Blitzen

Executive Summary

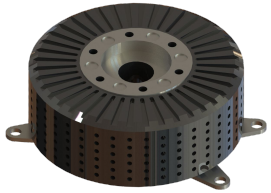
Undergraduate Design Team
University of Maryland, College Park

39th Annual Vertical Flight Society
Student Design Competition

Sponsored by Bell

Key Features

1. 100% electric propulsion and power distribution



2. Lightweight hub fairing for low drag and high speed

3. Cost-effective hybrid rotorprop design for hover and cruise

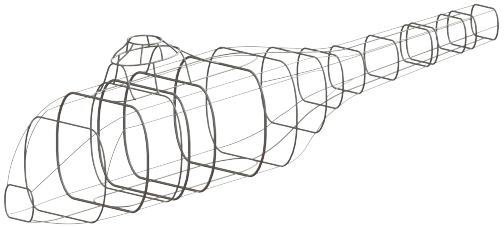
8. Glass cockpit & wide-screen IDU

4. Swiveling Mechanism for anti-torque and forward thrust

7. Efficient wing offloads 80% of lift from main rotor in cruise

6. Wheelchair-accessible

5. Strong, lightweight structure



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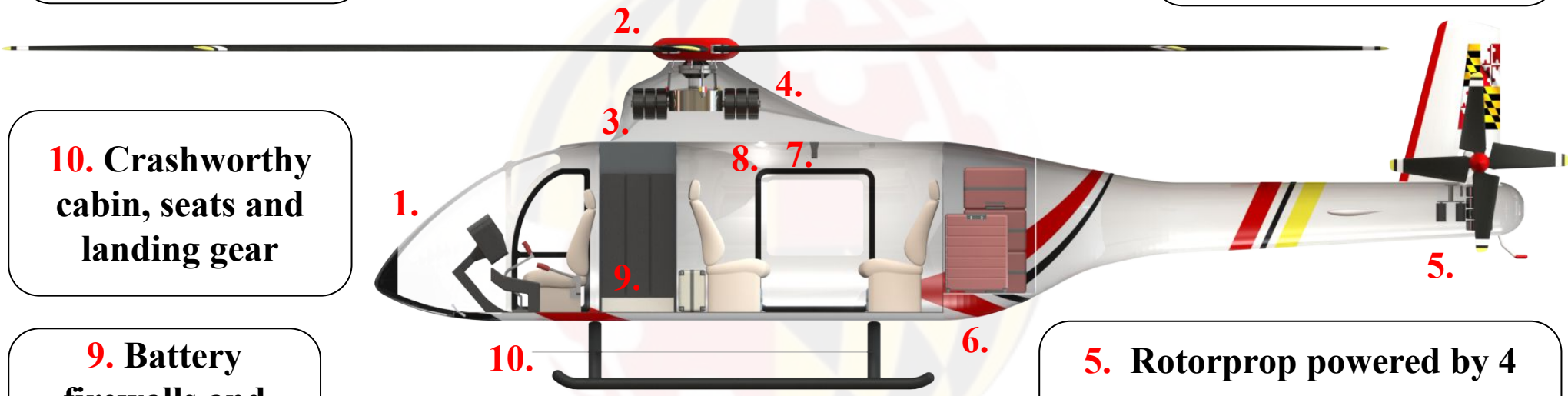
Safety Highlights

1. Wide-view windshield

2. Autorotation capability

3. Redundant battery, electric distribution and control systems

4. 6 motors power main rotor, capable of hover with 2 failed motors



10. Crashworthy cabin, seats and landing gear

9. Battery firewalls and shock absorption

5. Rotorprop powered by 4 motors, capable of cruise with 2 failed motors

8. Cabin safety buttons, lights, and signage

7. Audio and text-to-speech cockpit-cabin communication

6. contained luggage bay separate from passengers

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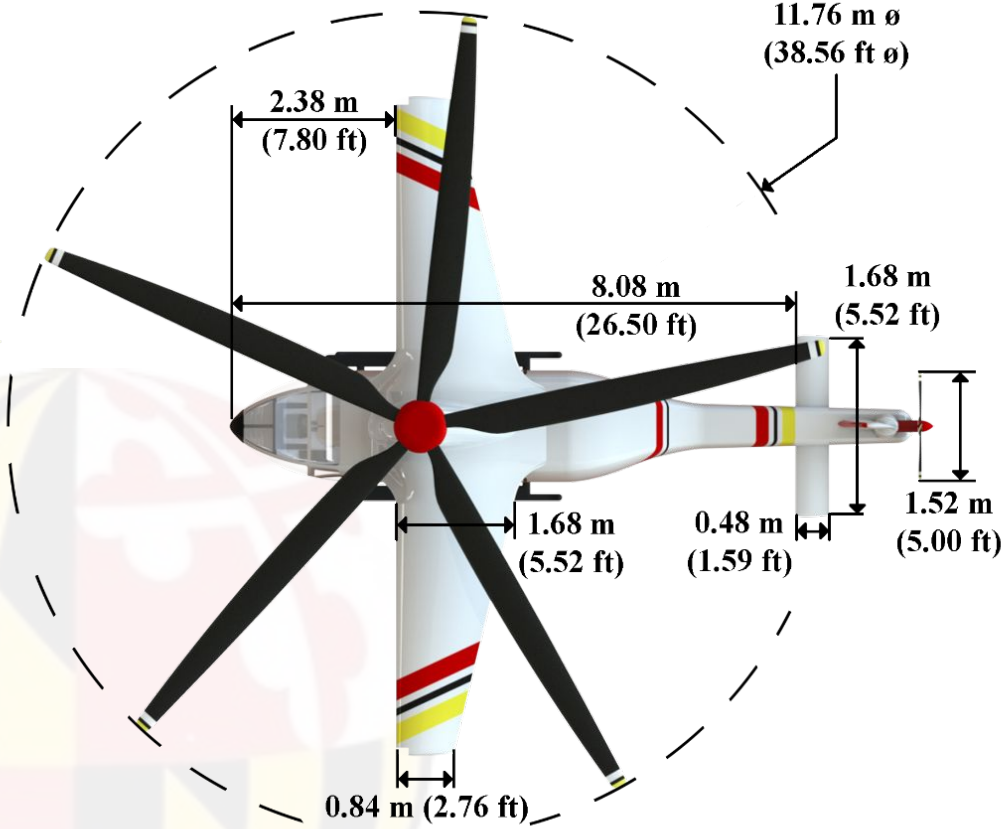
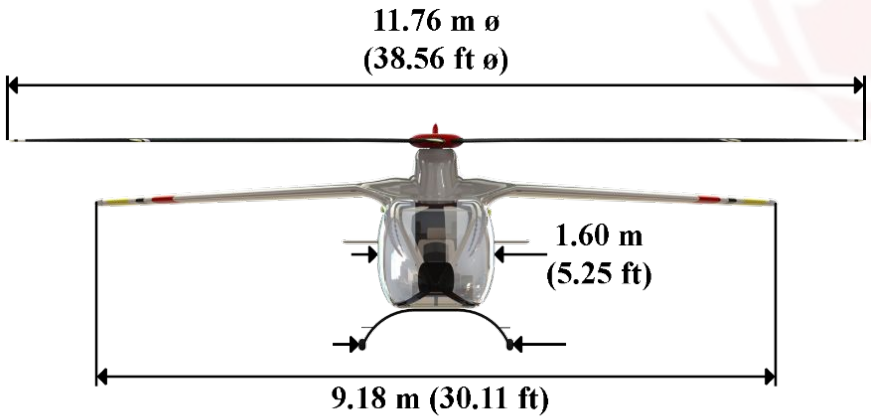
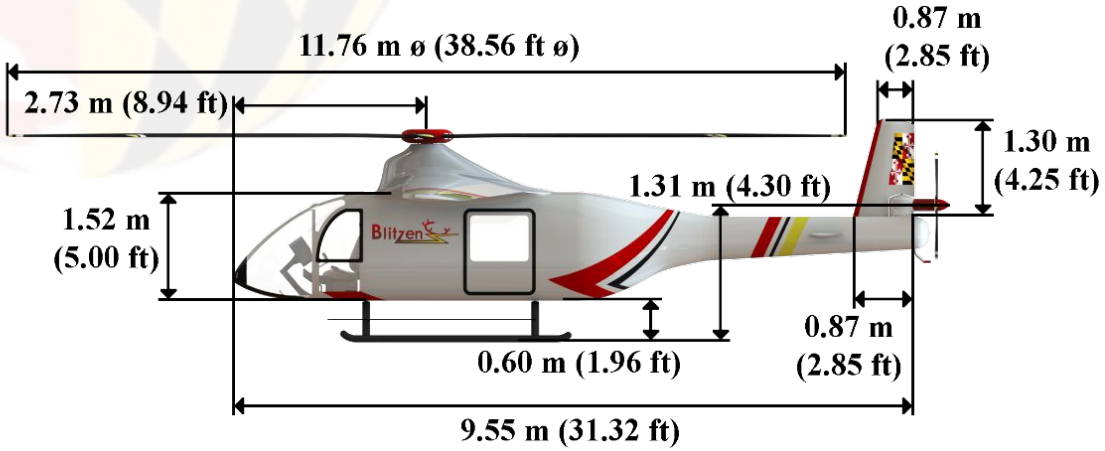
External Dimensions



Footprint: 11.76 x 13.30 m
(38.56 x 43.65 ft)





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Introduction

The University of Maryland undergraduate team presents Blitzen as its solution to the Vertical Flight Society's 39th annual student design competition Request for Proposal (RFP). The team was tasked with designing an electric vertical takeoff and landing (eVTOL) air taxi for accommodating passengers with varying disabilities. Blitzen's name is inspired by the German word "Blitz", which translates to lightning, as well as the name of the mythical flying reindeer. With Blitzen, everyone can enjoy the future of lightning-fast, comfortable, and convenient transportation.

Design Features

Blitzen follows an energy-efficient lift and thrust compounding single main rotor (SMR) design with a fixed wing and swiveling rotorprop that provides anti-torque in hover and forward thrust in cruise. Its spacious cabin provides several disability accommodations, including wheelchair accessibility, storage for large medical devices and resources for those with impaired hearing. A compact wide-screen avionics suite minimizes pilot workload. Outside the cockpit and cabin, all of Blitzen's systems are designed to prioritize safety and comfort without compromising vehicle performance.

Vehicle Overview

GTOW	**2593 kg (5717.8 lb)**
Payload	**558.8 kg (1232 lb)**
Battery Energy	**287 kW-hr (384.87 hp-hr)**
Cruise Speed	**67.06 m/s (130.35 kts)**
Empty Weight (including Battery Weight)	**2034 kg (4485.6 lb)**

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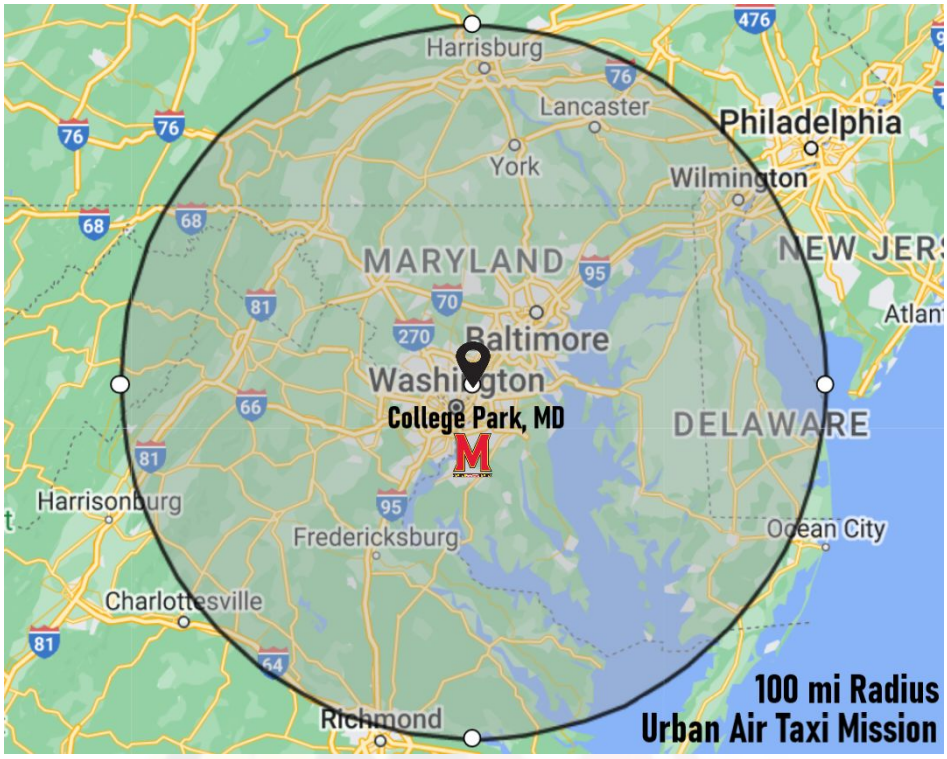
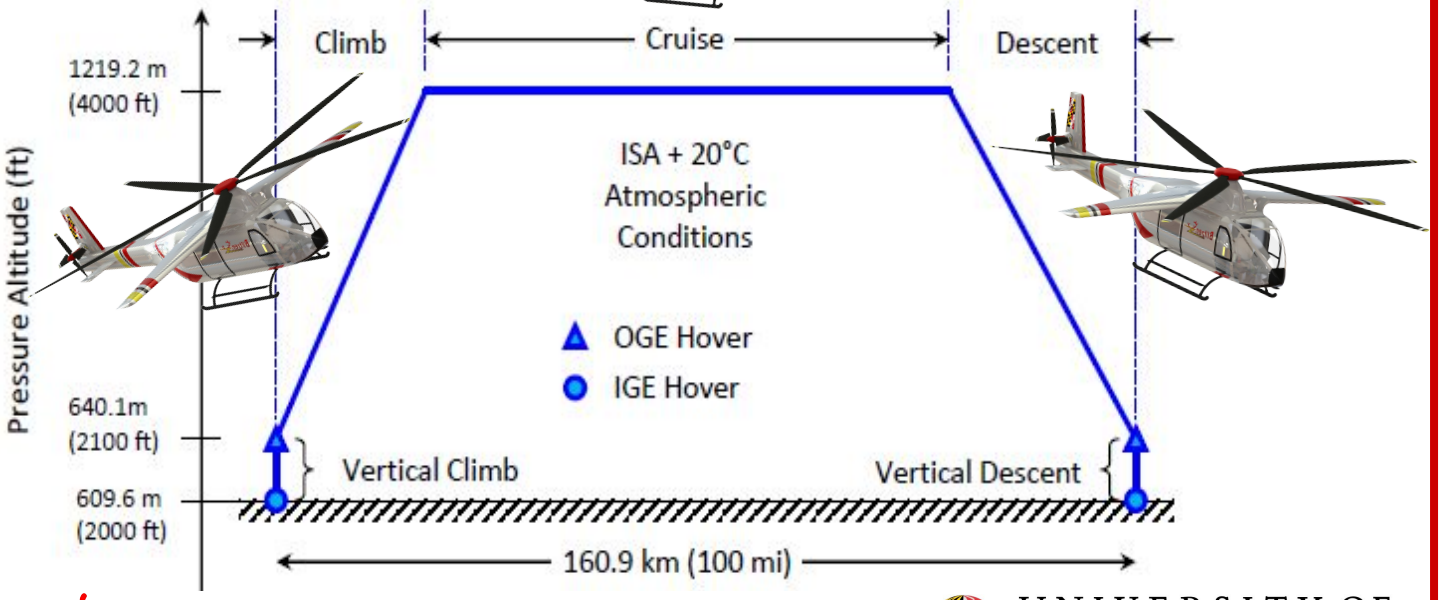
Mission Profile



Description

Blitzen can transport 4 able-bodied passengers or 2 passengers with reduced mobility within a radius of 100 miles (161 km). Its climb, cruise and descent profile is illustrated below. Blitzen features an additional 20 minute cruise reserve flight time.

Mission Profile



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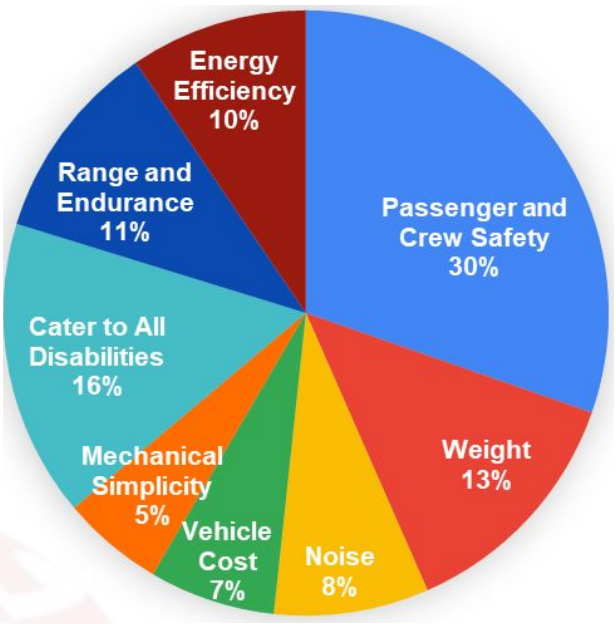
Vehicle Configuration Selection

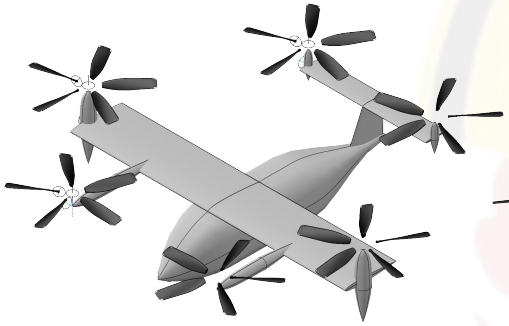
Configuration Space

Design Drivers

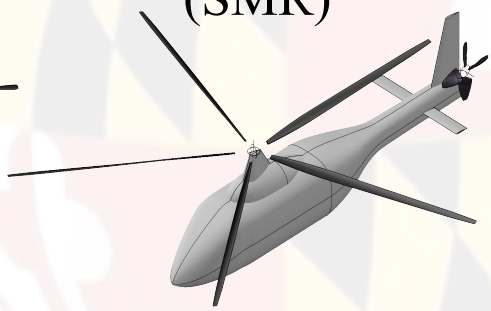


Downselection

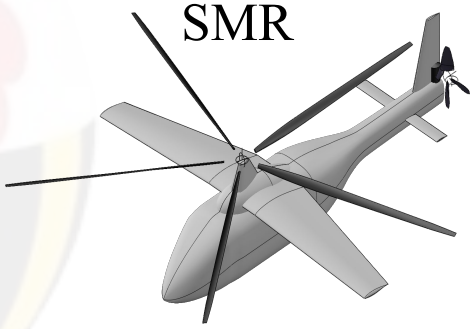
Tiltrotor



Single Main Rotor (SMR)



Lift and Thrust Compound SMR



Parametric trade studies were performed to design the best vehicle of each configuration for the mission profile before final selection.

Final Selection

Lift and Thrust Compound SMR

- Fixed wing for MR lift offloading
- Propulsive thrust compounding using a swiveling tail rotorprop
- Low cruise power requirement
- Spacious cabin
- Redundant motors
- Low acoustic signature
- Simple transition between hover and cruise

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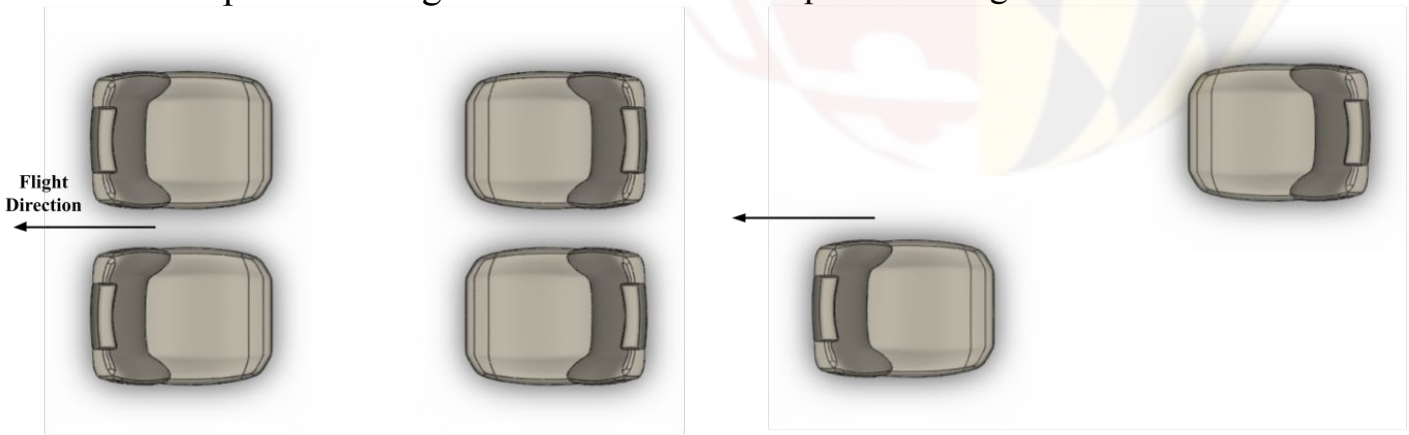
Ingress and Egress

Retractable, motorized ingress/egress lift for passengers with wheelchairs will be stored at landing sites

Cargo areas allow ample space for foldable wheelchairs, personal luggage, and large devices (oxygen tanks, walkers, etc.)

4-person arrangement

2-person arrangement



Removable cabin seats allow for safe and easy ingress/egress of passengers with wheelchairs and can accommodate up to 4 fully-mobile passengers without and 2 passengers with reduced mobility

Seating Arrangement

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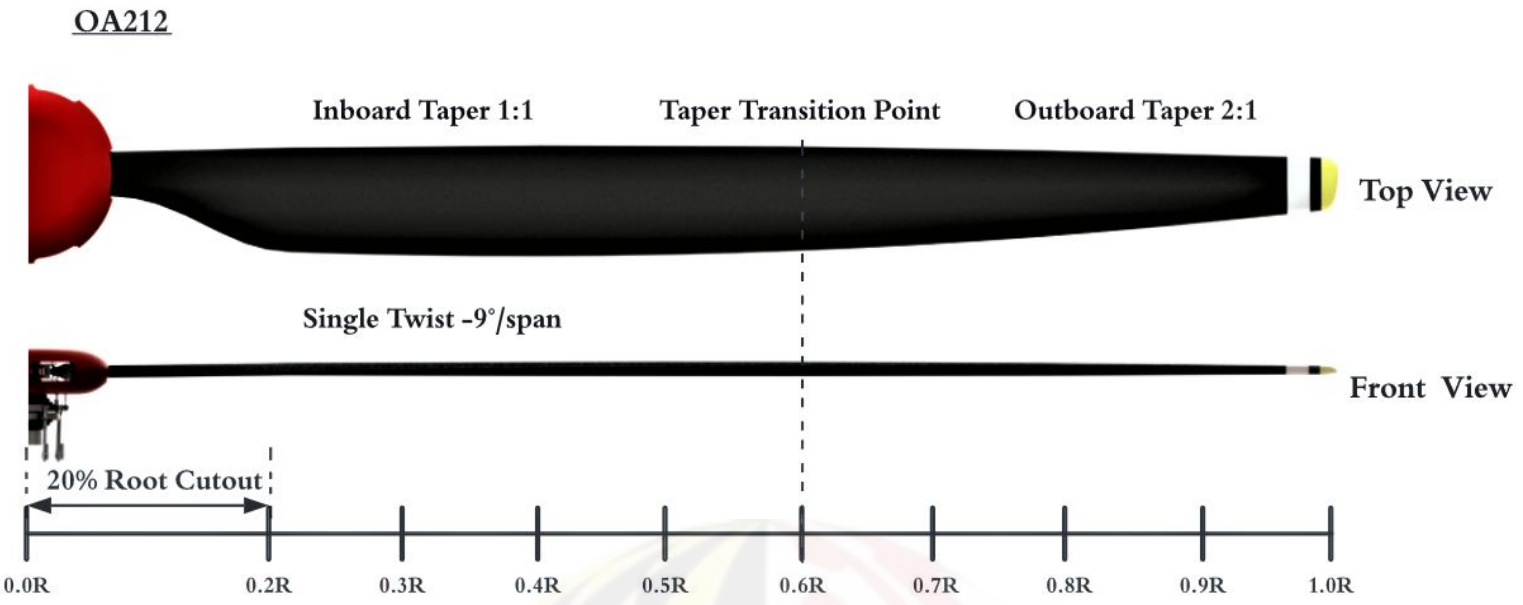
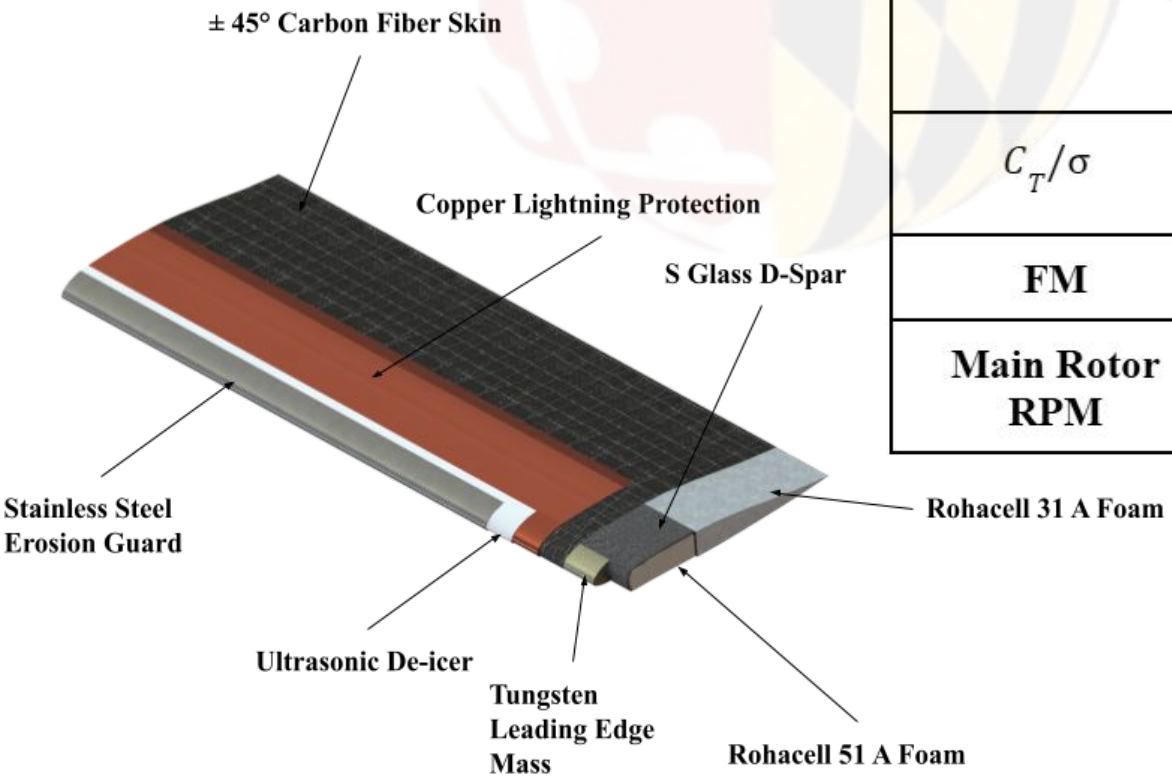
Main Rotor Blade Design



Blitzen's main rotor blades were designed using team-developed BEMT code for optimal hover and cruise performance and minimal noise production.

Airfoil	OA212
Disk Loading	277.71 N/m^2 (5.8 lb/ft^2)
Power Loading	49.5 N/kW (8.30 lb/hp)
C_T/σ	0.118
FM	0.84
Main Rotor RPM	247.65 rpm



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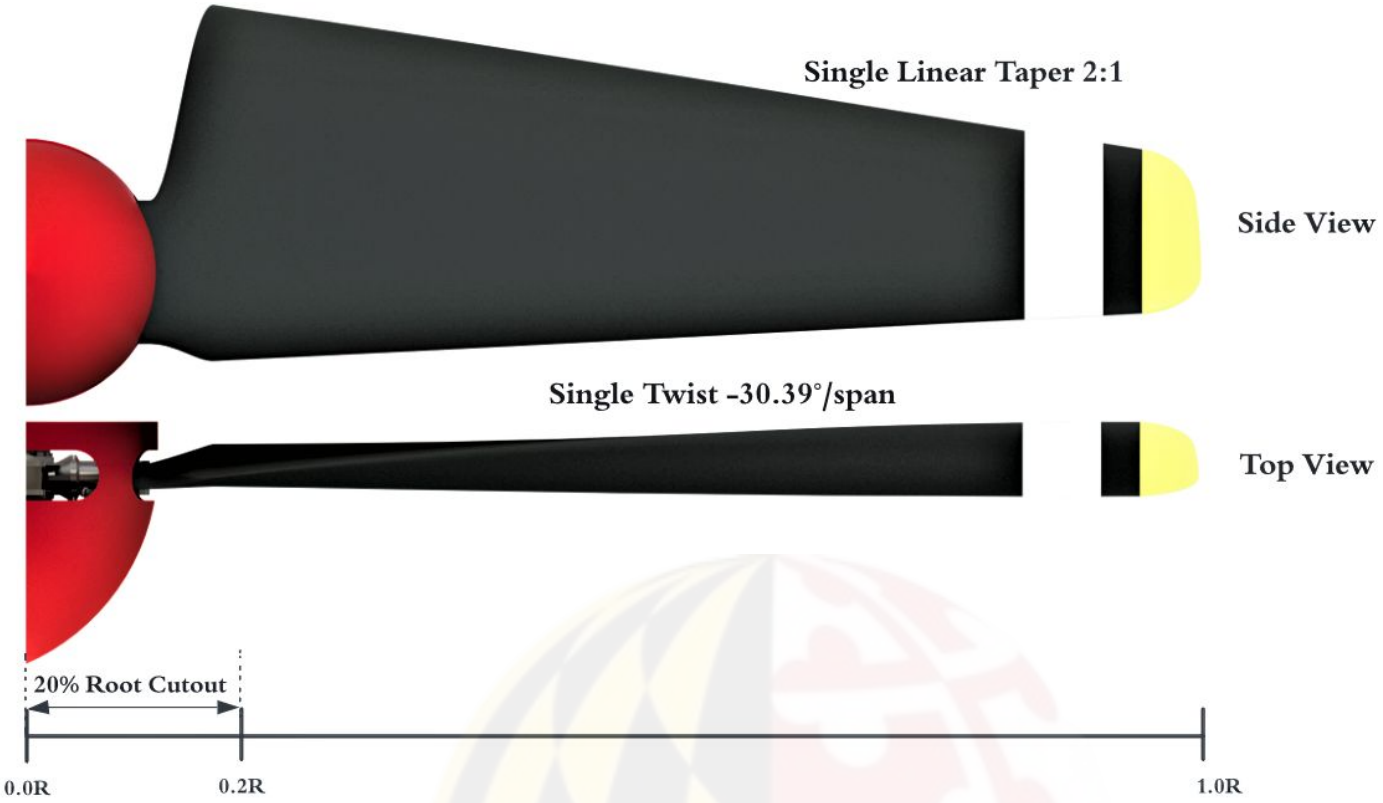
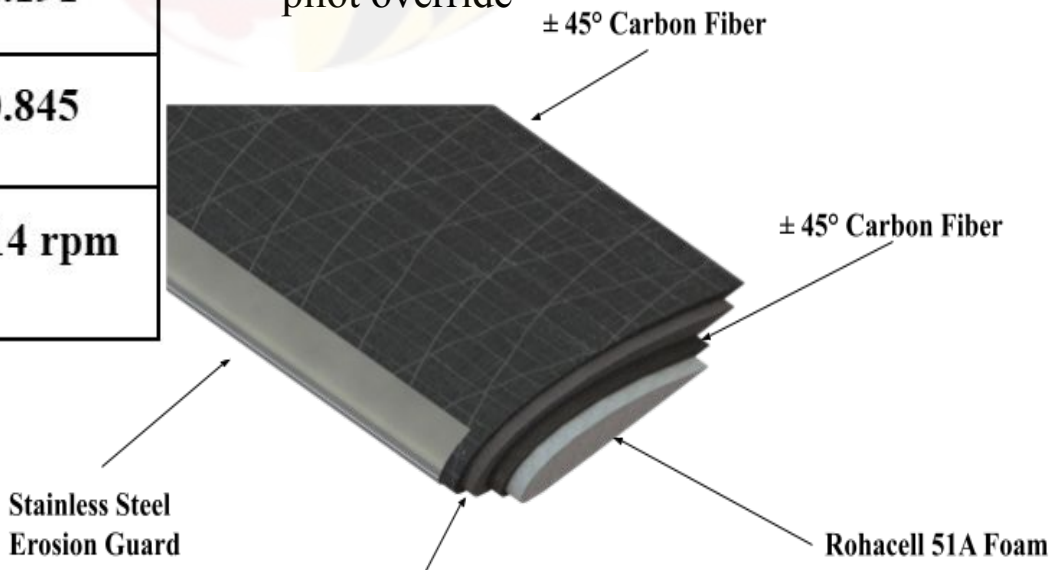
Rotorprop Blade Design



Airfoil	Clark-Y
No. of Blades	4
Solidity, σ	0.251
$J_{@Vcruise}$	1.191
$\eta_{p_{@Vcruise}}$	0.845
Tail RotorProp RPM	2214 rpm

Unique Swivel Capabilities

- Provides anti-torque and yaw in hover mode
- Acts as a pusher prop in forward cruise
- Swiveling is activated automatically by flight computer (based on airspeed) or manually by pilot override



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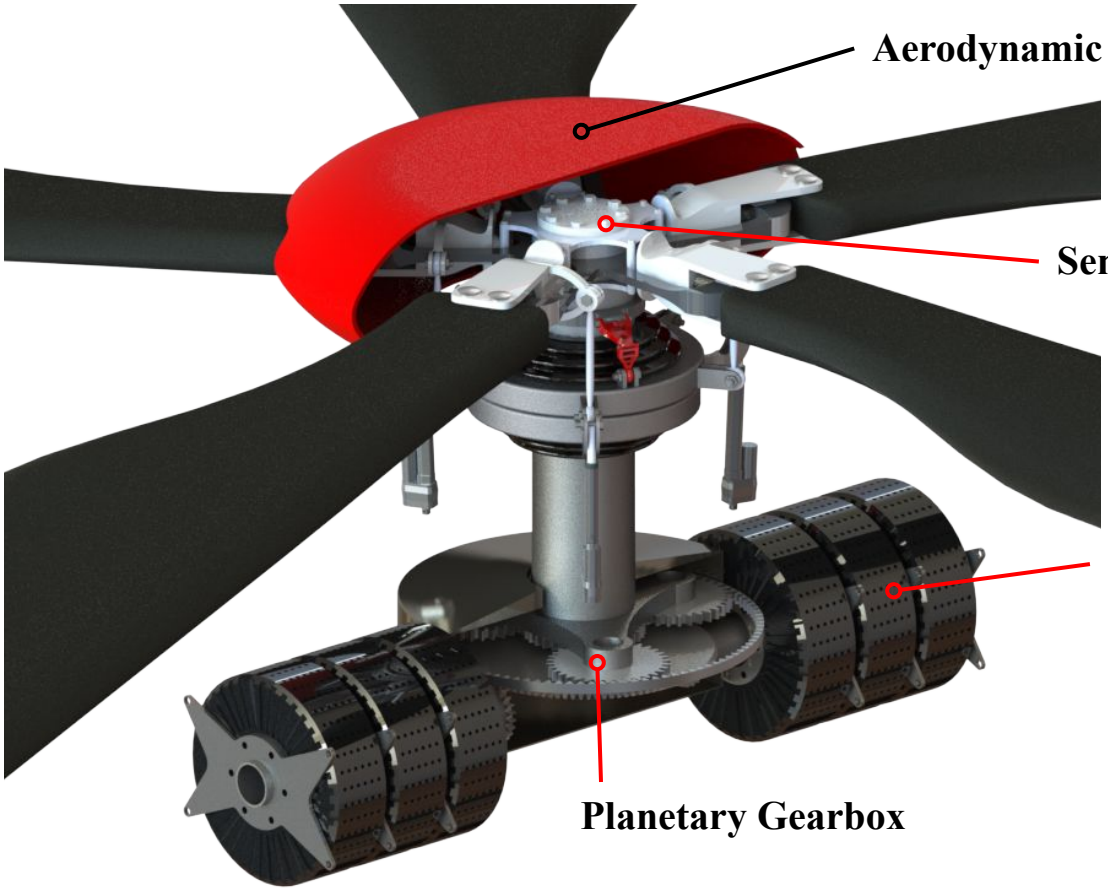
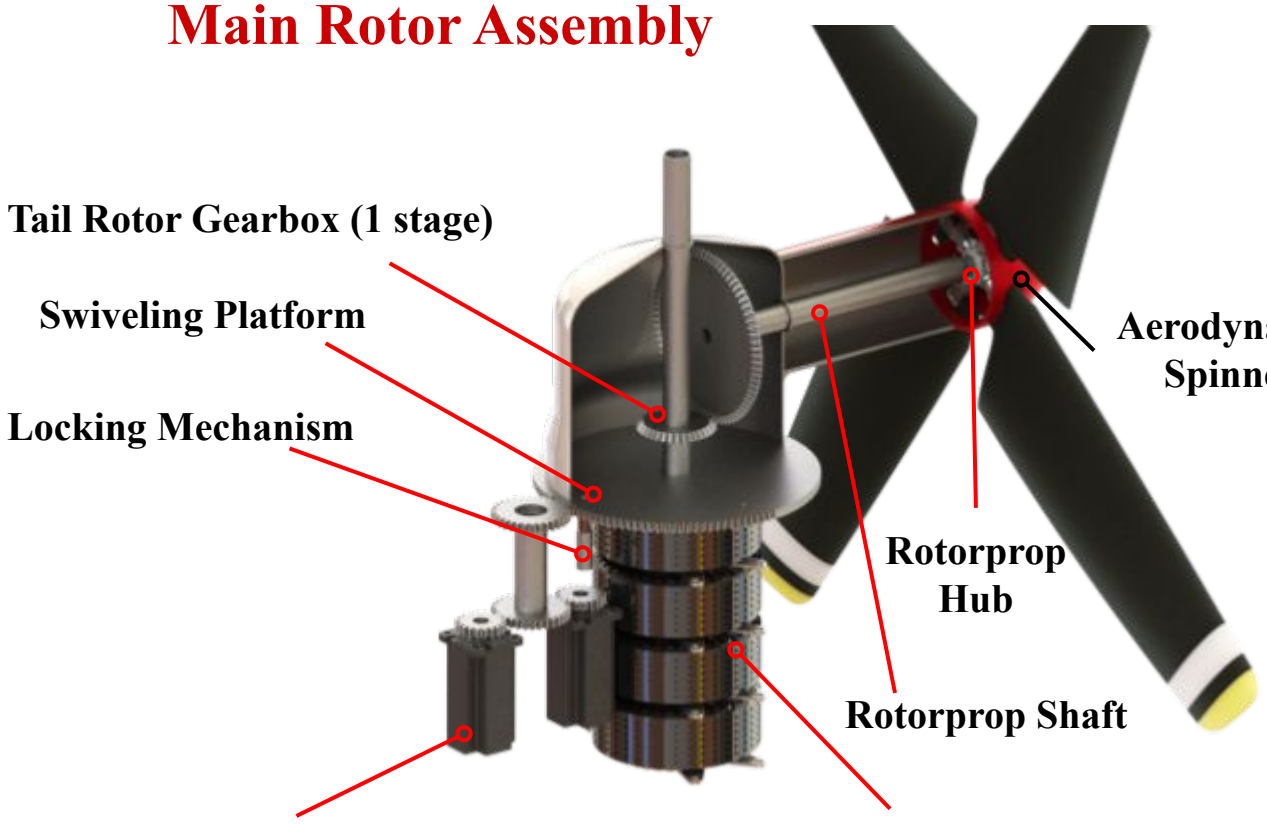
Main Rotor and Rotorprop Assemblies



Main Rotor Assembly



Rotorprop Assembly

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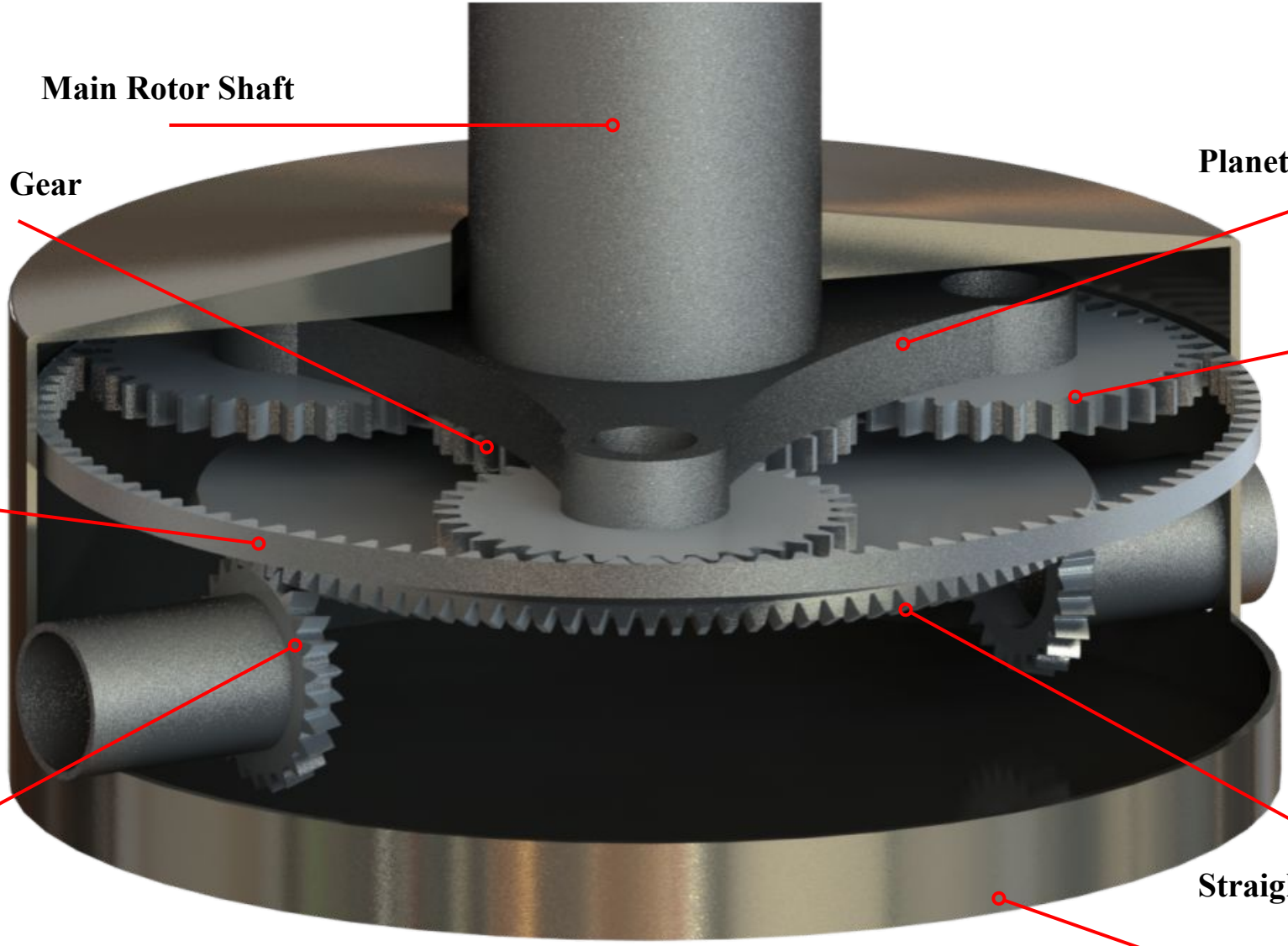
Main Rotor Gearbox



- Planetary and Straight Bevel Gear Construction
- Gears made with AISI 9310 Steel
- Casing made of Magnesium Zirconium (Mg-Zr)
- Fitted with 6 oil injectors for consistent lubrication
- Overall Gear Reduction ratio of 16.48

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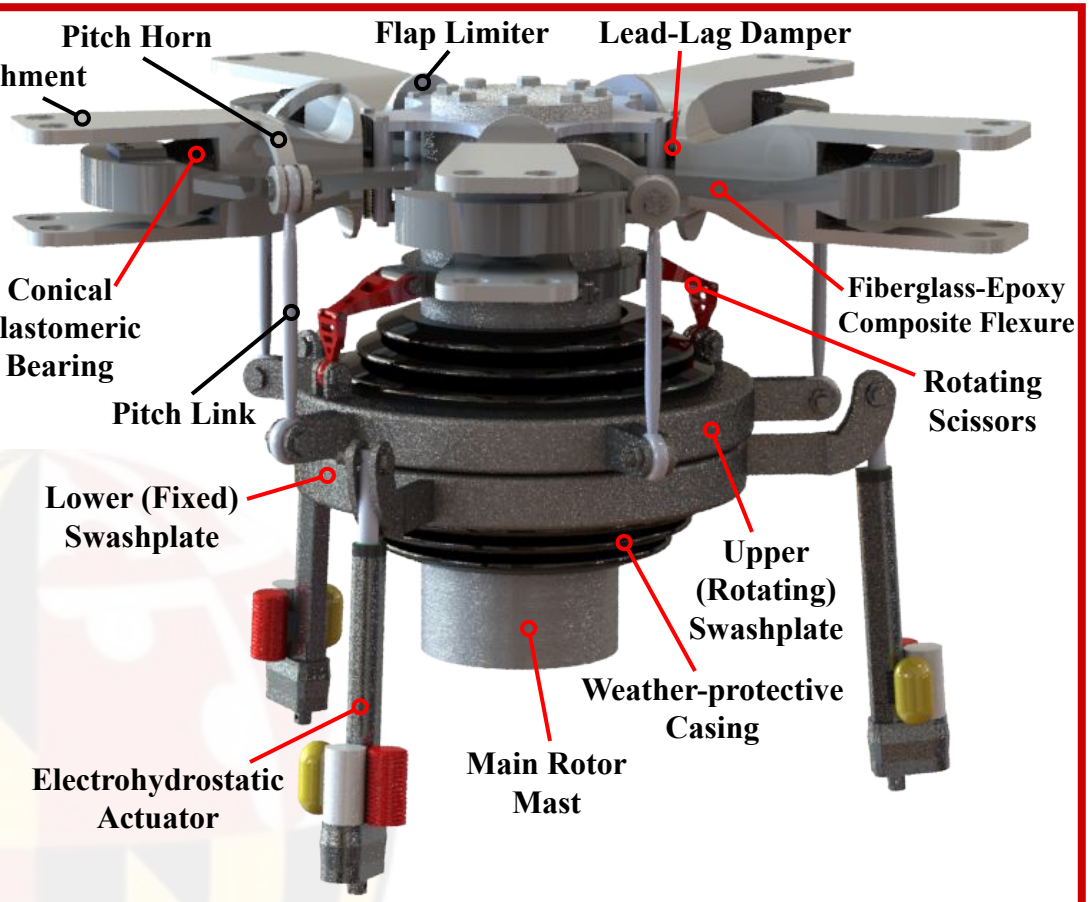
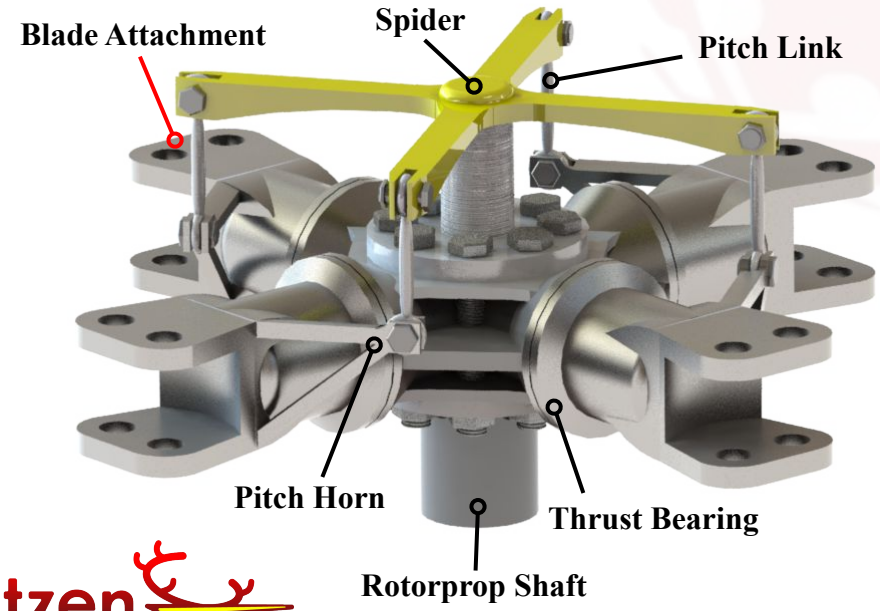
Rotor System Hubs

Main Rotor Hub

- Semi-articulated design is compact, mechanically simple, and low-weight
- Configuration maintains good stability and low vibrations, enhancing passenger comfort
- Encased inside aerodynamic fiberglass fairing for significant drag reduction





Rotorprop Hub

- Rigid in lead-lag and flapping for better control of rotorprop in cruise
- Thrust bearings with pitch spider allow fixed-RPM anti-torque and variable thrust
- Conical spinner reduces hub drag

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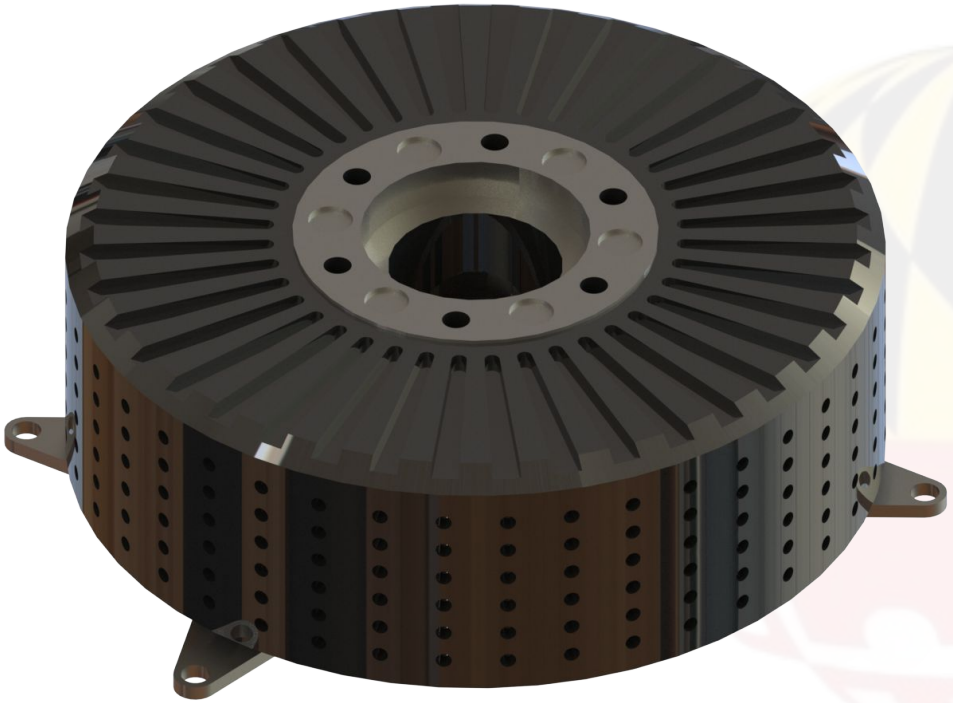
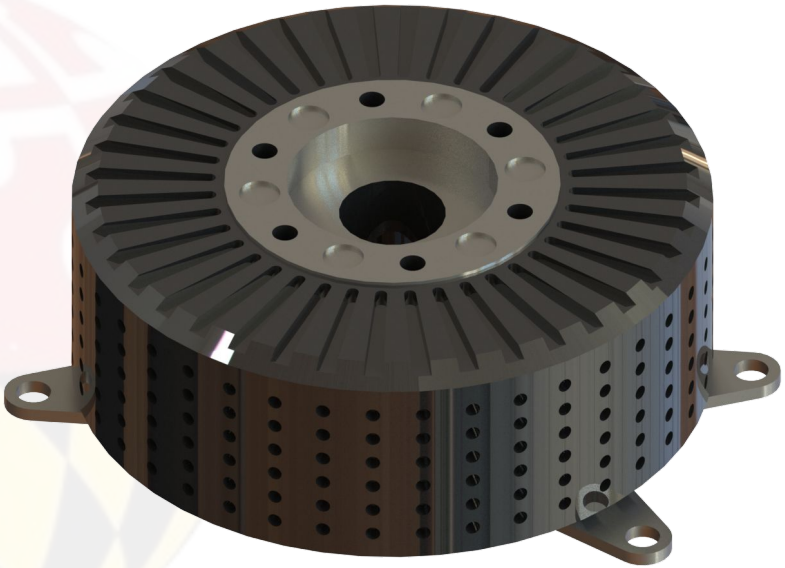
Drive Systems

EMRAX 268 (Main Rotor)



- 6 motors powering the main rotor
- Continued safe flight despite dual motor failure
- Running at 4087.40 RPM
- Providing 200 N-m of Torque each

EMRAX 228 (Tail Rotor)



- 4 Motors powering the tail rotor
- Continued safe flight despite dual motor failure
- Running at 4973.96 RPM
- Providing 96 N-m of Torque each

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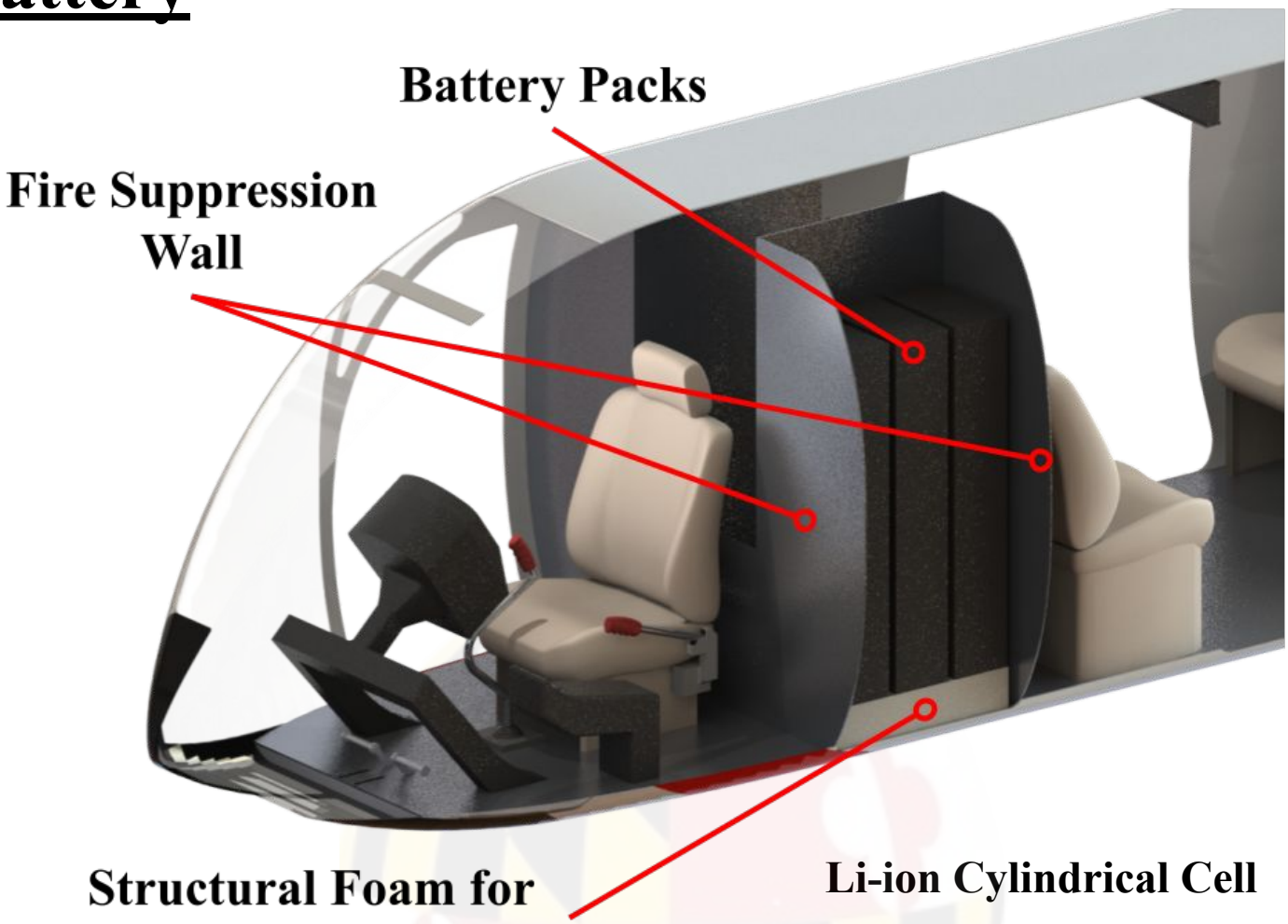
Battery



Battery Weight	678.48 kg (1495.8 lb)
Battery Size	0.38 cubic m (13.40 cubic ft)
Volumetric Energy Density	770 Wh/L (29.23 hp-hr/cubic ft)
No. of Cells in Series	195
No. of Cells in Parallel	52

Li-ion Cylindrical Cell

- Most commonly used
- High energy density
- Safe to use compared to other chemistries and configurations
- Inexpensive
- Uniform cell size across many industries

Li-ion Cylindrical Cell

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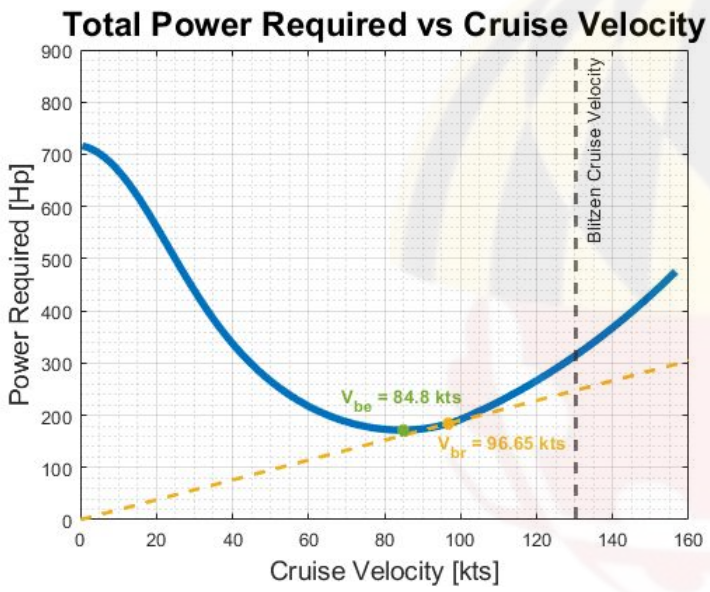
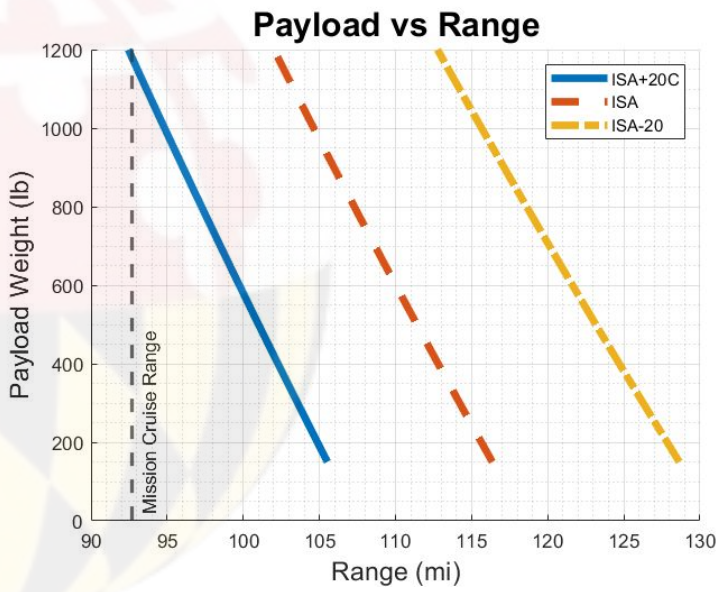
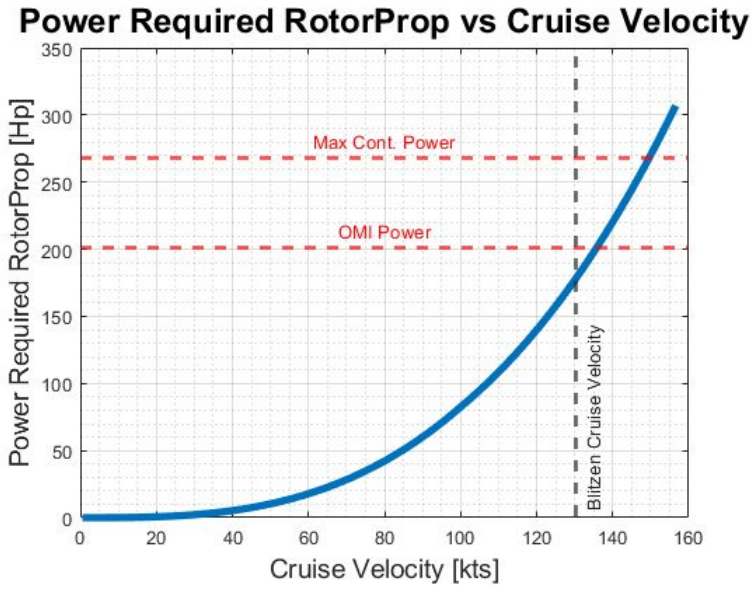
Vehicle Performance

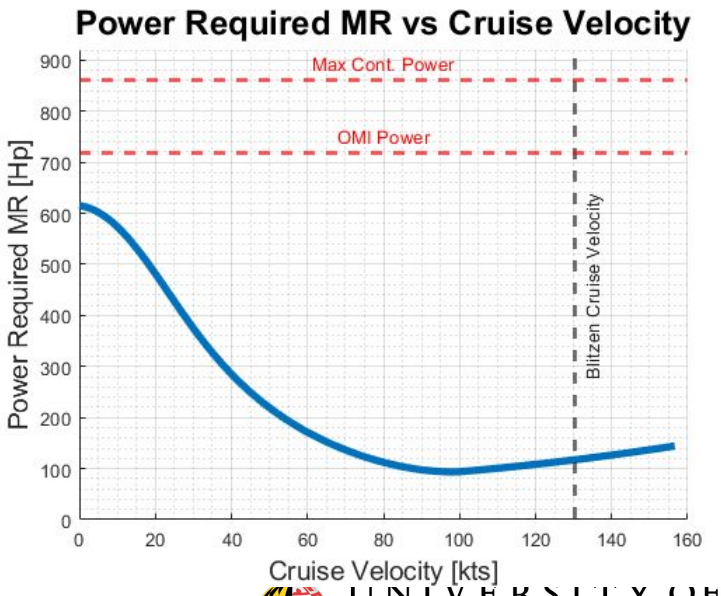
Blitzen's performance exceeds mission requirements. It features high forward flight lift to drag ratio, high cruise speed, and low main rotor drag at a high advance ratio due to the wing and swiveling rotorprop. Hover and high velocity cruise are possible with one motor inoperative.

V_{Cruise}	67.06 m/s (130.35 kts)
V_{be}	43.62 m/s (84.8 kts)
V_{br}	49.72 m/s (96.65 kts)
Range	160.9 km (100 mi)
Flight Reserves	20 minutes at V_{Cruise}, 80.5 km (50 mi)









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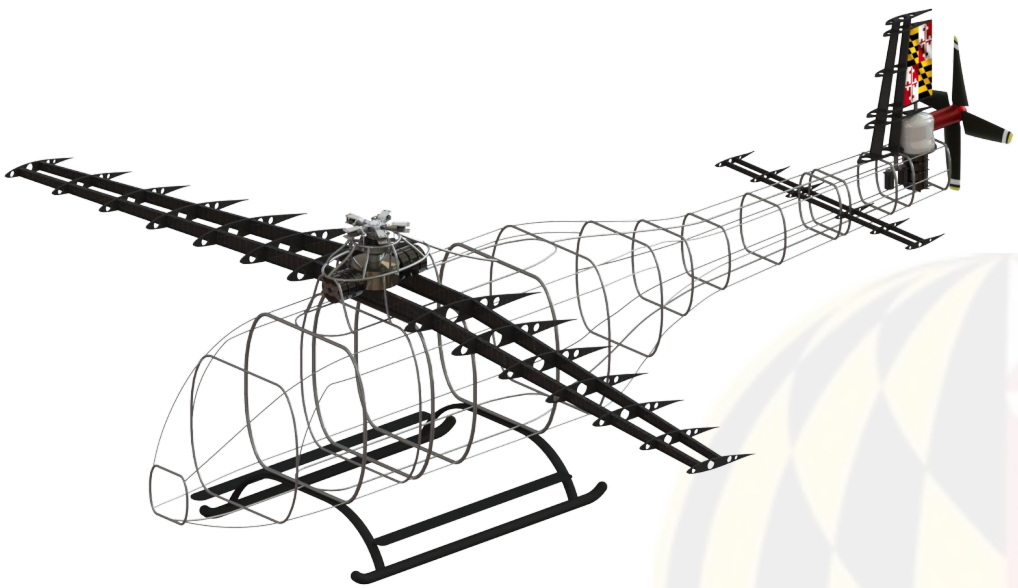
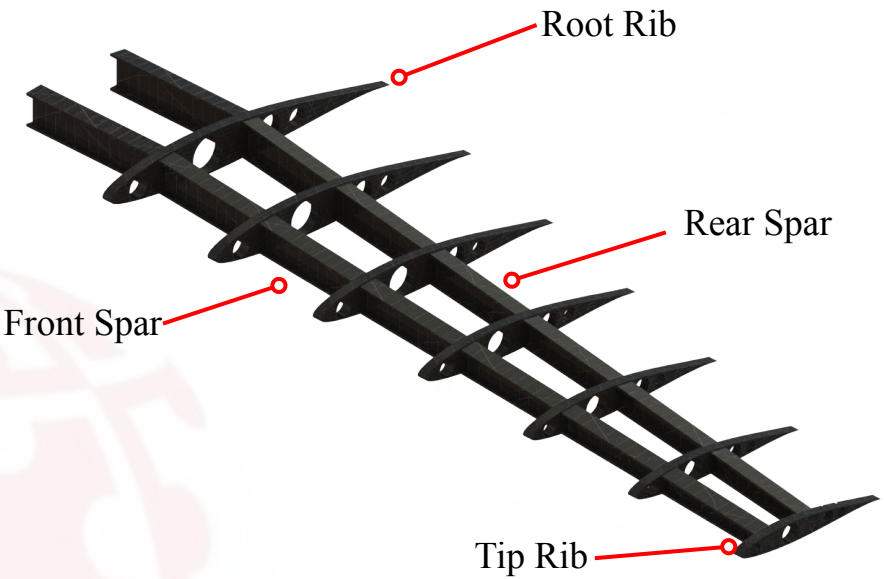
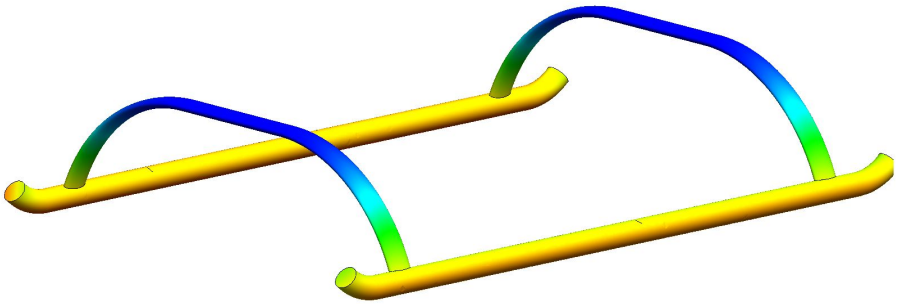
Structure Highlights



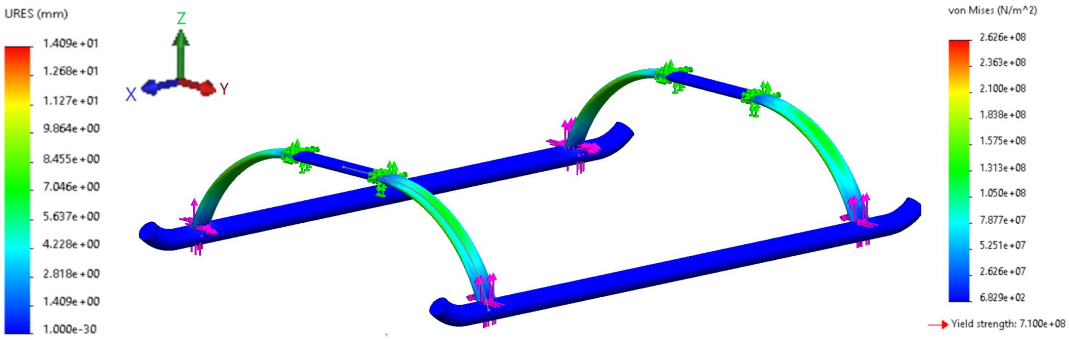
Fuselage airframe structure consisting of 10 primary I-beam bulkheads and 7 tail bulkheads



Wing structure with 7 ribs on each wing



Deformation of landing gear



Stress on landing gear

The landing gear design properly disseminates loads to maintain a safety factor of 2.7

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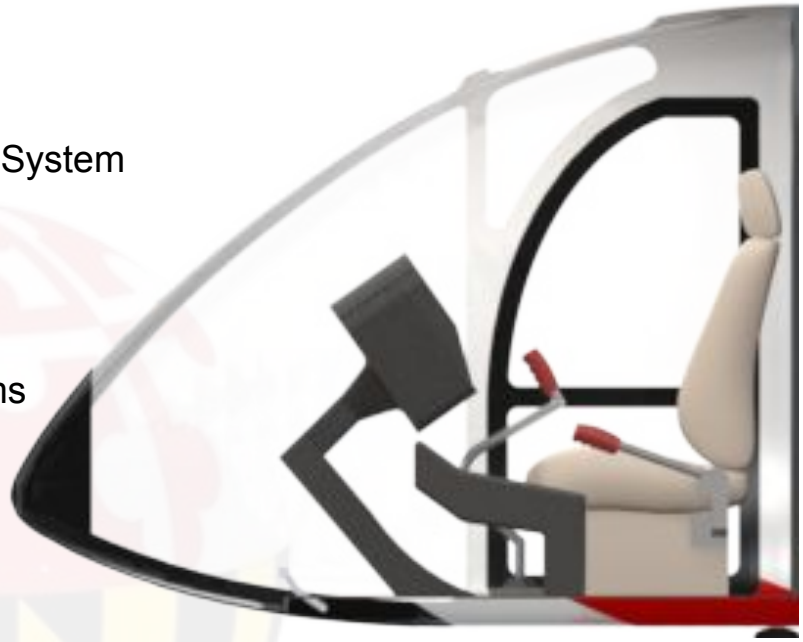
Avionics

Thales FlytX Avionics Suite



Blitzen Cockpit Cutaway

- Compact, wide-screen avionics dashboard and large windshield provides excellent vision for the pilot
- Advanced glass cockpit maximizes pilot situational awareness
- Thales FlytX avionics and sensor suite with integrated display unit and synthetic vision systems reduces pilot workload for safe VFR and IFR flight
- Blitzen will be operated by a single pilot, with infrastructure in place for autonomous adaptation

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Cost and Weight Breakdown

Item	Weight (kg)	Weight (lb)
Aerodynamics Group		
MR Blades	171.8	378.8
Rotorprop Blades	10.8	23.8
Wing	77.0	169.7
Vertical Stabilizer	57.8	127.4
Horizontal Stabilizer	27.3	60.3
Fuselage Group		
Skid Landing Gear	82.0	180.8
Exterior Skin	38.3	84.6
Floor and Walls	86.6	191.0
Airframe Structure	237.1	522.8
Motors Group		
MR Motors	120.0	264.6
MR Motor Controllers	40.8	90.0
Rotorprop Motors	48	105.8
Rotorprop Motor Controllers	27.2	60.0
Swivel Mechanism Motors	10.6	23.4
Propulsion Group		
MR Gearbox	81.8	180.4
MR Hub	52.7	116.2
MR Fairing	13.7	30.1
Rotorprop Gearbox	22.5	49.6
Rotorprop Hub	13.2	29.1
Rotorprop Spinner	1.1	2.5
Furnishing and Equipment Group		
Pilot Seat	13.6	30
Passenger Seats	36.3	80
Miscellaneous		
Batteries	719.1	1585.7
Flight Control	7.5	16.5
Instruments	7.5	16.5
Avionics	30	66.2
Load and Handling		
Pilot	81.6	180
Passengers Control	326.5	720
Baggage	150.6	332
Total	**2593**	**5717.8**

Component	Parameter
C_{Rotors}	$538,300
C_{Wing}	$213,000
$C_{Fuselage}$	$444,100
$C_{Motors\ and\ Controllers}$	$79,600
$C_{Transmission}$	$10,900
$C_{Avionics}$	$35,300
$C_{Empennage}$	$93,000
$C_{Furnishings}$	$53,300
$C_{Battery}$	$37,900
$C_{Controls\ and\ Instruments}$	$35,900
$C_{Total\ Aircraft\ components}$	$1,541,300
$C_{Manufacturing\ and\ Profit}$	$385,400
$C_{Total\ Purchase\ Cost}$	$1,926,700

Blitzen offers an affordable Cost of Purchase:
$ 1,926,700.00

Total Battery Charging Cost:
$ 35.00

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Summary

In response to the RFP for the 2021-2022 VFS Student Design Competition, sponsored by Bell Helicopter, the University of Maryland undergraduate team presents the Blitzen. Blitzen bolts through city skies at 130 knots using its fully electric propulsion system. It safely and efficiently ferries passengers, with special consideration for people with disabilities, and provides them with luxurious and speedy transportation. It quietly cruises with its large wing and rotorprop in pusher configuration, efficiently conducting its role as an air taxi while handily exceeding the required 100 mile radius. The configuration is a Lift and Thrust Compound SMR, and is designed to charge into the electrifying future of eVTOLs, while using the time-tested and proven single main rotor design as the backbone for its design.

Not only is Blitzen feature-packed with innovative and cutting-edge technologies, it is also structurally sound and designed with safety in mind for every component. All electrical and propulsion systems have redundancies to prevent single point failures. The large composite main rotor allows for auto-rotation in the event of emergency. The Blitzen is easily reconfigurable and has the potential to be a standard-use eVTOL aircraft with many applications, such as a delivery vehicle, emergency evacuation (MEDVAC), and combat search and rescue (CSAR). It is easy to see the growth potential and the need for eVTOLs in today's environmentally driven and fast-paced society, and equally easy to see that as lightning graces the sky now, Blitzen will soon follow.

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