VIBHRAM

24 Hours Hovering Helicopter

In response to

34th Annual

AHS International

Student Design Competition

By

Team endureair

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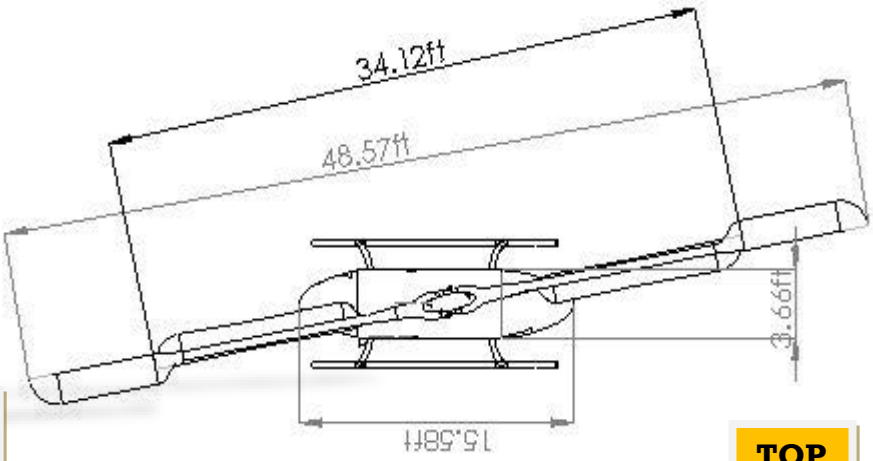
2017

VIBHRAM AIRFRAME 4-VIEW

ISOMETRIC



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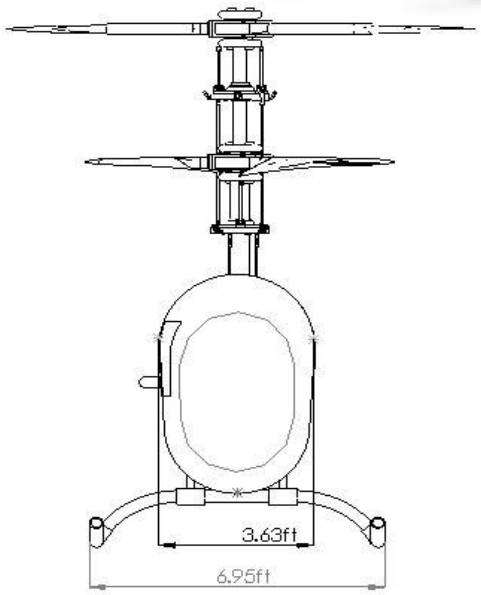

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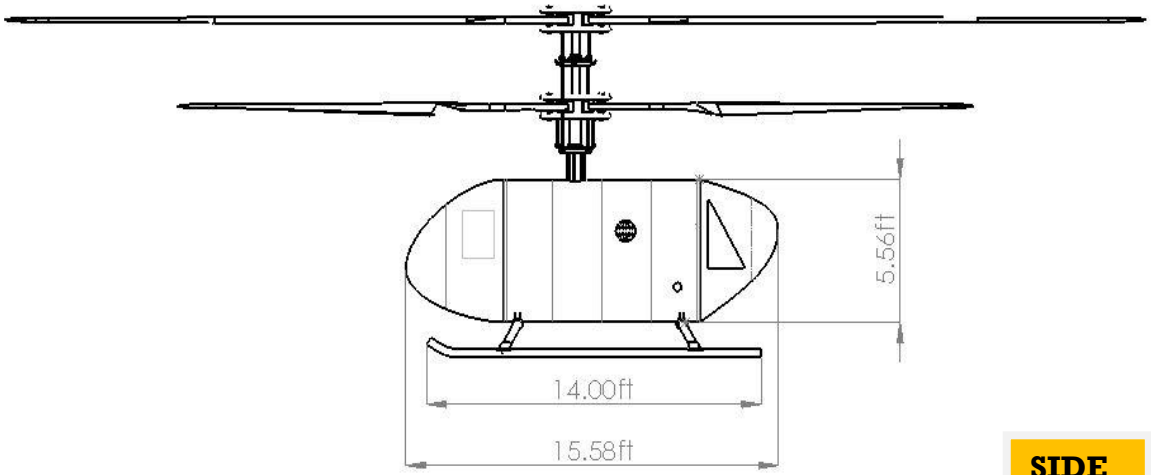

SIDE

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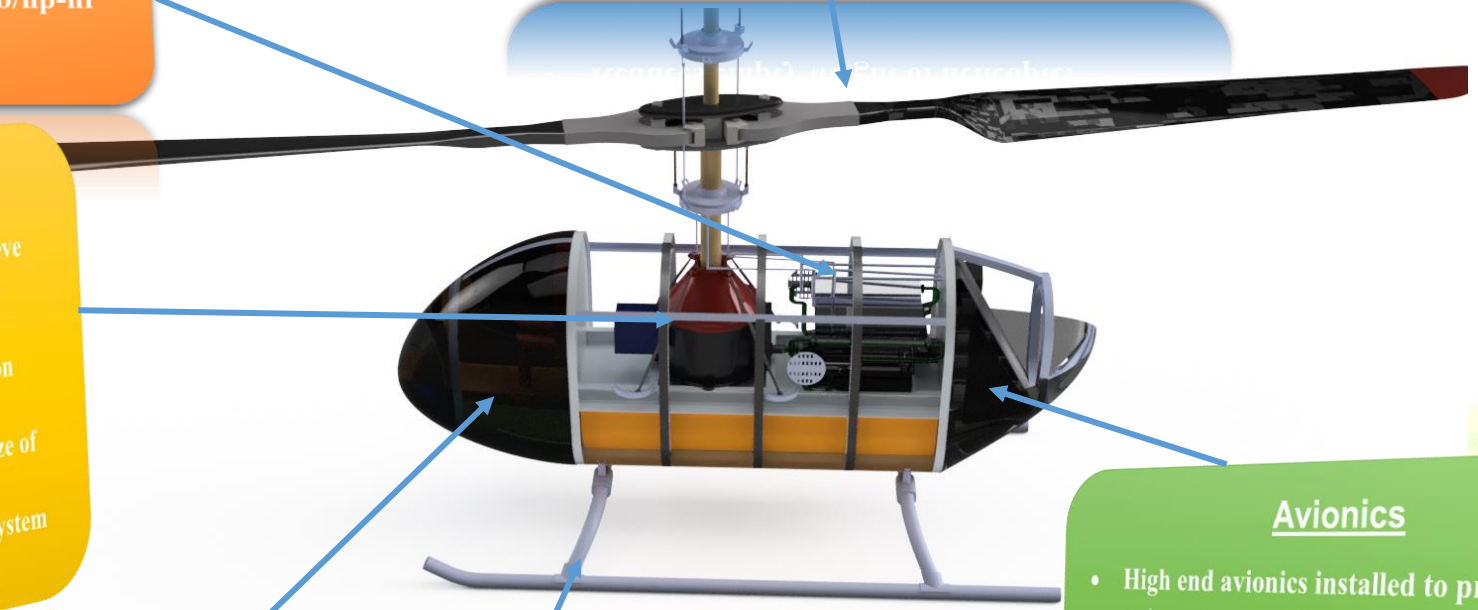
HELICOPTER SYSTEMS OVERVIEW

Dissimilar Coaxial Rotor System

- New patented technology for efficient
- Minimizes downwash interference losses between rotors
- Reduces empty weight of helicopter

Vision 350 V8 Diesel Engine

- Engine shaft output of 350hp
- Specific fuel consumption of 0.32lb/hp-hr



Transmission System

- Innovative design concept to achieve differential RPM in coaxial rotor system
- Fluid elastic dampers for vibration isolation
- Use of spiral bevel gear makes size of gear box compact
- Highly Optimized Lubrication system using Pressurized Lubrication.

Avionics

- High end avionics installed to provide full autonomous capability to the helicopter
- Sophisticated systems like FADEC,AFCS,AHRS,VMS keeps track of helicopter attitude and control at every stage

Payload delivery

- Enough space given for payload to simulate human occupancy

Landing Gear

- Light weight and high strength Al 7068 Aluminum alloy was used for Skid Landing Gear
- Its Analysis shows Factor of Safety lies within limits.

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DISSIMILAR COAXIAL ROTOR

A new concept is proposed to increase the hover efficiency of a rotorcraft called "Dissimilar Coaxial Rotor".

Asymmetric coaxial rotor consists of two rotors with different blade radius and rotor speeds, spinning in opposite direction. One rotor with small root cut-out and small radius but long blade length is called the "main rotor" the other rotor has large radius with large root cut-out and short blade length and is called the "anti-torque rotor".

- **Main rotor produces most of the lift and the torque produced by the main rotor is balanced by the anti-torque rotor. In addition to providing the anti-torque, it also produces the thrust vector in the direction of main rotor thrust.**
- **The interference between the two rotors is avoided by offsetting the blade lifting areas. Since the blade radius of the top rotor is large, rotor speed equal to 50% of the main rotor speed is sufficient to provide torque balance.**

The anti-torque rotor consumes only around 30% of the total rotor power. The design of dissimilar coaxial configuration patent has been filed in the name, "Coaxial Rotor System with Asymmetric Rotor Arrangement and Method Thereof", with Patent Application No. 201711013049, Dated11/04/2017 by Rahul and Dr. Abhishek.

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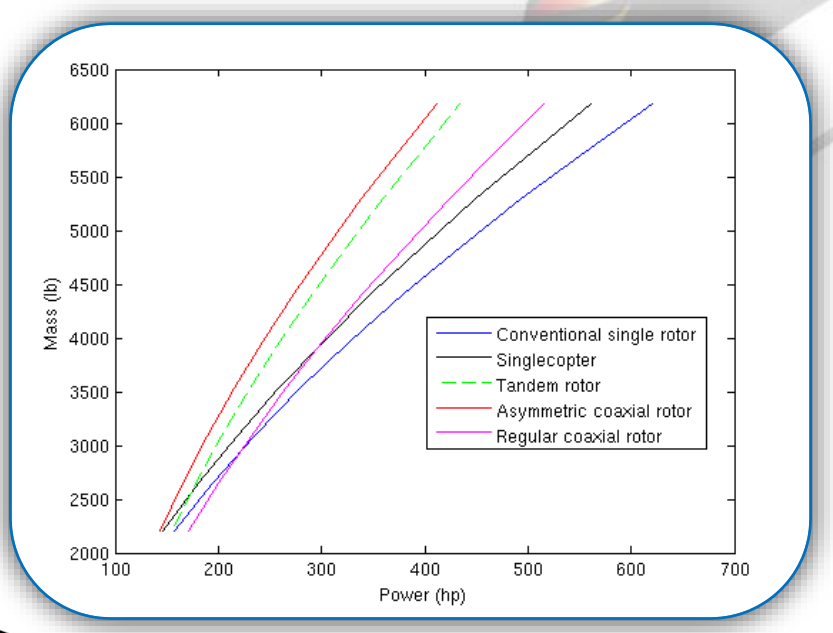
DISSIMILAR COAXIAL ROTOR

Dissimilar coaxial rotor optimization is done by fixing the maximum radius of the anti-toque rotor to 7.5 m. Rotor parameters such as main rotor blade radius, rotor speeds, blade chords and twist are optimized for maximum power in hover. The rotor performance analysis is done using Blade Element Momentum Theory (BEMT).

Main rotor parameters	
Number of Blades	2
Radius(ft.)	17
RPM	286
Chord(ft.)	1.64
Twist	-16^o

Anti-torque rotor parameters	
Number of Blades	2
Radius(ft.)	24.2
RPM	143
Chord(ft.)	1.64
Twist	0^o

The Dissimilar coaxial is compared with existing rotorcraft configuration such as conventional single rotor, single copter, Tandem rotor, regular coaxial helicopter. The comparison is made for the main rotor radius of 17 ft. It is observed that the proposed concept is the most efficient among all the existing designs.



Power saving of around 15 to 20 %is observed when compared with regular coaxial rotor.

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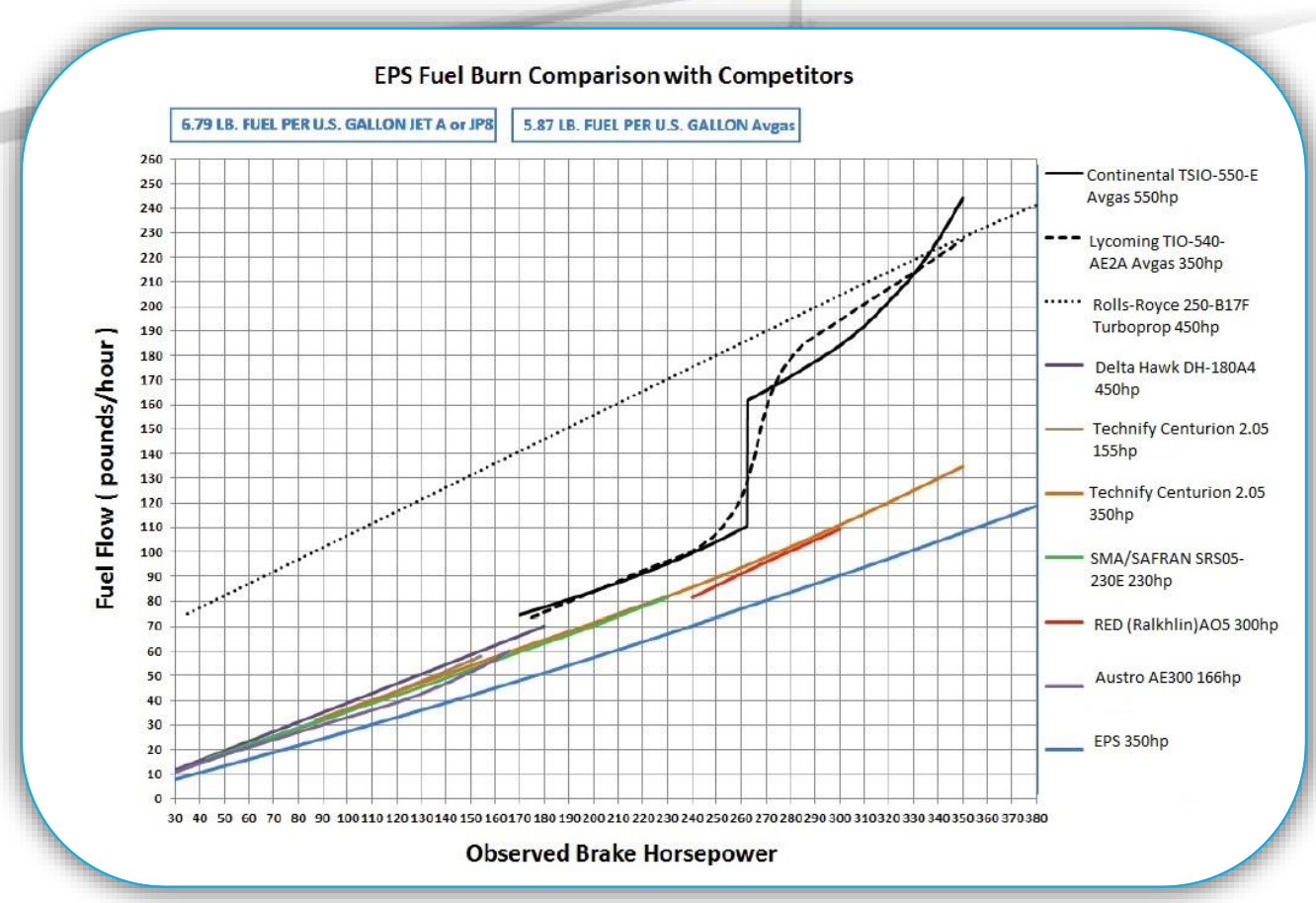
PROPULSION SYSTEM

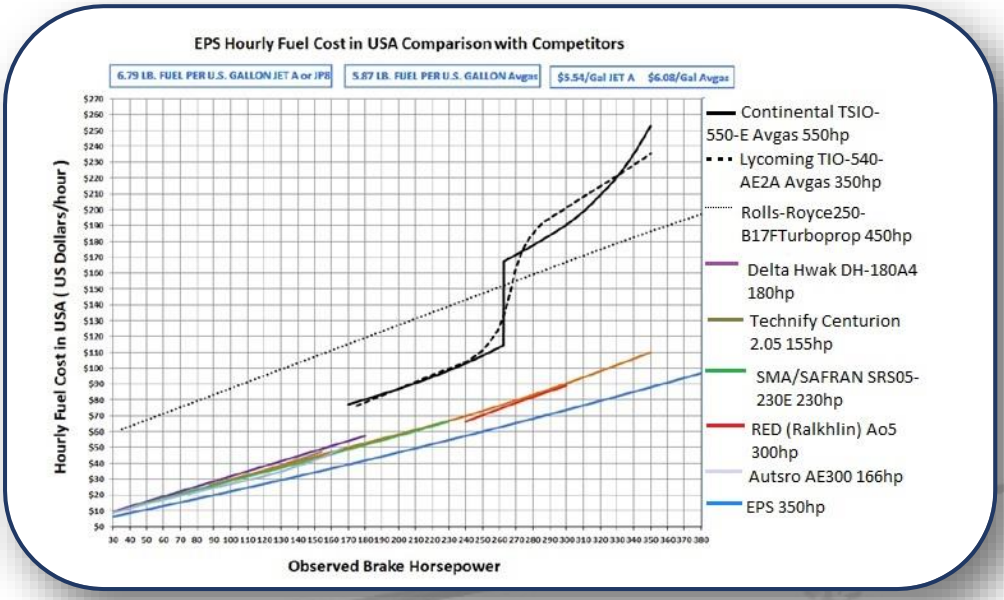
The engine selected for Vibhram helicopter is VISION 350 developed by the EPS and industry leader Bosch General Aviation Technology designed the electronic control system.

- **Vision 350 runs in the power range of 350HP to 380HP.**
- **8 Cylinder, four stroke piston engine.**
- **Compacted Graphite Iron Cylinder Block (CGI)**
- **3,000 hour target Time between Overhauls (TBO).**

DIESEL ENGINE	
Engine parameters 'VISION 350'	
Engine units	1
Power Output (hp)	350-380
SFC(lb/hp-hr)	0.32-0.34
RPM	3800



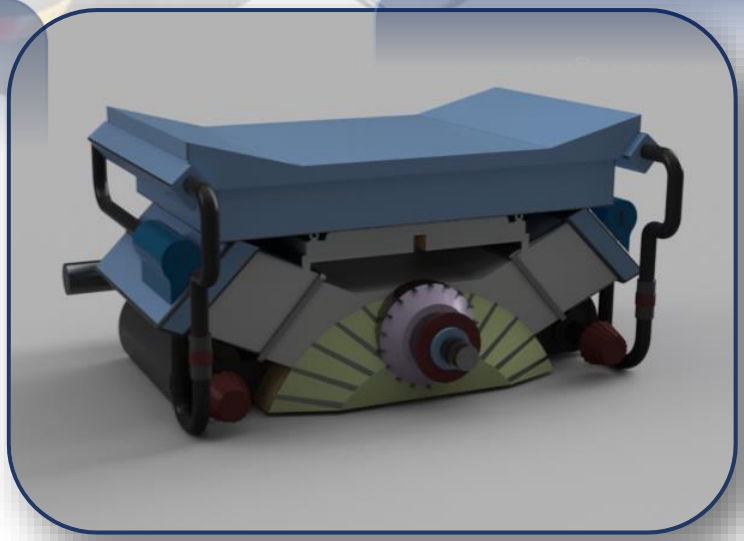
PROPULSION SYSTEM



41% Average fuel saving than continental IO-550(horizontally opposed) engine.

Uses variety of heavy fuels including Jet A, JP-8 or straight diesel.

15% better fuel efficiency than the 6 (showed in curve) other diesel engine.



Output of CO_2 is 30 percent less than comparable Avgas engines and 17 percent less than comparable diesel engines.

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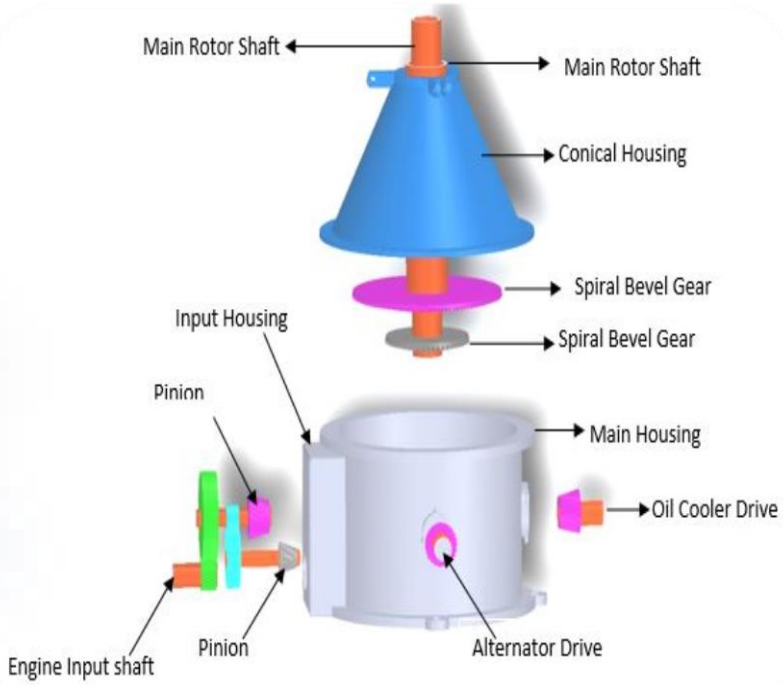
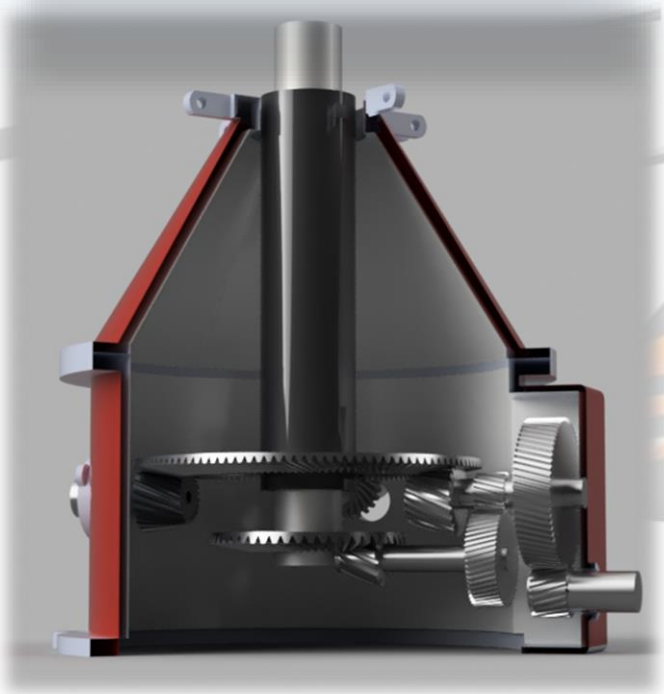
TRANSMISSION SYSTEM

- To minimize power loss during such long time operation, continuous lubrication is provided using pressurized lubrication system.
- Pressurized lubrication is employed for lubrication purpose which is an optimized and more reliable method for longer duration of flight.





- A unique and new transmission system is developed to meet the need of different RPM in Coaxial rotors
- As rotors have different radius, hence it is required to have different RPM to counteract the torque generated by the bottom rotor.

Gear Mesh Details (for first rotor)

stage	power	Input speed	Output speed
1	274	3800	1534
2	91	1404	518
3	91	518	144

Gear Mesh Details (for second rotor)

stage	power	Input speed	Output speed
1	274	3800	1403
2	183	1403	288

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- Vibration plays a key role in long time operational requirements
- Gearbox is attached to the structure with four pylon struts having vibration isolation system.

AIRFRAME ASSEMBLY

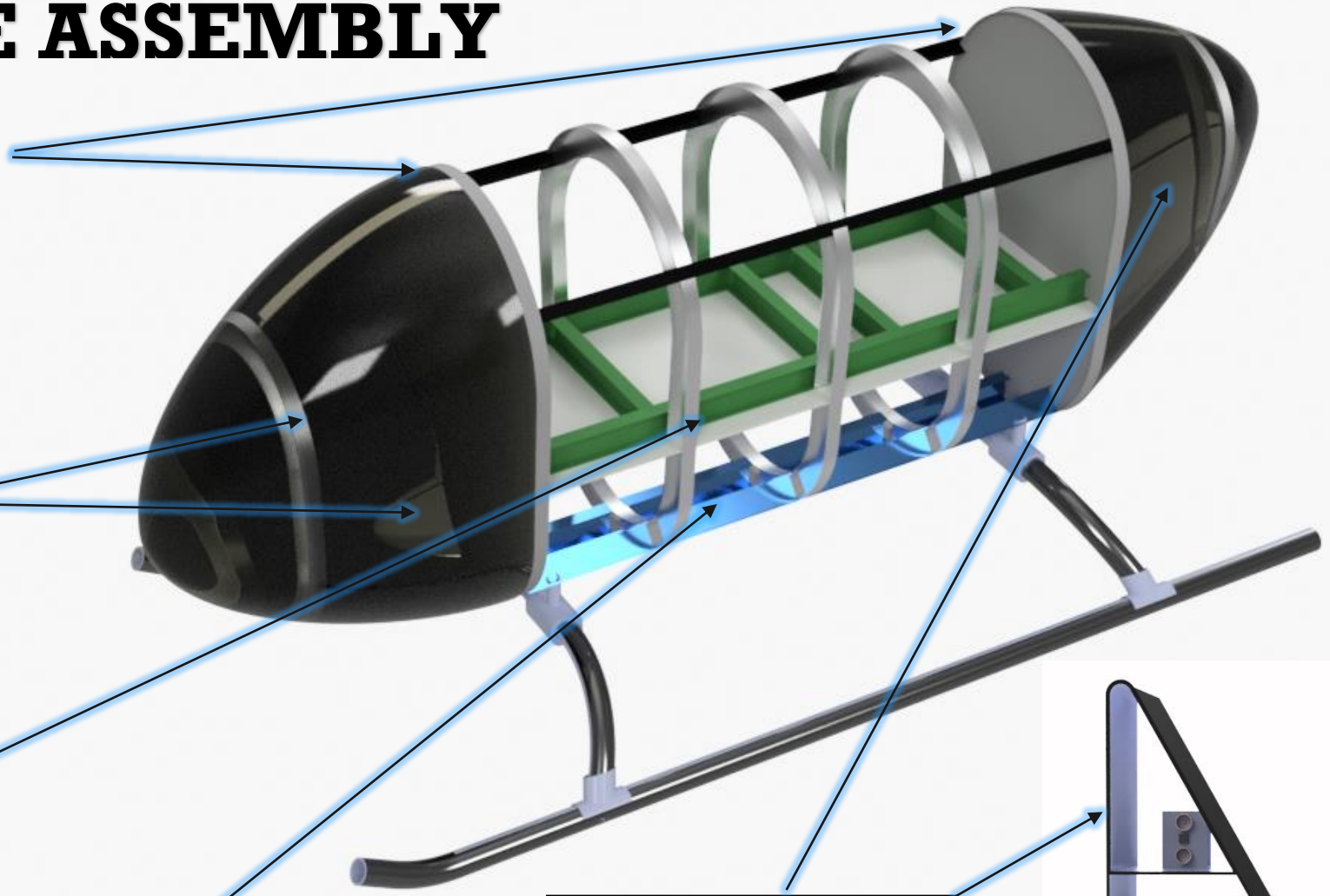
Two main bulkheads accompanied by Formers and Longerons

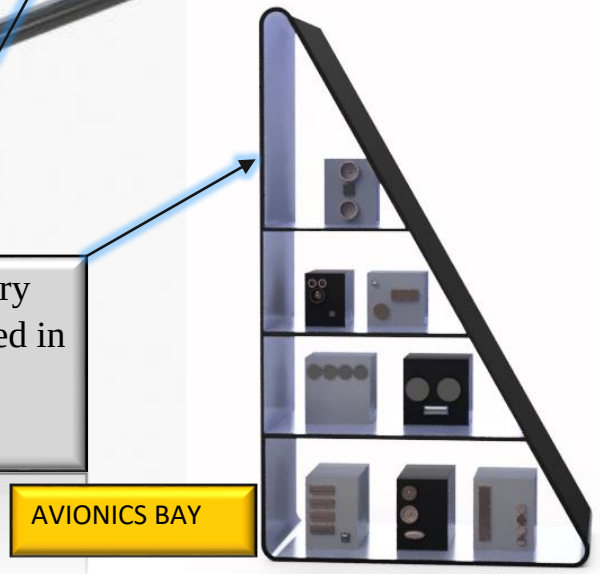
Nose section houses payload and auxiliary fuel tank

Transmission deck with lateral and longitudinal I-beams

Bottom Deck with three keel beams which support interconnected fuel tanks and Skid landing gear

Avionics Bay with battery and actuator box is placed in aft section





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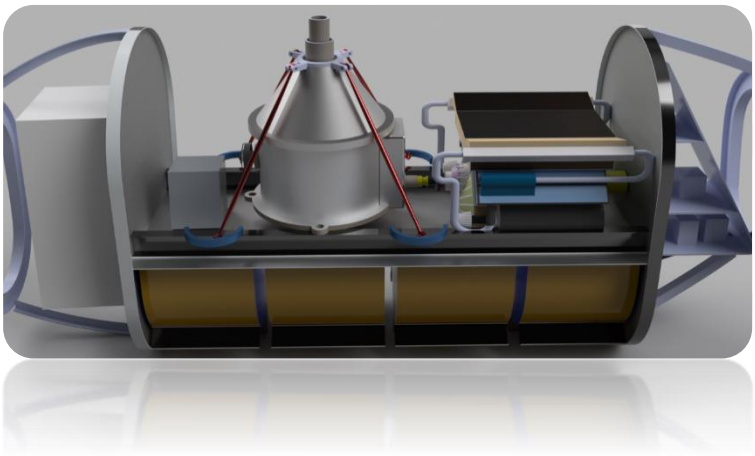
AIRFRAME DESIGN

Innovative Design

- Conventional fuselage of helicopter is designed aerodynamically more efficient in forward direction
- The cross section of the fuselage of Vibhram has been chosen in such a way that the drag is reduced in both inflow direction and in the forward flight directions.
- Moreover due to hover being major flight regime, the vehicle is designed without tail boom which drastically reduces the weight of the vehicle.



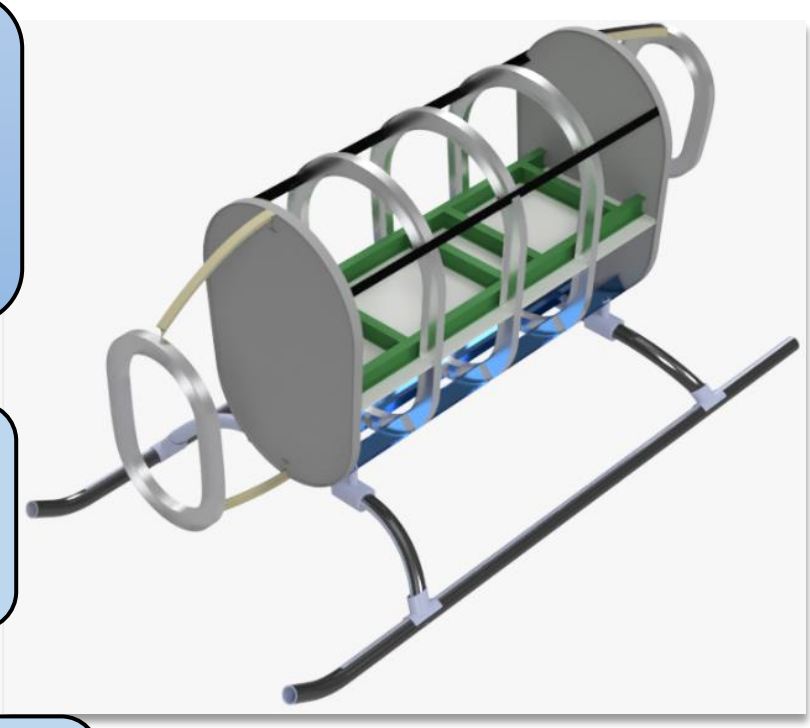
- Normally, Engine and the transmission system are kept on the top deck of the airframe. But in this design, the transmission and propulsion system are shifted downward and is kept as close as possible to the centre of gravity of fuselage. This concept thus limits the CG travel in Z-direction and ensures stability of the vehicle.

CONSTRUCTION

- The fuselage is divided into three modules longitudinally namely Nose , Centre fuselage and Aft fuselage
- Bulkheads, formers and longerons are used to connect different sections and transfer loads from rotor assembly to airframe.
- The construction of the fuselage is semi-monocoque. Metal is used in the construction of bulkheads, formers and longerons while skin of the fuselage and transmission deck are sandwiched construction made up of Nomex/flex cores with carbon/glass epoxy.

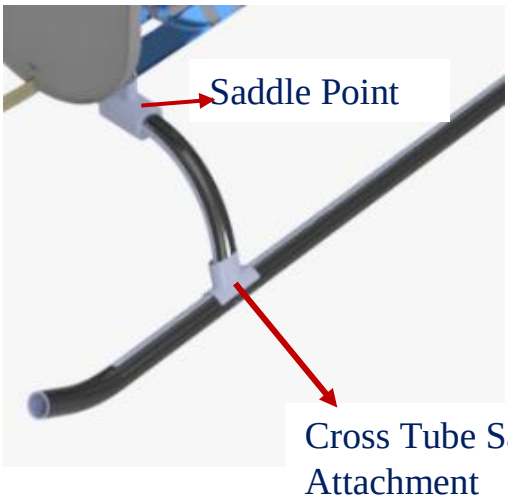
LANDING GEAR

Skid landing gear is simple, light-in-weight, easy to maintain, they are replaceable as well. The elimination of wheels, tires, brakes and braking system reduced the maintenance and less expensive in manufacture than other landing gears.



Skid gear is used in light weight helicopters where the normal landing energy is absorbed in tubular or rectangular strut members.

In case of hard landing, the energy is absorbed by the permanent deformation of strut members. The static deformation in skid type landing gear is less than oleo gear.



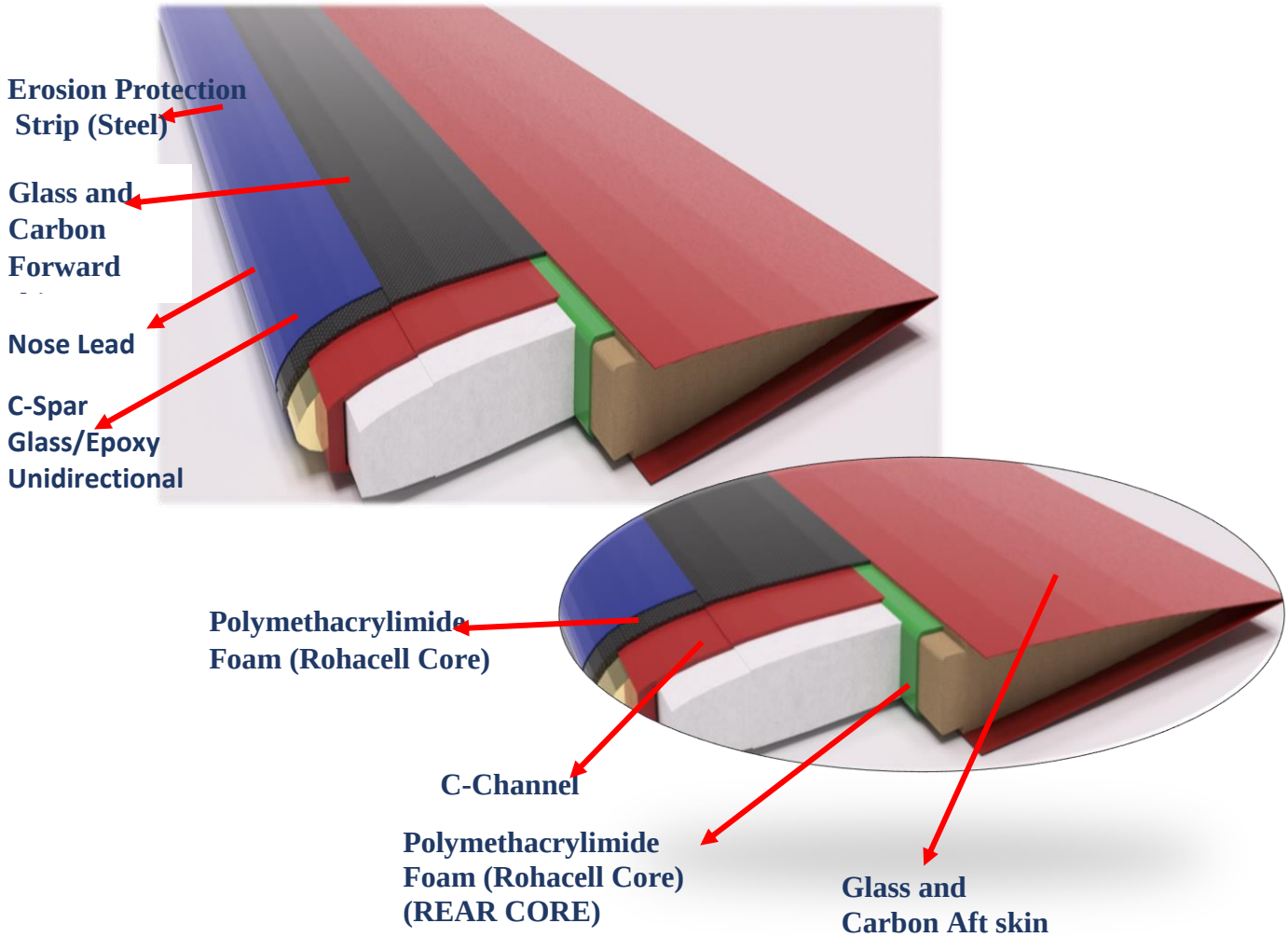
Attachment of Skid bars with forward cross tube and aft cross tube is done by using cross tube saddle assemblies providing a rigid joint.

Al 7068 Aluminum alloy was used as material for stress analysis.

ROTOR & HUB DESIGN

Vibhram Rotor system is a unique design meant to alleviate the interference losses occurring in the conventional co-axial rotor systems.

- **Hingeless Construction.**
- **Segmented blades, completely made up of glass and carbon composites, tailored stiffness and mass properties for reduced vibration.**
- **Manufactured using hydraulically operated moulds under controlled environment.**
- **Rohacell foams used as cores, for better forming capabilities, machinability**
- **Weights of the top and bottom rotor blades are less than 50kgs and 70kgs**



Cross section of Rotor Blade

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ROTOR & HUB DESIGN

Materials used for Rotor Blade construction		
Component	**Material**	**Density((gm/cc))**
Erosion Strip	Steel	7.922
Fore	Cu Mesh	2.550
	Glass Fabric	1.838
	Carbon Fabric	1.500
Spar	Glass UD	1.978
Front Core	Rohacell Foam	0.050
Nose lead	Lead mass	11.340

Upper control system

- Modified co-axial rotor swashplate mechanism to cater for the different rotor speeds.
- Bottom rotor: 1 non-rotating swashplate and 1 rotating swashplate.
- Top Rotor: 2 rotating swashplates.
- 3 electromechanical linear actuators to provide a combination of collective and cyclic inputs to the non-rotating swashplate.
- High power density, easily controllable from the autopilot with 30V DC power supply.

HUB DESIGN

- **Use of elastomeric bearing in hub warrants the reduction of moving parts and decrease in maintenance cost.**
- **FEM & Modal analysis was carried out to optimize the size of the hub plates.**
- **Sufficient stiffness is provided for the elastomeric bearing for better vibration characteristics.**
- **Aerodynamic shape of the hub helps reducing the drag during forward flight.**

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AVIONICS SUITE

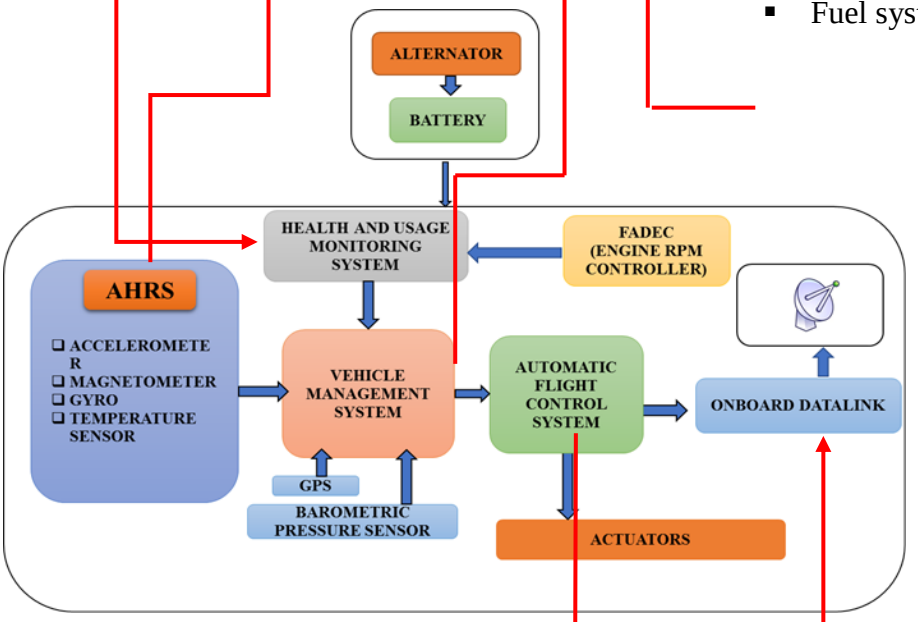
Best available avionics systems have been used to provide the full autonomous capability to the helicopter.

HUMS

- T-HUMS processing unit.
- Suitable for tactical UAV's as well as a wide variety of other platforms.

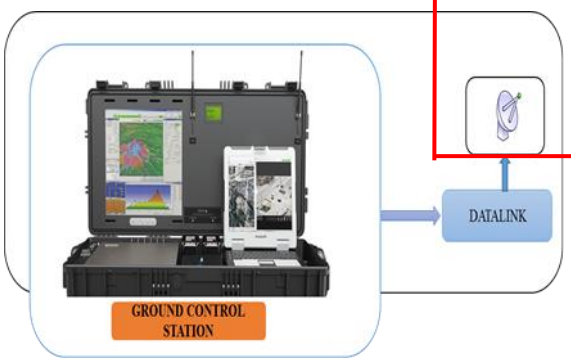
Vehicle Management System

- Engine control.
- Electrical power distribution.
- Fuel system monitoring.



TELEM05 (Datalink)

- Allow the transmission and the reception of information between the aircraft and the ground control system.
- Consist of a transmitter and a receiver.



Autopilot

- Auto take-off.
- Auto flight plan execution (waypoints).
- Fly-to.
- Hover/hold.
- Auto Return-To-Base in case of communications failure.
- Auto landing. Multiple Datalink management.

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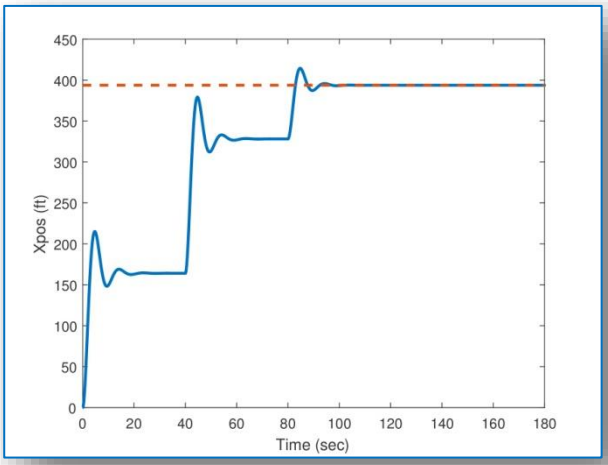
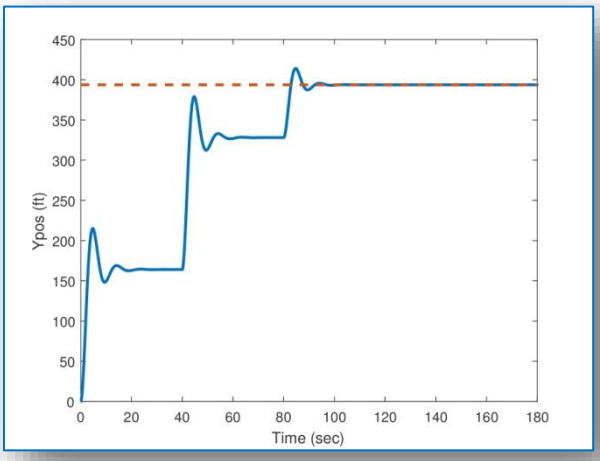
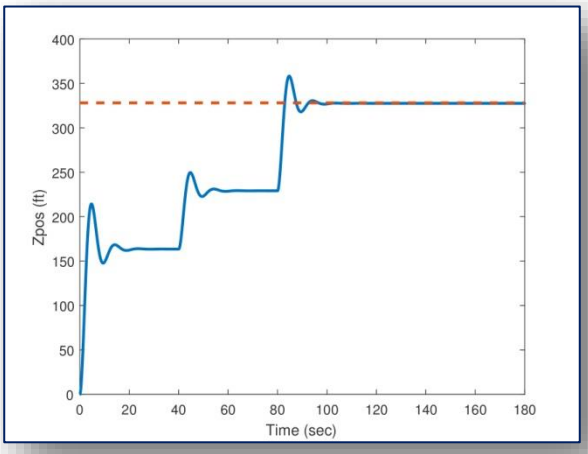
STABILITY AND CONTROL

Control law development for a helicopter is a complicated and iterative system engineering process. For a helicopter, we have four control inputs [theta_0, theta_1s, theta_1c, theta_0T] and six output (position and attitude) needs to be controlled. Thus, the helicopter is an under actuated system.

To overcome this problem, the control design considers two loops: outer loop and inner loop. The outer loop is mainly designed for tracking purpose whereas the inner loop is designed to provide stability. The inner loop works on rotation dynamics and provides attitude stabilization.

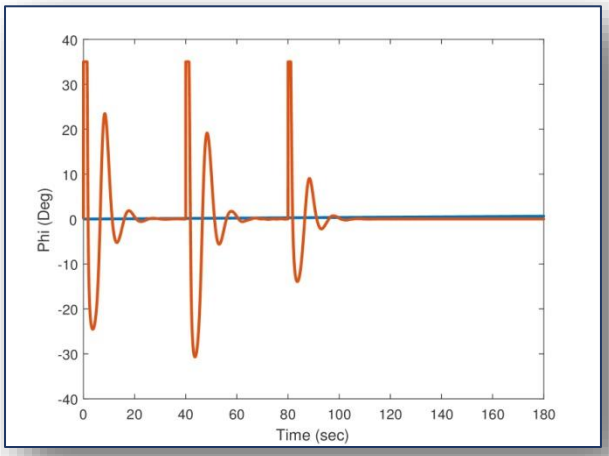


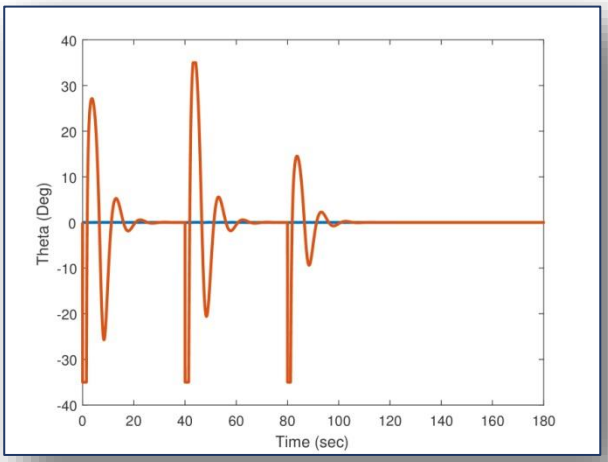


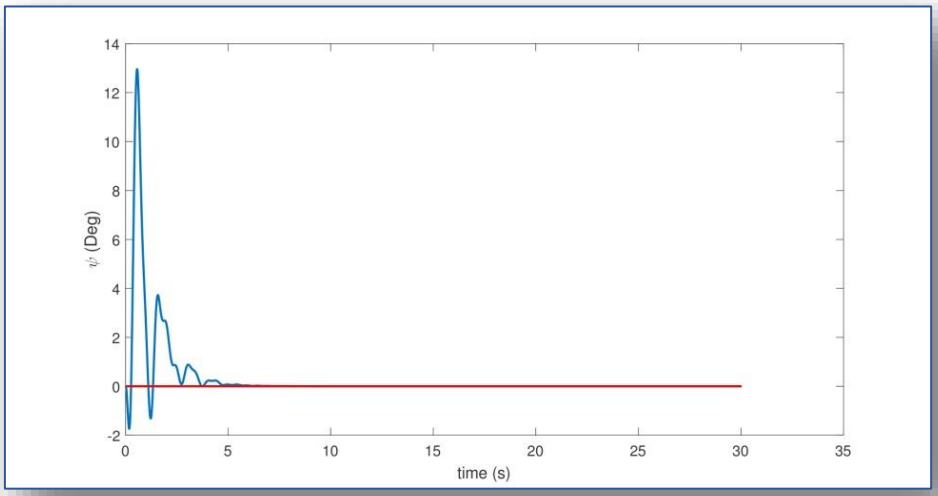


STABILITY & CONTROL

A mathematical model was developed in MATLAB for simulation. Simulation results are given for three cases, in the first case three desired points were chosen in space, defined by three coordinates with respect to the inertial frame of reference. The control algorithm is tuned for the quickest desired point achievement.







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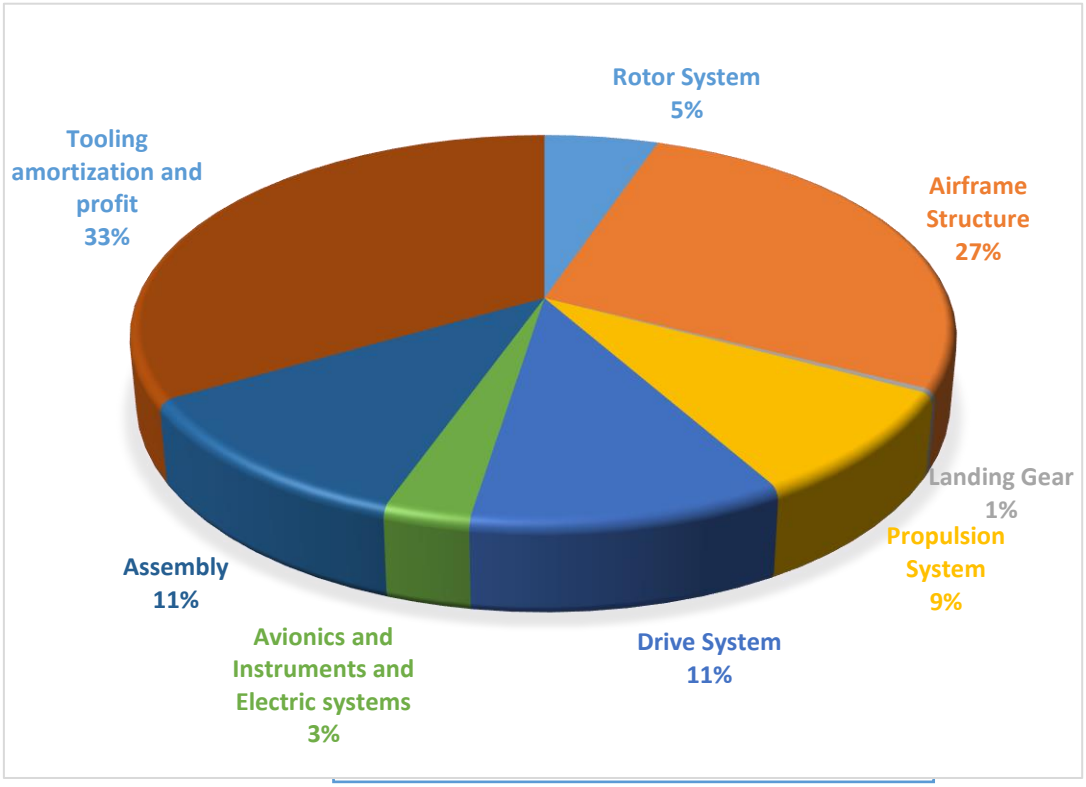
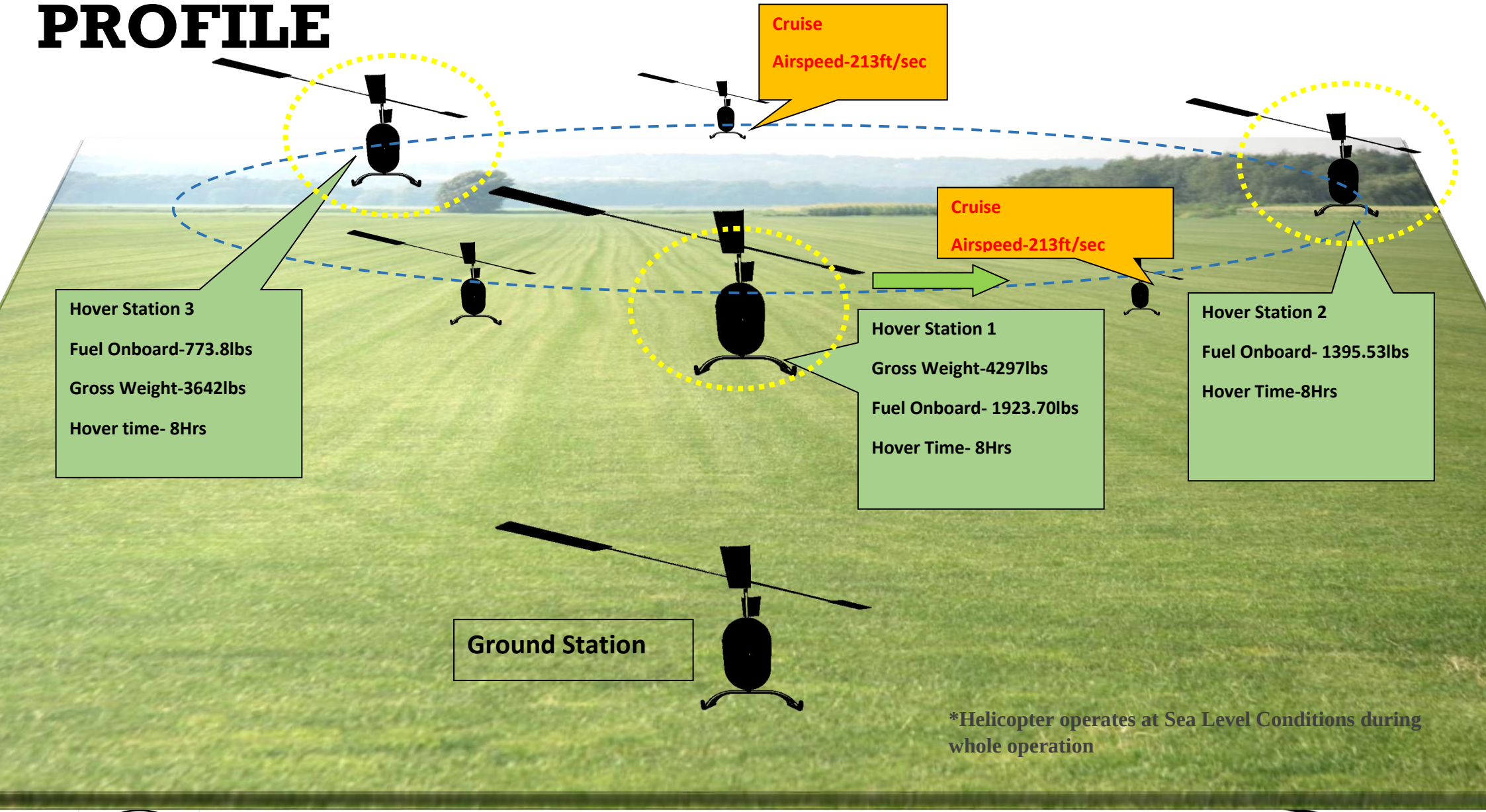
COST ESTIMATION

The cost estimated for 10 helicopters as given in table below:

Components	Cost as per 2002 (US $)	Cost in the year 2017 (US $)
Rotor System	707042	961027
Airframe Structure	3682594	5005462
Landing Gear	45176	61404
Propulsion System	1216568	1653450
Drive System	1453255	1975296
Avionics and Instruments and Electric systems	402221	546707
Assembly	1516293	2060978
Total Manufacturing	9023149	12264324
Tooling amortization and profit	4511574.5	6132162
TOTAL PRICE	13534723.5	18396486



MISSION PROFILE



*Helicopter operates at Sea Level Conditions during whole operation

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SUMMARY

Vibhram is the complete solution in response to the 34th AHS competition requirement i.e. Hover for 24 hours. Dissimilar Coaxial rotor with efficient propulsion system is the key feature to make it possible for helicopter to hover for high endurance.

- Dissimilar coaxial rotor is 15-20% efficient than other conventional coaxial rotors.
- Innovative fuselage designed that is aerodynamically more efficient in forward direction.
- Rotor system is a unique design meant to alleviate the interference losses occurring in the conventional co-axial rotor systems.
- Propulsion system (V8 Diesel Engine) having ultra-low SFC i.e. 0.32lb/hp-hr.

- Vibhram comes under category light utility of helicopter. Also, having compact design due to tailless configuration.
- State of the art transmission system to cartel to two differential rpm to drive the differential rpm coaxial rotor.
- Avionics suite to control helicopter autonomously to achieve 24hr hover endurance.

----------Flying Forever----------

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