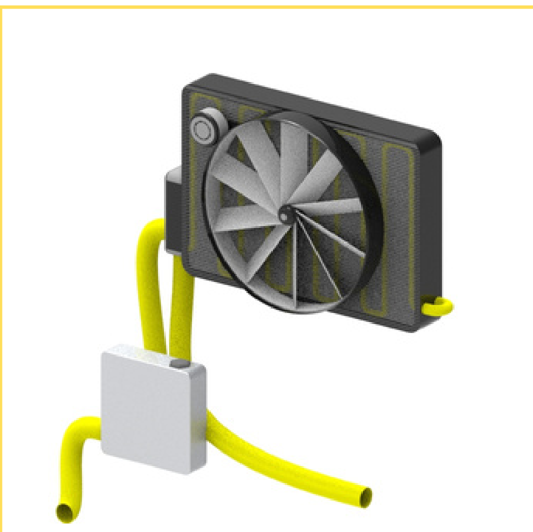


fig - 19: Finned Cross Flow Radiator

## COOLING SYSTEM DESIGN

### 1) Air Inlet Distribution:

Cooling air enters the cabin from both sides, ensuring better distribution.

### 2) Optimized Air Intake Area:

Air intake is angled slightly not fully perpendicular to the flow increasing the effective intake area.

### 3) Laminar Flow Enhancement:

Vertical fins are placed at the intake to promote smooth, laminar airflow into the system.

### 4) Heat Exchange Efficiency:

Utilizes a finned cross flow heat exchanger, enhancing thermal exchange efficiency.

### 5) Active Cooling Support:

Includes a motor-driven fan inside the cabin to actively boost cooling performance.

### 6) Velocity Control at Exit:

Air exits through a converging nozzle at the rear, increasing exit velocity for better airflow management.

### 7) Flow Management via Internal Frame:

The converging outlet is designed to allow flow to exit through the internal frame, aligning with structural and functional goals.

# FUEL CELL

Our reference model was Toyota TFCM2s-B,PEM Fuel Cell tech converts hydrogen and oxygen into clean electricity with only water as byproduct, featuring Toyota's self-humidifying membrane system that eliminates the need for external humidifiers.

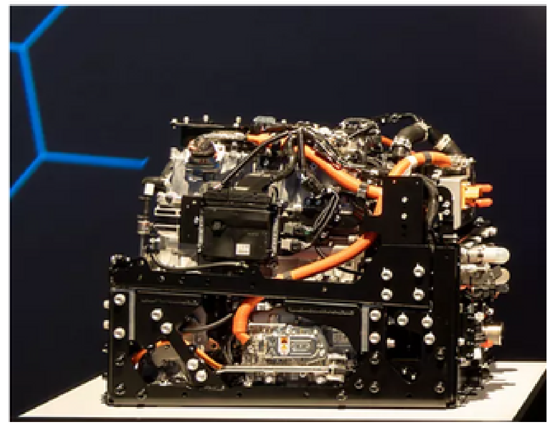


Fig - 20: Toyota TFCM2s-B PEM Fuel Cell

## NOW LETS LOOK AT OUR DESIGNED CAD MODEL

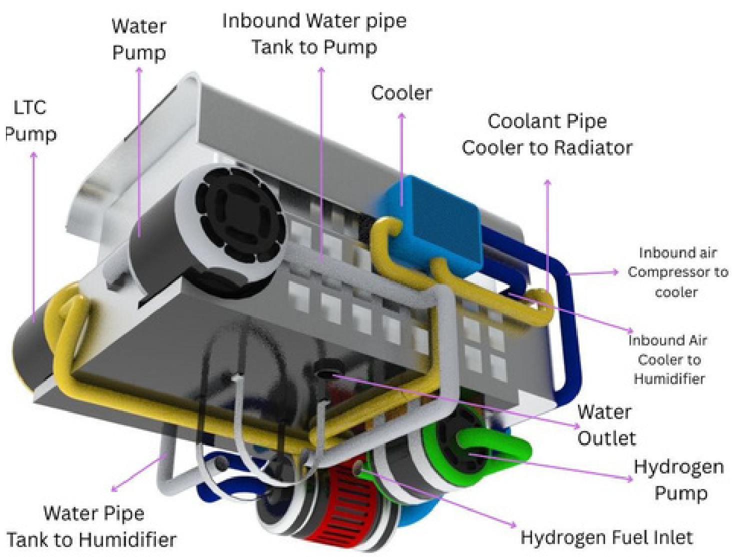



Fig - 21: Fuel cell defined

| Generated power by the engine | |
|---|---|
| **Rated Power (EOL)** | 85kW |
| **MINIMUM** | 0kW(idle),15kW |
| **Response** | 40kW/sec |

Table - 3:Generated Power by Engine

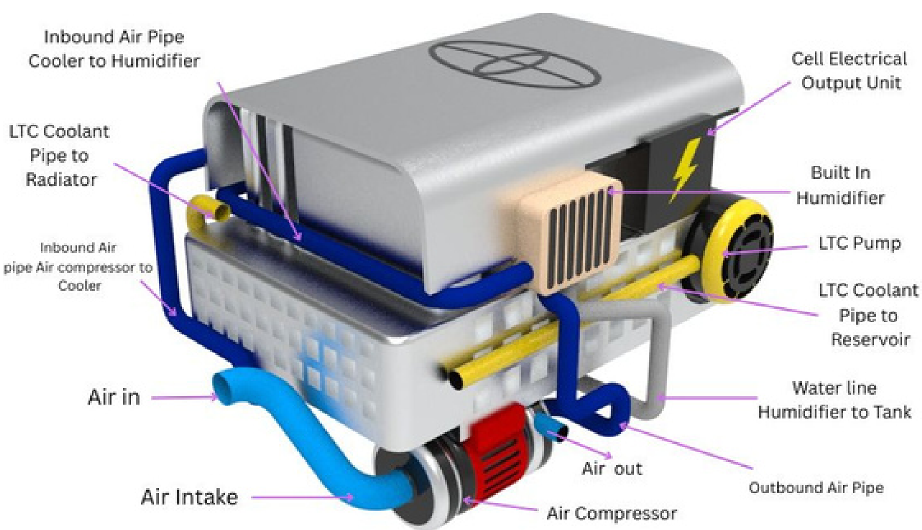
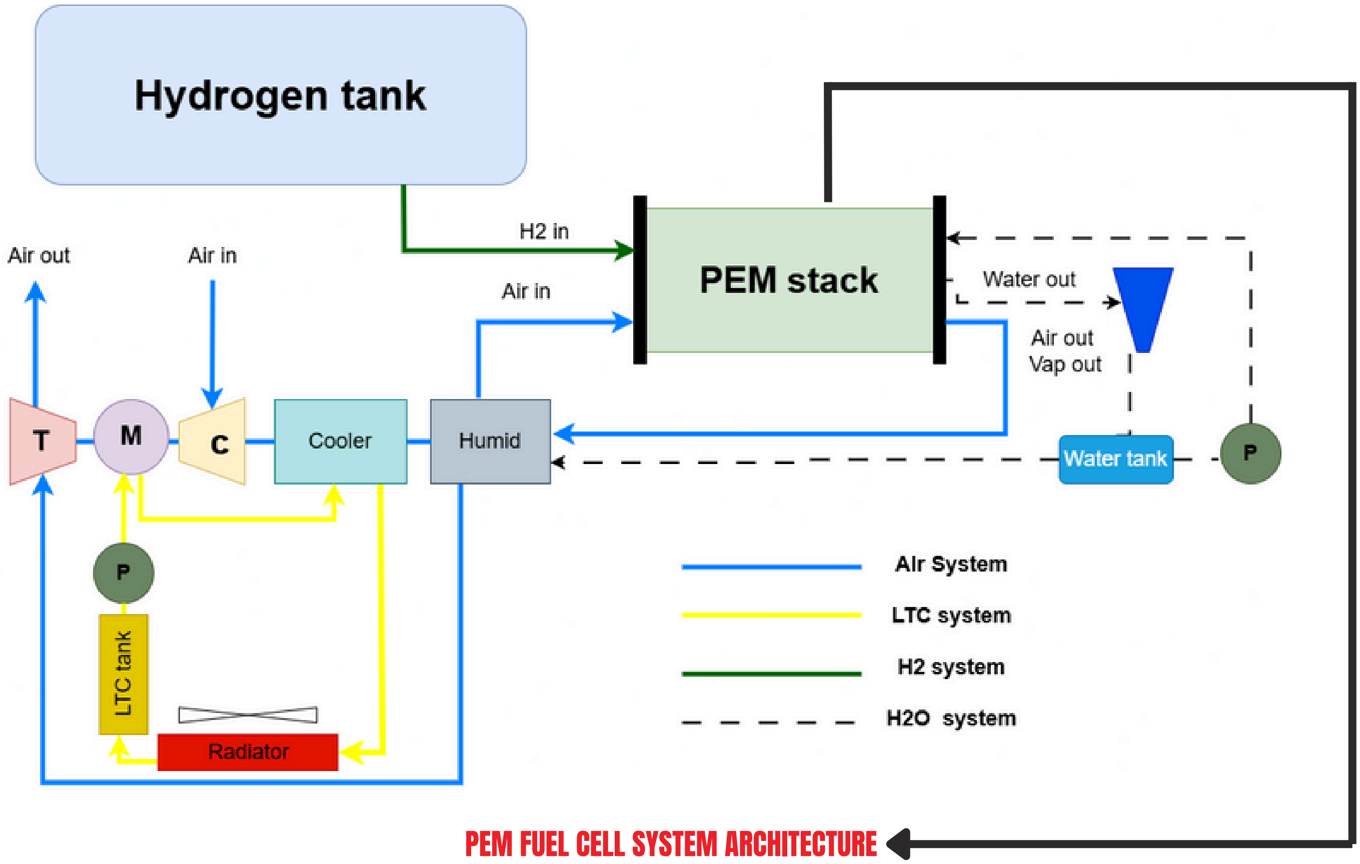



Fig - 22:Fuel Cell Isometric View with each parts defined

# FUEL CELL WORKING PRINCIPAL



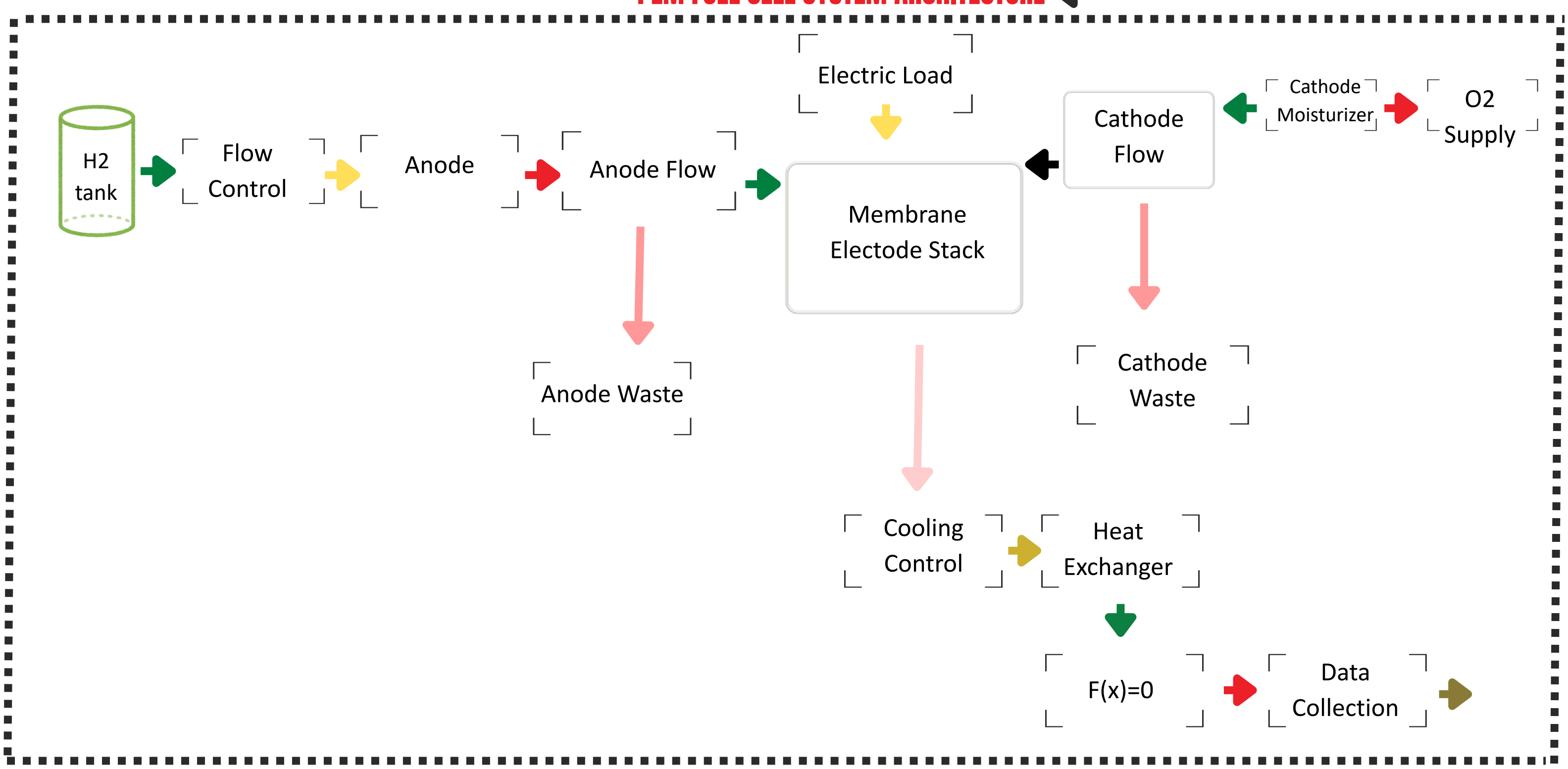




Fig - 23:PEMC Fuel Cell System Architecture

# PERFORMANCE ANALYSIS

We ran MATLAB-based simulations to assess the TFCM2s-B PEMFC integrated into The Hawk. This gave us valuable insights into aspects like current draw, power output, efficiency, hydrogen consumption, and thrust generation.

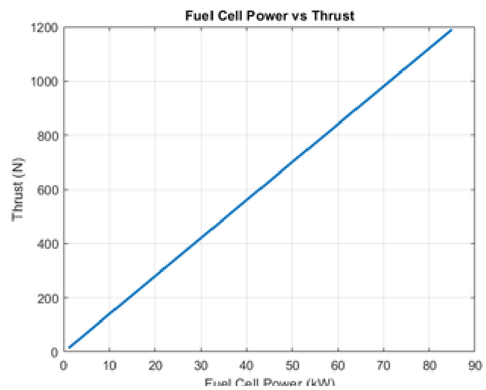



Fig - 24:Power vs Thrust

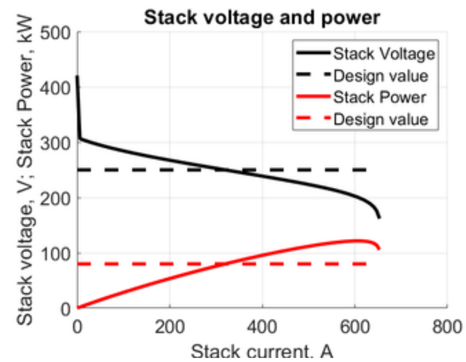



Fig - 25: Voltage vs Current

**POWER VS THRUST**
Simulation confirms there is enough aerodynamic thrust at cruising speeds when operating with 40-60 kW of power.

**STACK VOLTAGE AND POWER VS CURRENT**
The plot shows that the TFCM2-B module is capable of providing the necessary output while keeping current levels safe, even with the usual polarization losses.

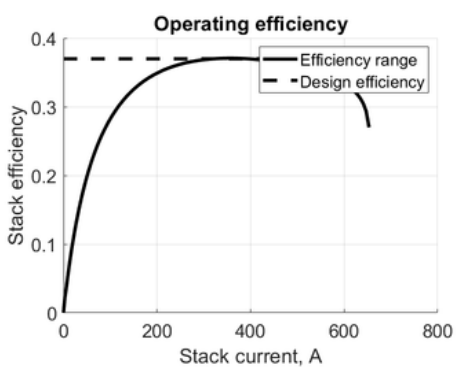



Fig - 26:Efficiency vs Current

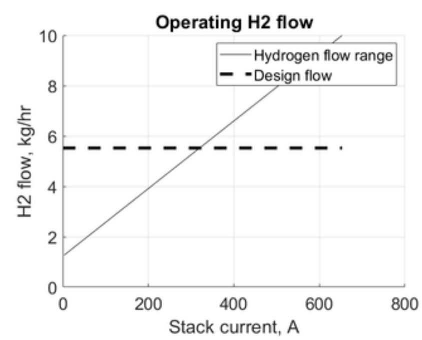



Fig - 27:H2 Flow vs Current

**STACK EFFICIENCY VS. CURRENT**
The graph shows the electrical efficiency of PEMFCs, revealing that as the current draw goes up, the stack efficiency tends to drop.

**HYDROGEN FLOW RATE VS CURRENT**
Here is a linear relationship between hydrogen consumption and electrochemical reaction rate. Endurance estimates and reserve margins for a 700-bar COPV tank.

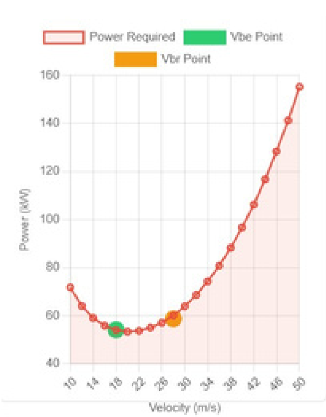



Fig - 28.1)Power vs Velocity

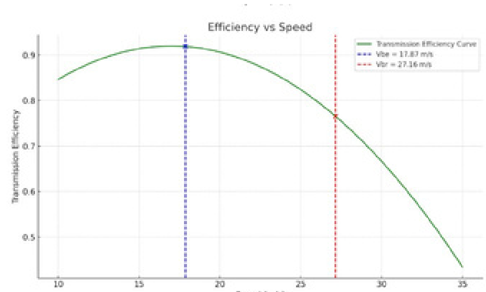



Fig - 28.2)Efficiency vs Speed

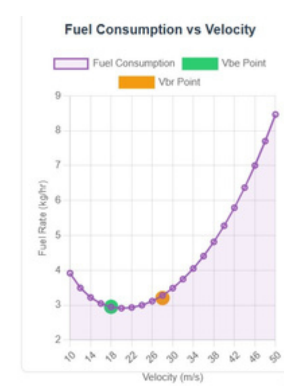



Fig - 28.3)Fuel Rate vs Velocity

# CFD ANALYSIS OVER BODY

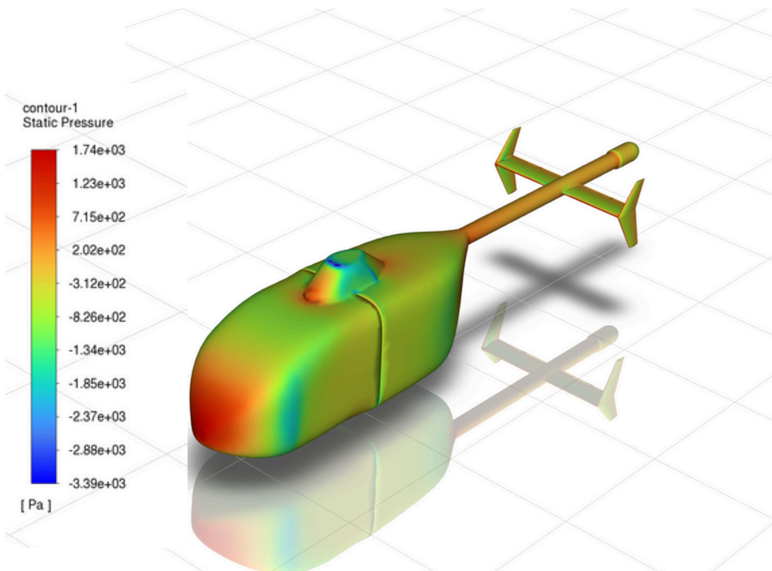



Fig - 29:Pressure Contour over Fuselage

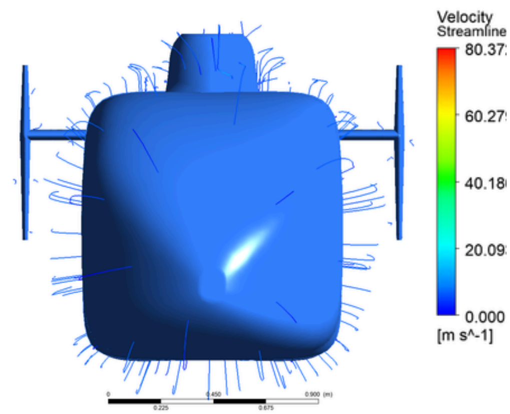



Fig - 30:Streamlined Velocity

- Has good aerodynamic efficiency amongst R22 and Cabri G2.
- Maintains structural coherence and flow interference is very minimal.
- Achieves higher lift and lower drag.
- The pressure gradient is very optimum.
- Displays strategically distributed turbulence, aiding stability and energy management
- Compared to R22 and Cabri, our fuselage dominates.

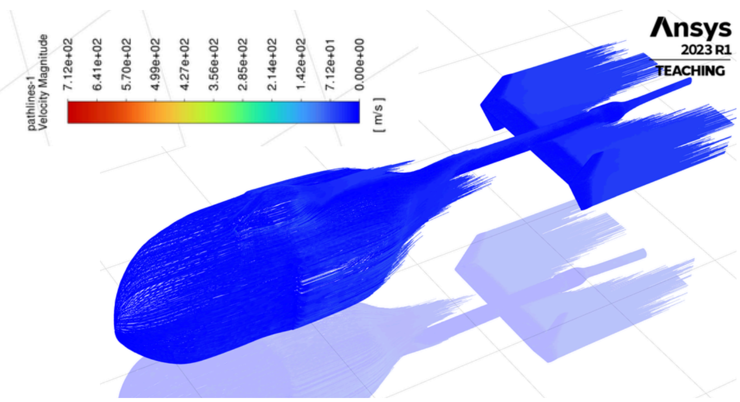



Fig - 31:Velocity Pathlines

## ANSYS FLUENT RESULT

| Parameter | The Hawk | Cabri | R22 | Hawk vs Cabri | Hawk vs R22 |
|---|---|---|---|---|---|
| Peak Streamline Velocity | 80.372 m/s | 65.1 m/s | 63.8 m/s | +23% | +26% |
| Max Pressure | 1544 Pa | 1226 Pa | 1455 Pa | +26% | +6% |
| Suction Pressure | -3626 Pa | -3010 Pa | -2377 Pa | +21% | +53% |

Table - 4: Flow Over Body Performance Results Comparison


Fig 32: Absolute Performance Graph

# FINITE ELEMENT ANALYSIS : AIRFRAME AND LANDING GEAR

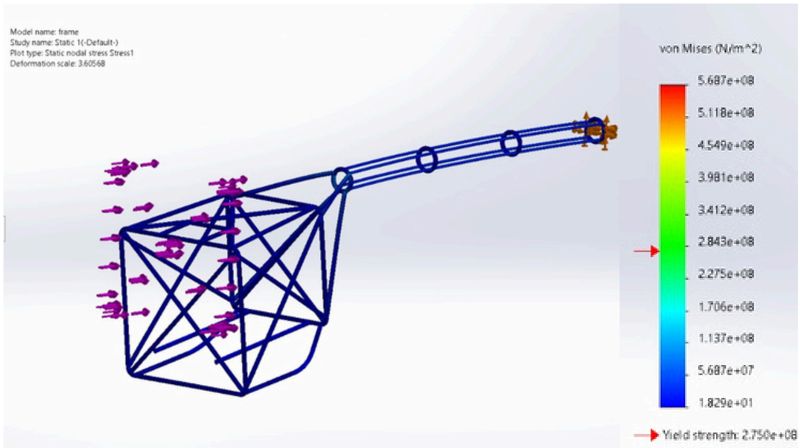
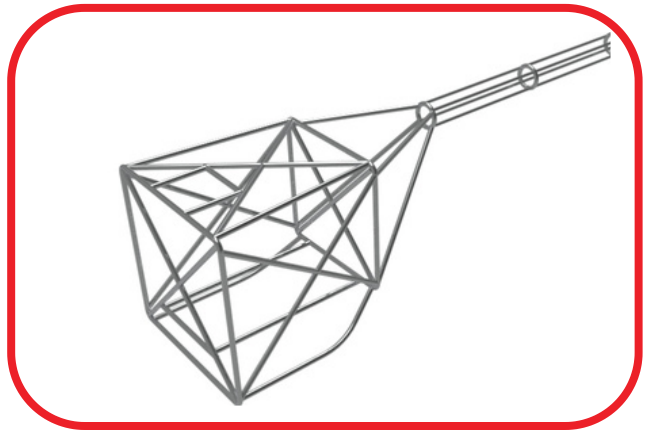



Fig - 33: FEA on Chassis



The static structural analysis of the Aluminum 6061-T6 chassis under a 1000 N load (rear fixed) shows safe stress levels and manageable deformation, confirming design integrity.

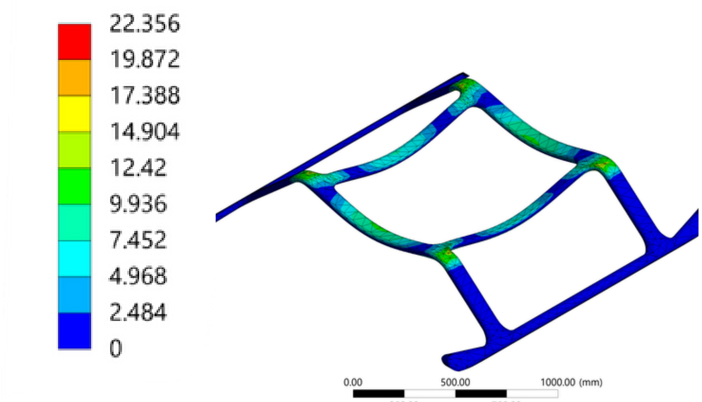



Fig - 34: FEA on Landing Gear

Landing Gear (Al 6061-T6):It can Withstand easily 5000 N vertical load in ANSYS; max deformation 247.34 mm under hard landing simulation, base remained stable and is capable of handling superior loads.

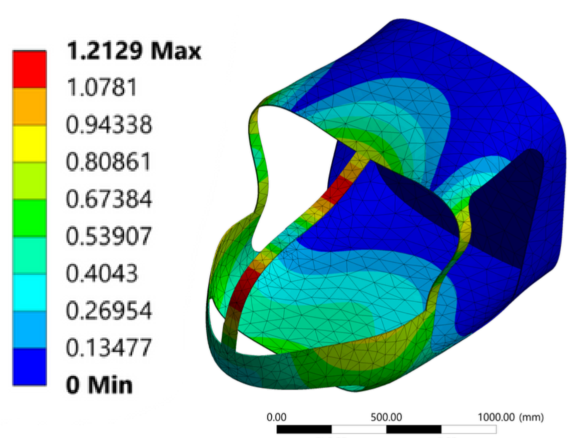



Fig - 35: Cabin Finite Element Analysis

- Rear being fixed; 0.001 MPa load on carbon fiber shell (E = 230 GPa) resulted in only 1.21 mm max deformation, well within aerospace limits which makes the material fit for our criteria.
- It supports strict MTOW and endurance requirements crucial for our design.
- The team accepted higher fabrication complexity due to its superior strength-to-weight ratio.

# OPTIMAL ALLIGATOR SPOTTING PLATFORM WITH COMFORT

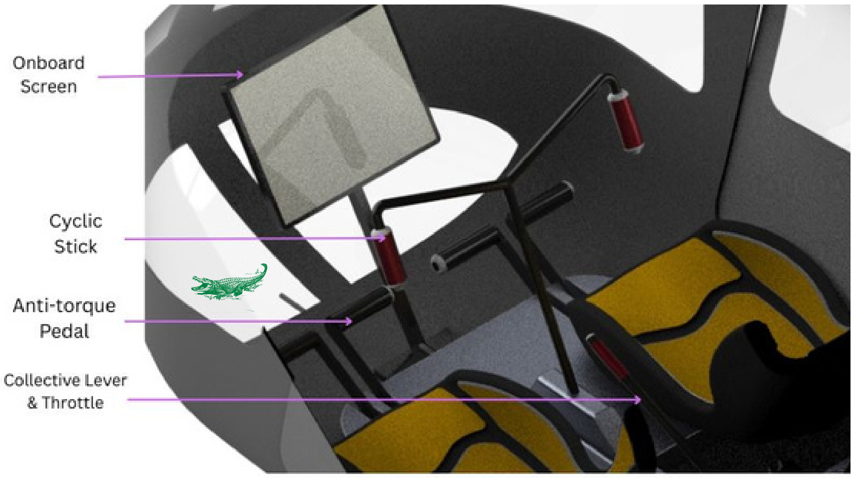



Fig - 36:Interior of Bubble Canopy Cabin

- **Panoramic Viewing:** Large bubble canopy provides 360° visibility for passengers to spot alligators from every angle.
- **Stable Observation Platform**: Advanced flight computer maintains steady hover and smooth flight for clear wildlife photography and observation.
- **Low-Altitude Capability:** Whisper-quiet hydrogen power allows close-range alligator detection without scaring wildlife away.
- **Comfortable Extended Viewing**: Ergonomic racing seats with climate control keep passengers comfortable during long spotting sessions.
- **Perfect Vantage Point:** Elevated helicopter perspective gives passengers unobstructed views of waterways, marshes, and alligator habitats below.


Fig - 37:Interior of Bubble Canopy Cabin with pasengers and luggage

According to the RFP our model is capable of carrying one passenger along with the pilot. The Cabin has been designed as such it has moving seats which enhances the luggage space for comfort. The Bubble canopy also provides superior visibility over a wide range.

# COST AND WEIGHT ANALYSIS

| Subsystem | Estimated Cost (USD) | Weight (kg) | Notes |
|---|---|---|---|
| PEM Fuel Cell Stack (120 kW) | $50,000* | 240 | TFCM2-B module; cost adjusted for prototype scale |
| Hydrogen Storage (Type-IV Tank) | $6,000 | 13.12 | 700 bar, ~5–6 kg capacity; cost includes tank and associated hardware |
| Li-ion Battery (4.5 kWh) | $1,000* | 18.12 | Based on 4.5 kWh capacity; weight from product specifications |
| Radiator (Lytron M05-050) | $550* | 2 | Commercial off-the-shelf liquid cooler |
| Fuel Cell Air Pump/Controls | $1,000 | (Integrated with PEMFC) | Includes compressor and ECU |
| Electric Motor (120 kW) X2 | $50,000* | 42.8 | Axial Flux Motor (Emrax- 268) |
| Inverter (120 kW) | $10,000 | (Integrated with PEMFC) | Weight based on comparable inverter models |
| Structure (Fuselage + cabin) | $20,000 | 92.41 | Carbon-fiber frame |
| Rotor Assembly | $10,000 | 24.05 | Hub, two blades, and controls |
| Avionics Systems | $10,000 | 6.5 | Electrical systems |
| Total(approx.) | $149,300 | 439 | |

**(NB: * INDICATES REAL PRICES IN THE CURRENT MARKET)**

Table - 5:Cost and Weight Analysis Chart

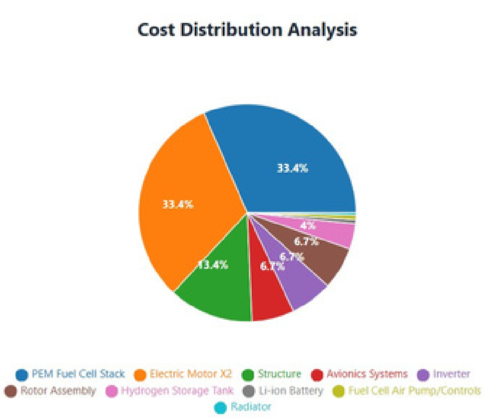



Fig - 38: Estimated Cost Pie Chart

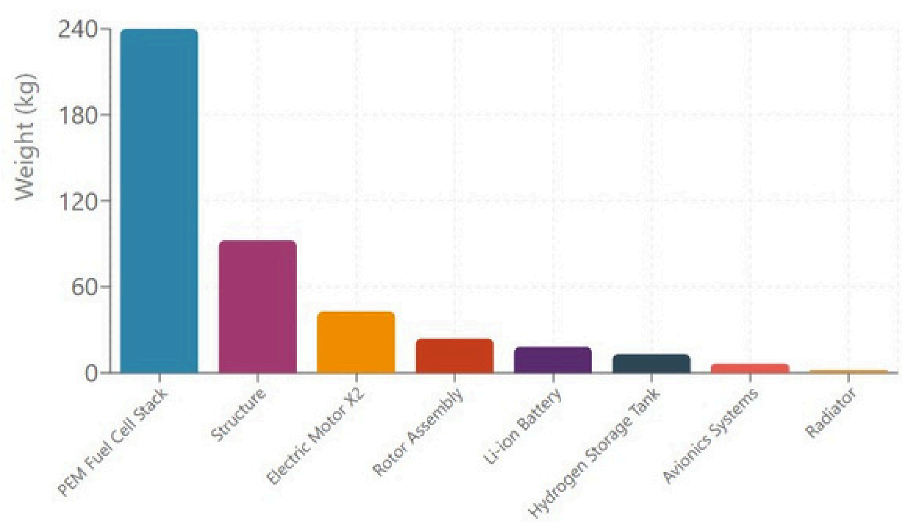



Fig - 39: Weight Analysis Graph

# CONCLUSION

The Hawk is the brainchild of seven passionate individuals. It is not just a conceptual helicopter but more than that. The Hawk is a bold leap into the future of aviation which was inspired by proven platforms like the Robinson R22 and Cabri G2. The Hawk is elevated with cutting edge technologies like hydrogen electric propulsion which is a leap into future sustainable aviation. The Hawks extended endurance with quieter operation and zero emission makes it a suitable candidate not just for the mission objectives but also real world scenarios keeping the characters of what a next generation rotorcraft should strive for.

The Hawk has a fully articulated rotor system and carbon fiber reinforced structure with aluminum truss body accompanied with advanced high end avionics system which has finessed its design. The model has been validated through iterative simulation approach on Ansys. Every details of The Hawk is engineered with precision and a purpose. Its a poetry, a notion and the future of the avitation sector.

Through this, we, The Hawks Team of Bangladesh University of Professionals (BUP), represent a machine, a brainchild ; which doesn't only meet the requirements stated by the RFP but redefines them with precision, innovation and ofcourse passion. This is our effort; a tribute on creating a machine capable of sustaining a cleaner sky,  smarter system and a greener future.