ALADRIUS

36th Annual VFS Student Design Competition

Extreme Altitude Mountain Rescue Vehicle

Sponsored by Airbus Helicopters

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The students listed above will receive credit for the course ENAE634: Helicopter Design.

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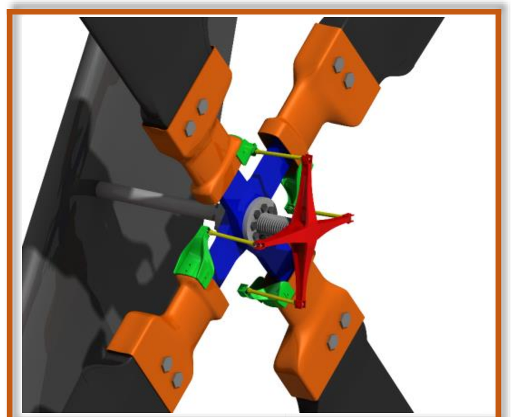
To Vertical Flight Society:

The members of the University of Maryland Graduate Student Design Team hereby grant VFS full permission to distribute the enclosed Executive Summary and Final Proposal for the 36th Annual Design Competition as they see fit.

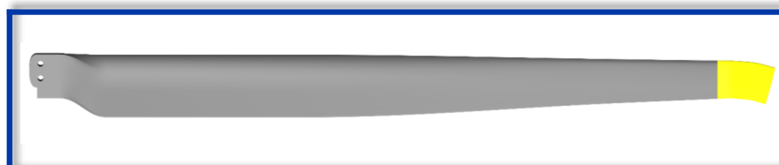
The UMD Graduate Design Team

Caladrius: Designed for Extreme Altitude Mountain Rescue



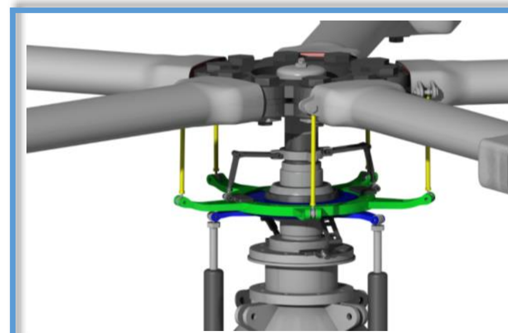
Tail Rotor

Large tail rotor designed for low power consumption and high wind speeds from any azimuth at extreme altitude



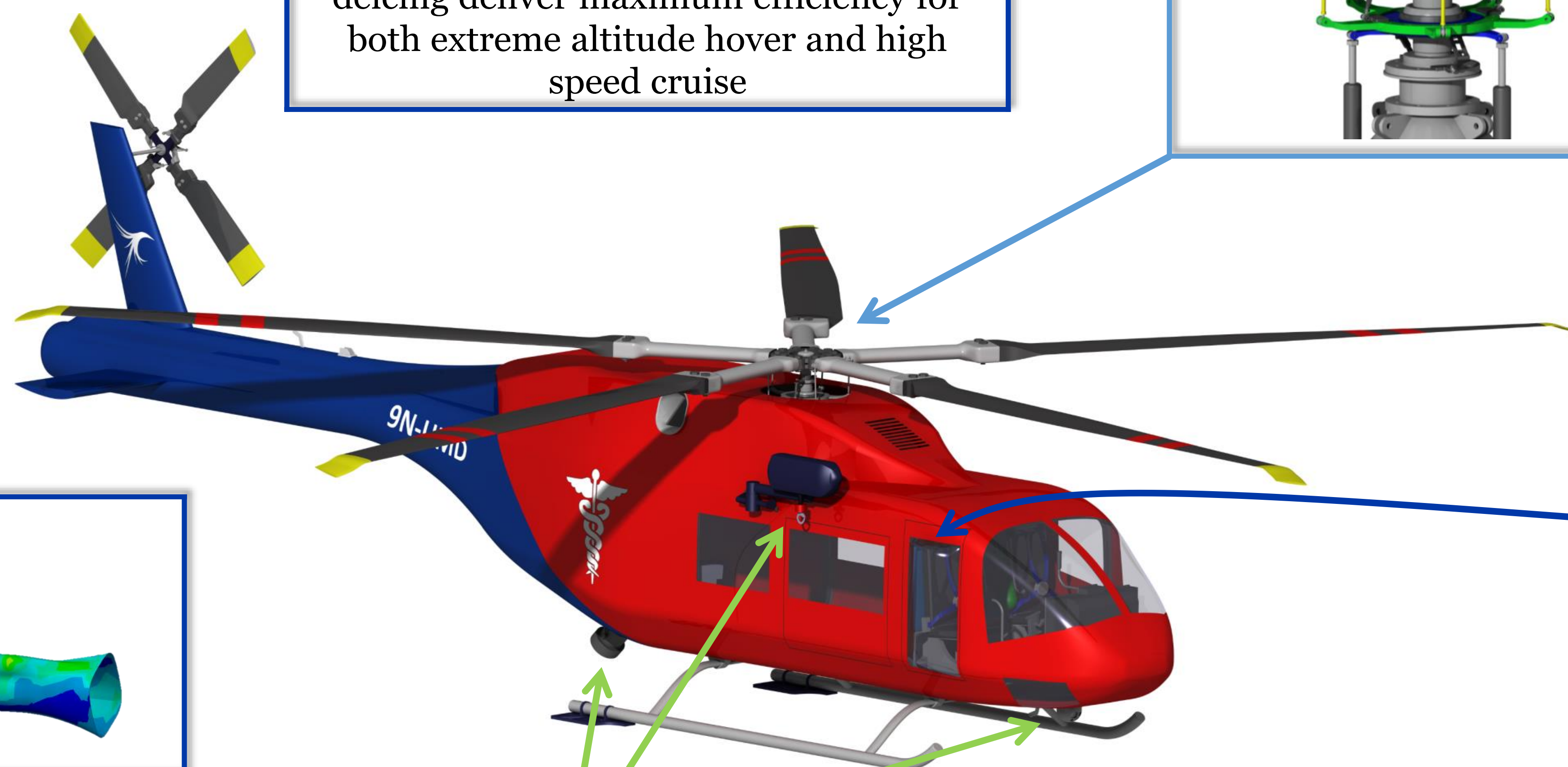
Efficient Blades

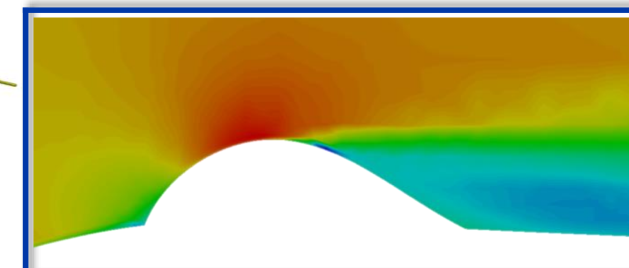
Aerodynamically optimized blades with deicing deliver maximum efficiency for both extreme altitude hover and high speed cruise



Bearingless Hub

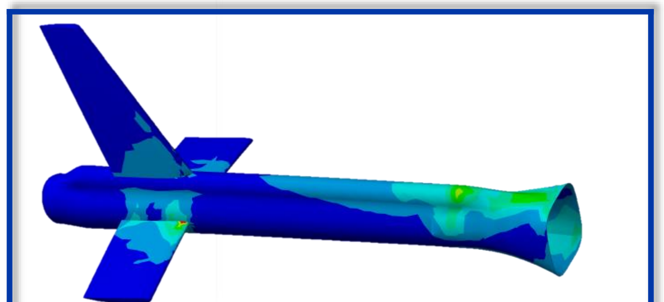
Low drag bearingless hub with a flap frequency of 1.06/rev provides agility during mountain rescue





Wide Field of View

Wide, bird strike resistant front windshield, bubble side window, and floor windows designed for maximum pilot field of view



Monocoque Tailboom

Sized to reduce weight and withstand extreme conditions

Search and Rescue Equipment

Equipment selected for effective operation for harsh weather conditions at Mount Everest

GTOW	3500 kg
Rotor Radius	6.88 m
Installed Power	2894 kW
Disk Loading	24 kg/m^2

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Caladrius: A Pilot's Helicopter

Only one bird has conquered the iconic Mount Everest: the Himalayan bar-headed goose. It is no ordinary bird, as ***Caladrius***, designed by the University of Maryland Graduate Design Team, is no ordinary helicopter. Like the bar-headed goose that has special hemoglobin to withstand hypoxia far beyond any human athlete, ***Caladrius*** has specially designed rotors, a capable flight control system, and powerful engines for extreme altitudes. The goose only has to cross the mountains, but ***Caladrius*** must battle the winds and the snow to pluck the bold and the brave from the jaws of inevitable death. It must also be swift, for every minute is precious for those fighting against the unforgiving elements on the Mount Everest.

Caladrius, named after a snow-white bird from Roman mythology with healing abilities, is a single main rotor helicopter designed for mountain rescue missions at unprecedented altitudes that no other rotorcraft can perform. ***Caladrius*** is not only a highly capable mountain rescue helicopter, it can also perform several other missions.

The design team interviewed a number of highly experienced pilots including Didier Delsalle from Airbus Helicopters, the only pilot to have ever landed a helicopter on the summit of Mount Everest, and Samuel Summermatter from Air Zermatt. The insights and sage recommendations provided by them helped focus the engineering efforts on designing a true **"Pilot's Helicopter"**. **Concept of operations, rotor hub and flight control system designs, avionics suite and search & rescue equipment selection, tail rotor, front windshield, side bubble window, and floor window designs** were all influenced by the valuable inputs obtained from these pilots. **High safety** and **low pilot workload** emerged as the main design objectives.

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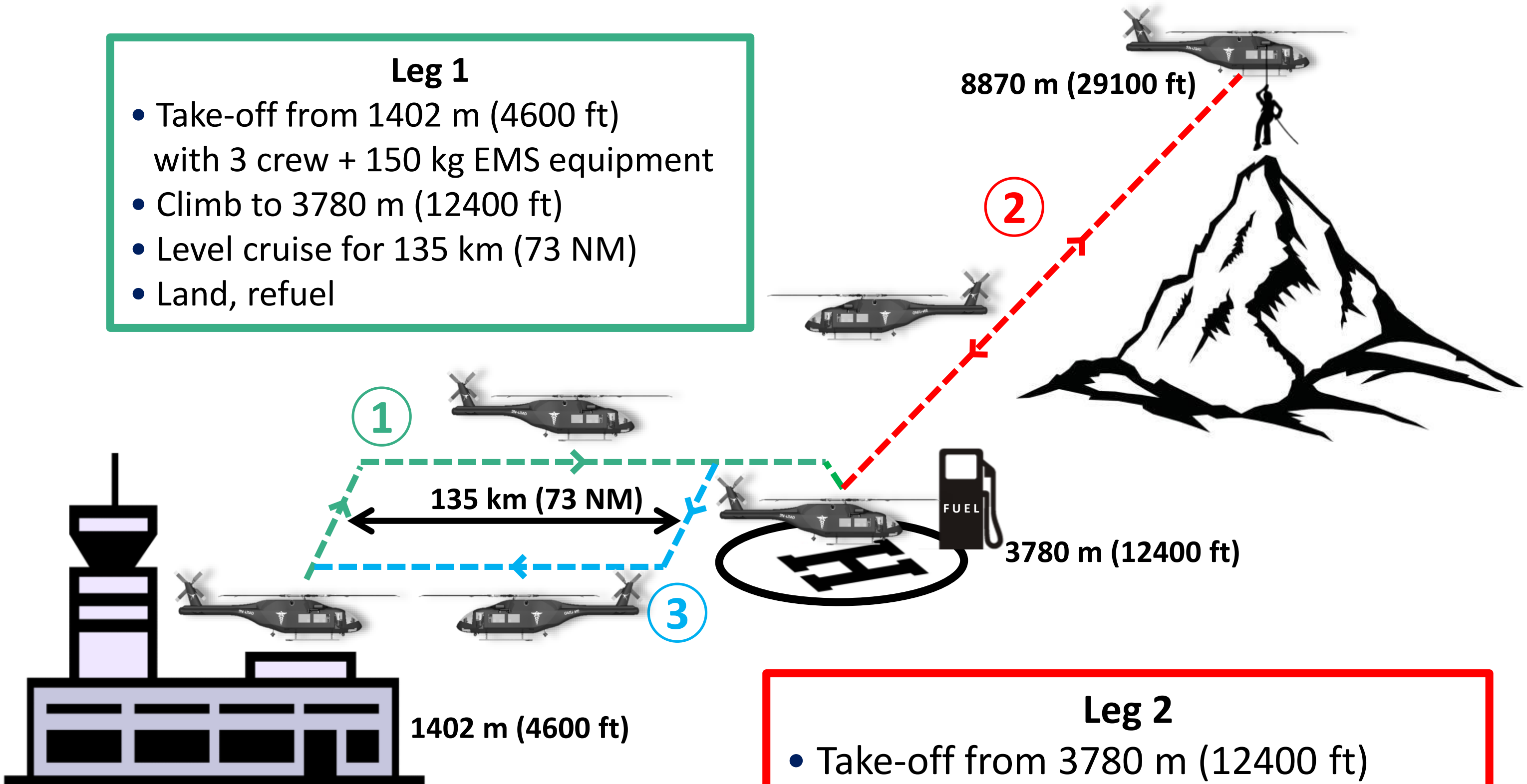
Extreme Altitude Rescue Mission Profile

Leg 1
- Take-off from 1402 m (4600 ft) with 3 crew + 150 kg EMS equipment
- Climb to 3780 m (12400 ft)
- Level cruise for 135 km (73 NM)
- Land, refuel



Leg 2
- Take-off from 3780 m (12400 ft)
- Climb to 8870 m (29100 ft)
- Level cruise for 28 km (15 NM)
- Payload increase by 2 passengers
- Hover out of ground effect for 30 min
- Descent to 3780 m (12400 ft)
- Land, refuel

Leg 3
- Take-off from 3780 m (12400 ft)
- Descent to 1402 m (4600 ft)
- Level cruise for 135 km (73 NM)
- Land

	RFP Requirement	Caladrius Mission Capability
Mission Time	3 hrs	**2 hrs 55 min**
Max. Wind to Maintain Hover Heading at 8870 m (29100 ft)	40 knots	**44 knots**
Single Pilot Day/Night IFR Capability	-	✓

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Concept of Operations Driven by the Pilots

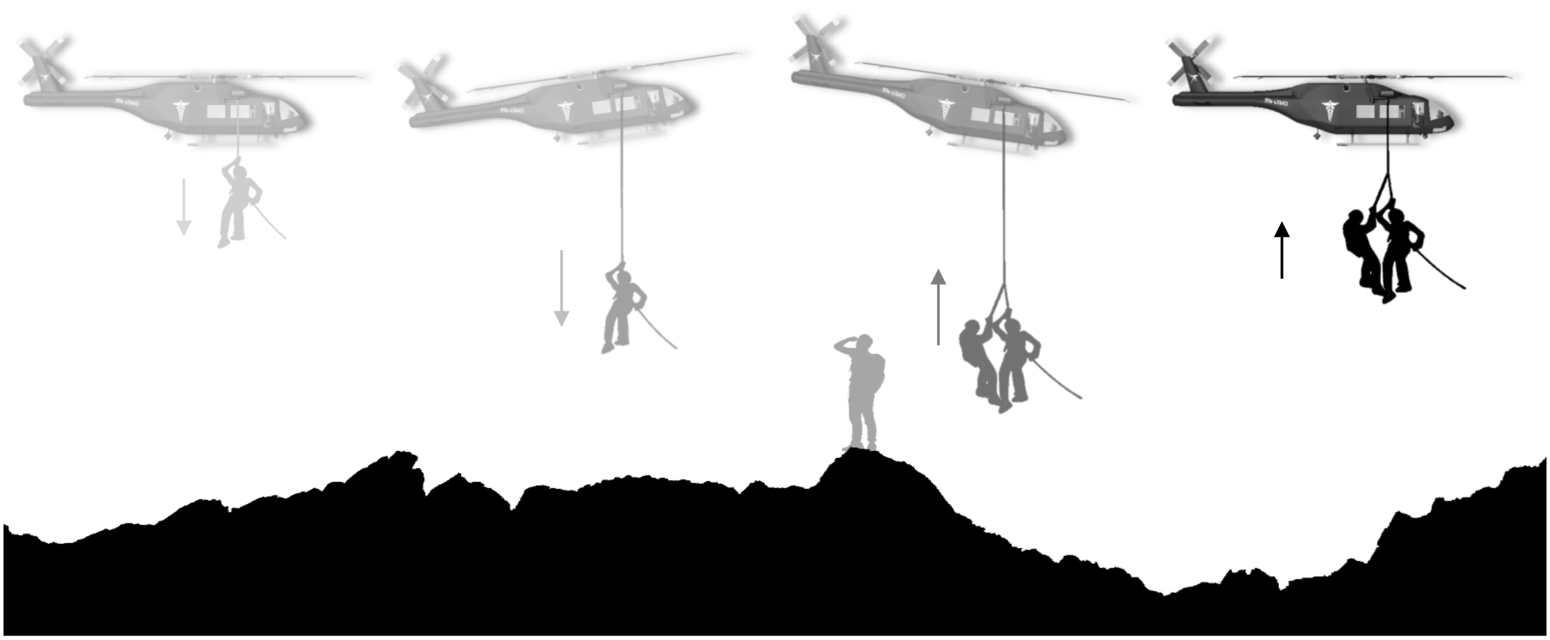
Understanding the details of rescue operations such as the crew composition and different hoisting methods was an important feature of ***Caladrius's*** design. Having interviewed,

- Baltimore County Police Aviation Unit
- Maryland State Police Aviation Command
- John Tritschler (Director of Research at U.S. Naval Test Pilot School)
- Christian Polyka (USCG Pilot)
- Samuel Summermatter (Search and Rescue Pilot at Air Zermatt, Switzerland)
- Didier Delsalle (Experimental Test Pilot at Airbus Helicopters, Marignane, France)

the requirements for this mission were fully analyzed and insights and recommendations provided by these experienced sources were applied to the design. ***Caladrius's*** crew composition is:

• Pilot • Co-Pilot/Hoist Operator (Crew Chief) • EMS Specialist

For safety on the ground and stability of the slung load, dynamic hoist operation (illustrated below) will be performed.



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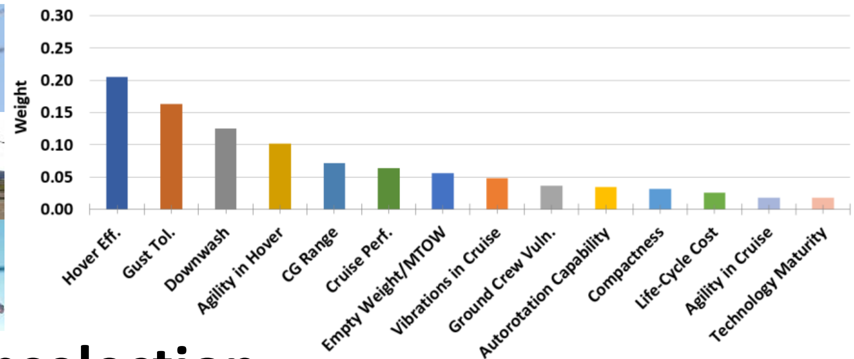
Vehicle Configuration

Configuration Space

Design Drivers



Downselection

Side by Side

Single Main Rotor

Tandem

Further Down Selection

Single Main Rotor Configuration

- Compact for access
- Superior cruise performance
- Low empty weight fraction
- Low vibrations in cruise
- High autorotation capability
- Low cost

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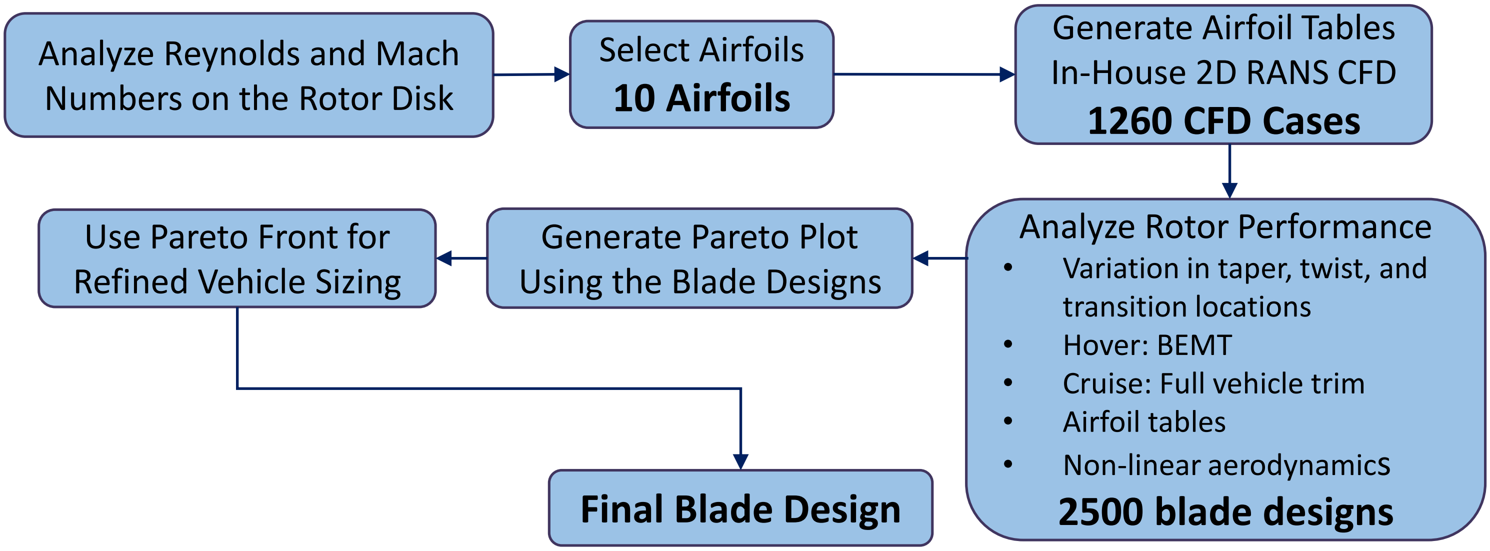
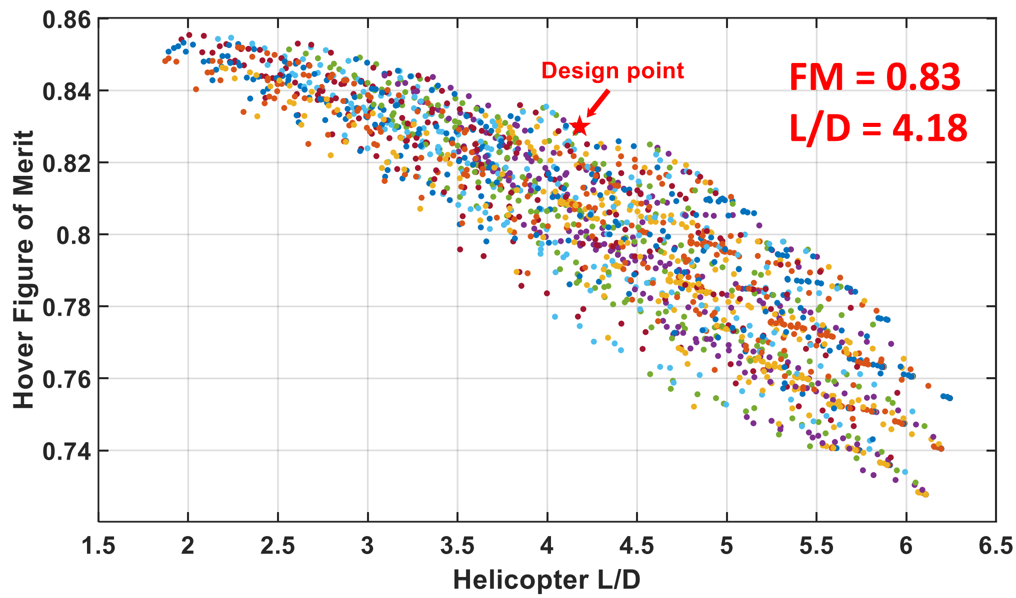
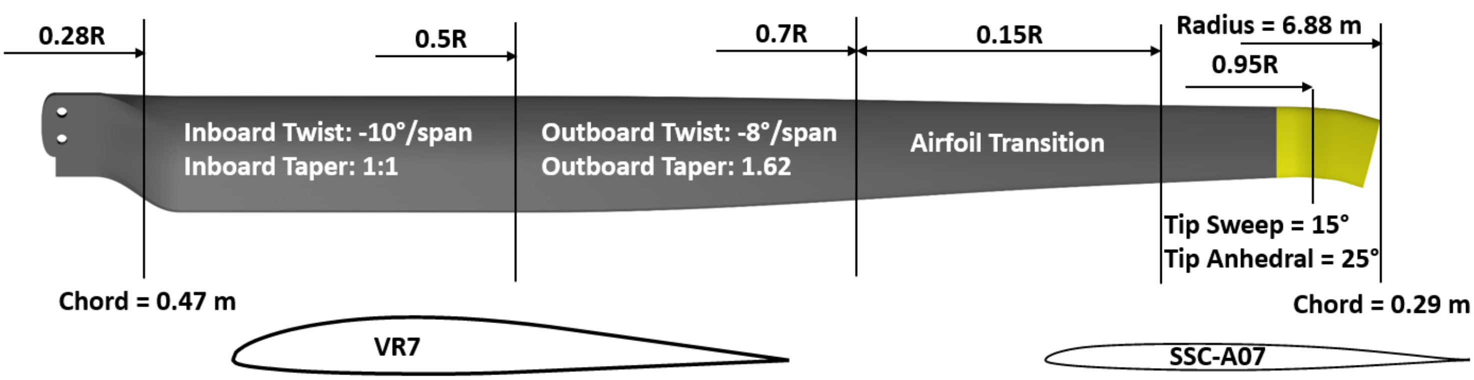
High Efficiency Blades

Caladrius's *blades* are aerodynamically optimized for both **extreme altitude hover** and **high speed cruise.**







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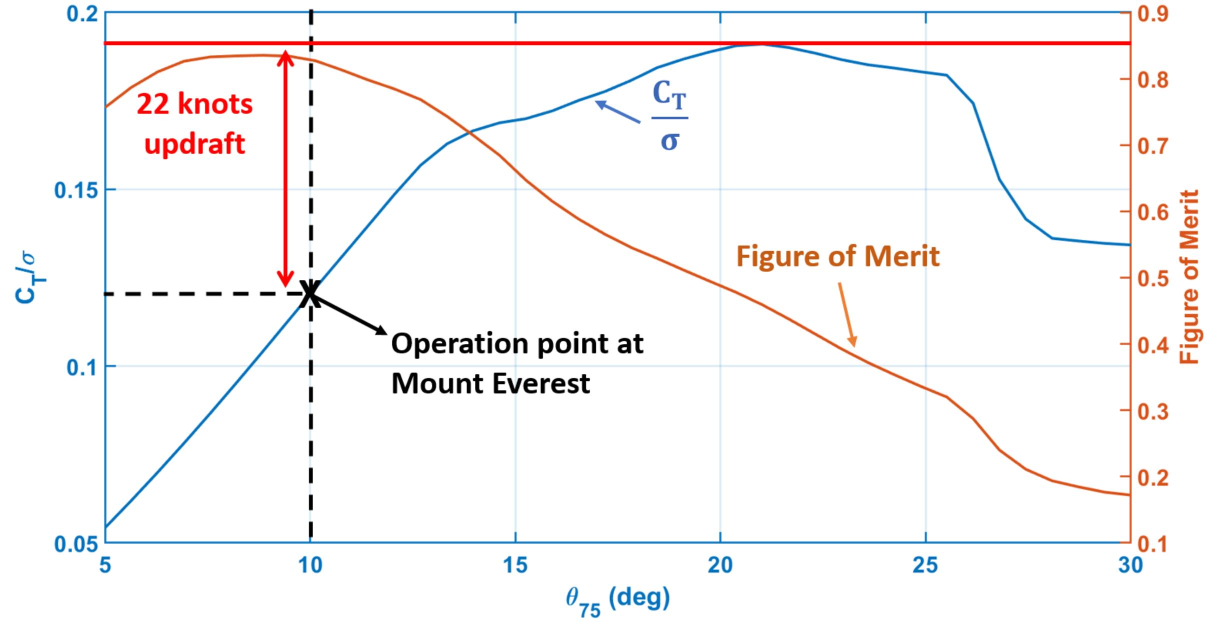
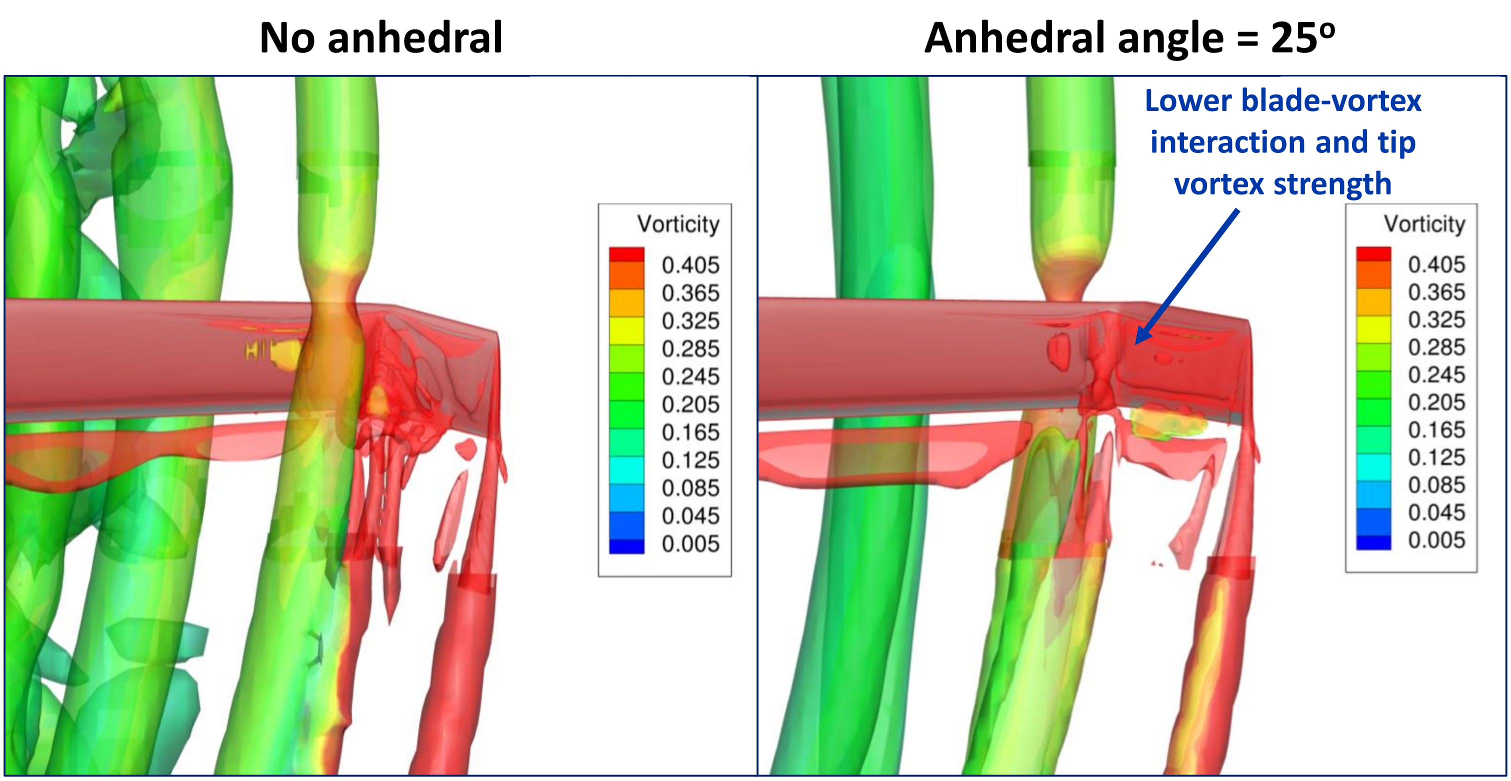
High Stall Margin and Low Vibrations

The rotor is **free of stall** while hovering in up to **22 knots updraft** at Mount Everest altitude.



Blade tip was designed with high-fidelity RANS for **high hover and cruise performance** and **low vibrations** to ensure EMS personnel can easily stabilize the condition of the rescuees.



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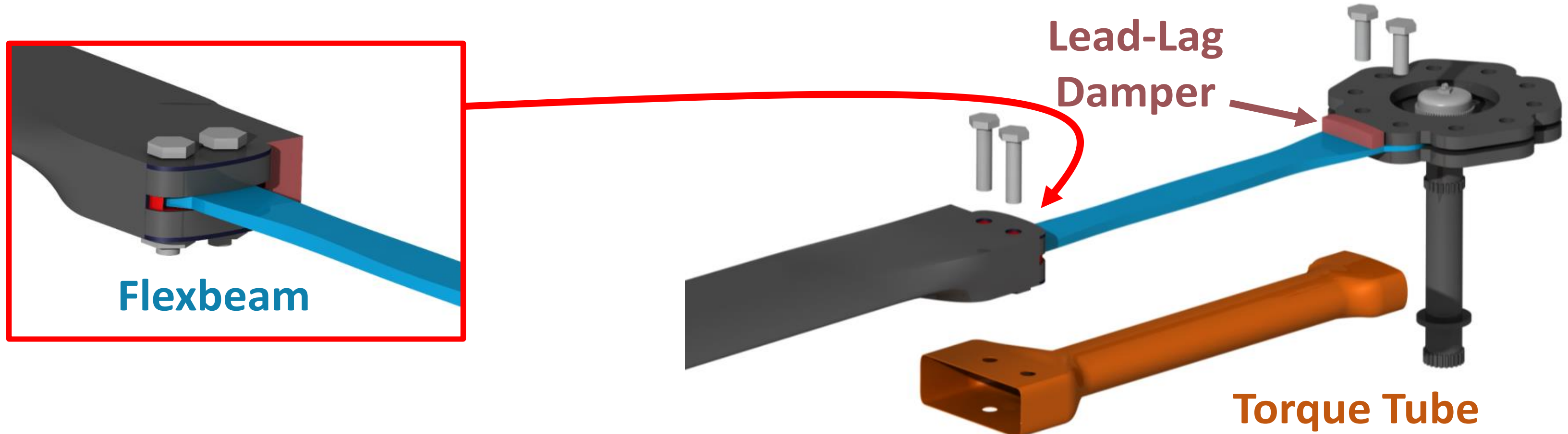
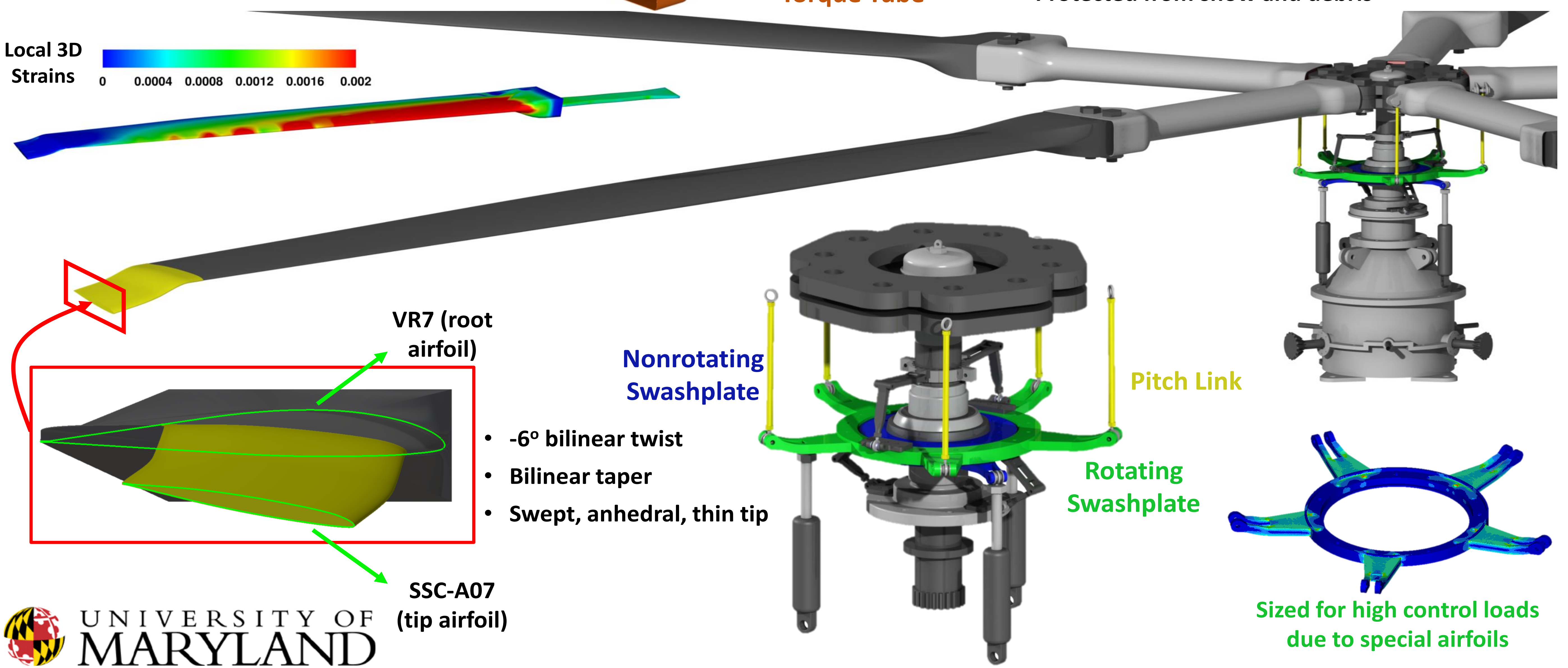
Hub Design: Bearingless Hub for Low Drag and Robustness



- Flap frequency: 1.06/rev to find the balance between high control power and high gust tolerance
- Soft in-plane
- Clean, robust, low drag profile hub
- Low part count
- Protected from snow and debris



- -6° bilinear twist
- Bilinear taper
- Swept, anhedral, thin tip

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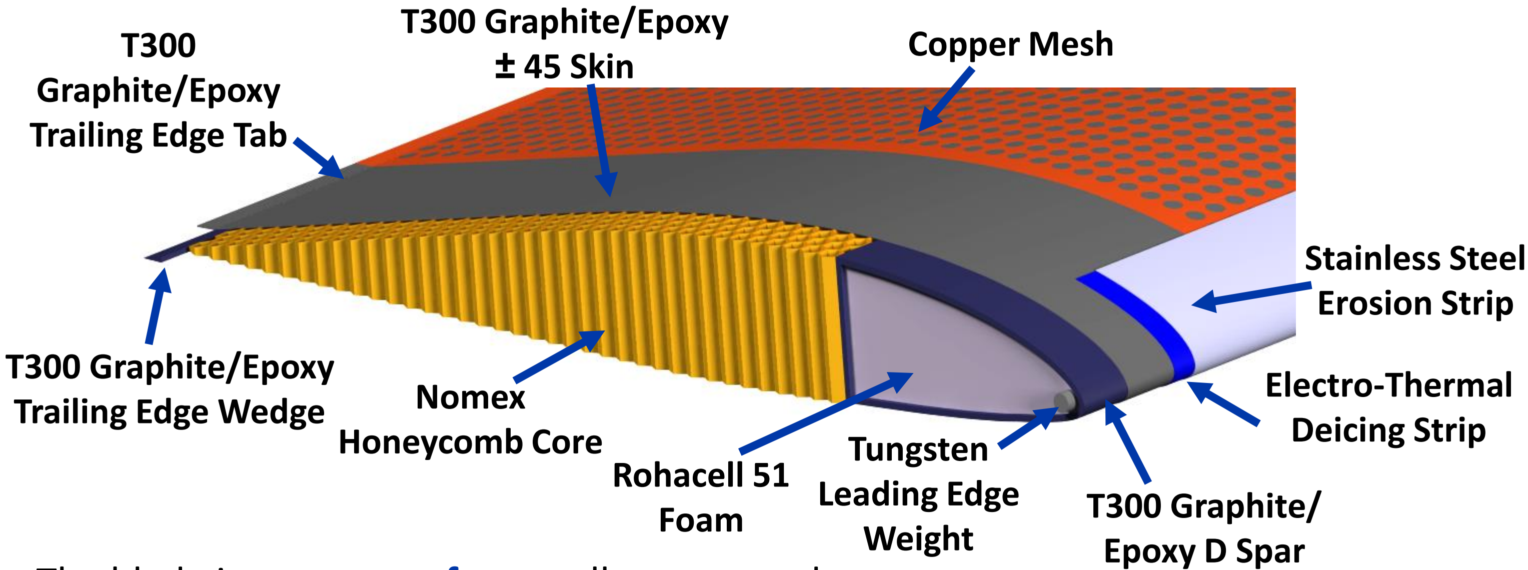
Extreme Altitude Blade Design

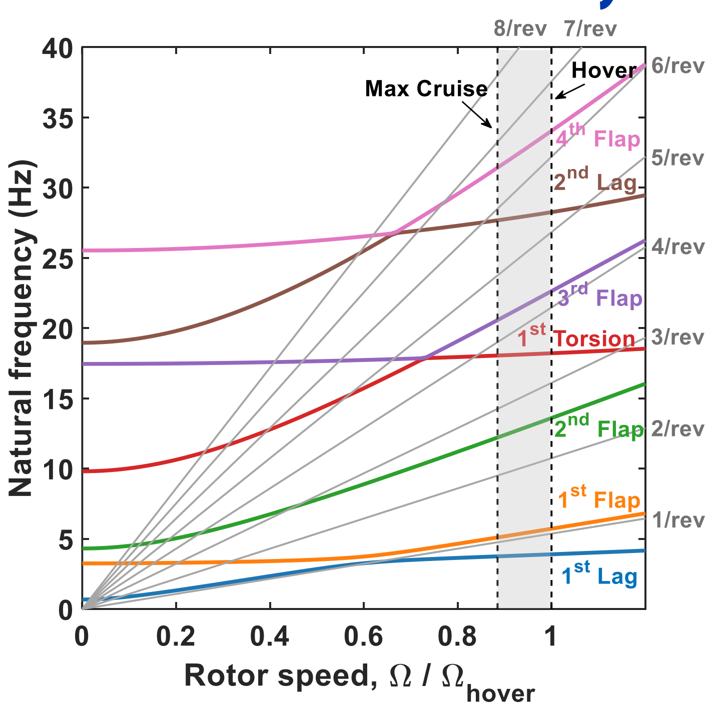
Blade and flexbeam were designed to achieve the balance between **control authority** and **gust tolerance** both of which are crucial for extreme altitude mountain rescue operations. **Electro-thermal deicing system** ensures **cold weather operation safety** and **performance.**



The blade is **resonance free** at all rotor speeds.

Rotor speeds:
- Leg 1 → 282.0 rpm
- Leg 2 → 320.5 rpm
- Leg 3 → 297.7 rpm

} **Chosen for maximum efficiency**



Mode	Hover (/rev)	Cruise (/rev)
1st Lag	0.72	0.79
1st Flap	1.06	1.07
2nd Flap	2.53	2.57
1st Torsion	3.4	3.8
3rd Flap	4.21	4.33
2nd Lag	5.27	5.82

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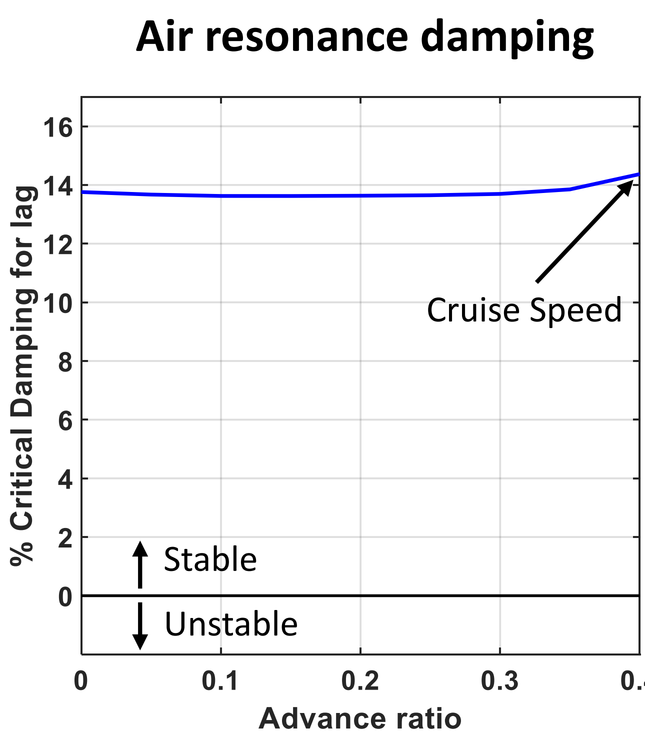
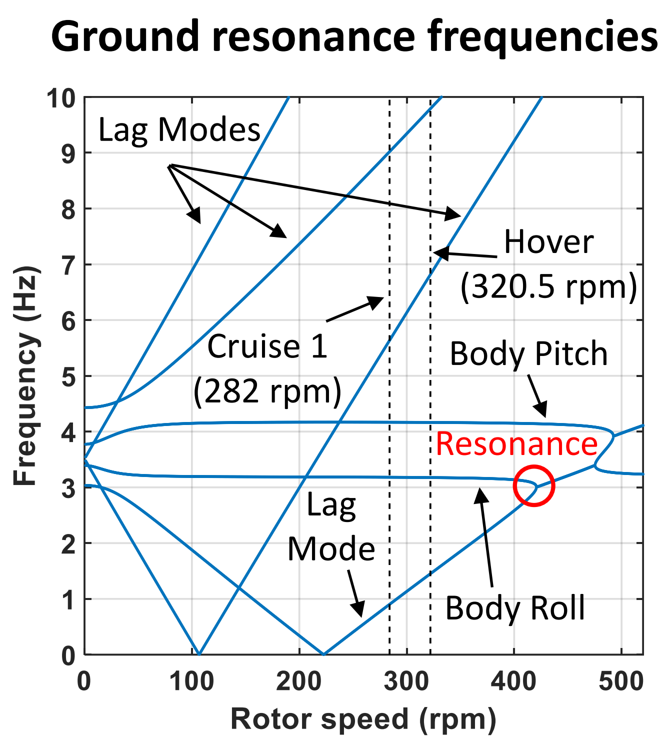
Rotors Free from Air and Ground Resonance

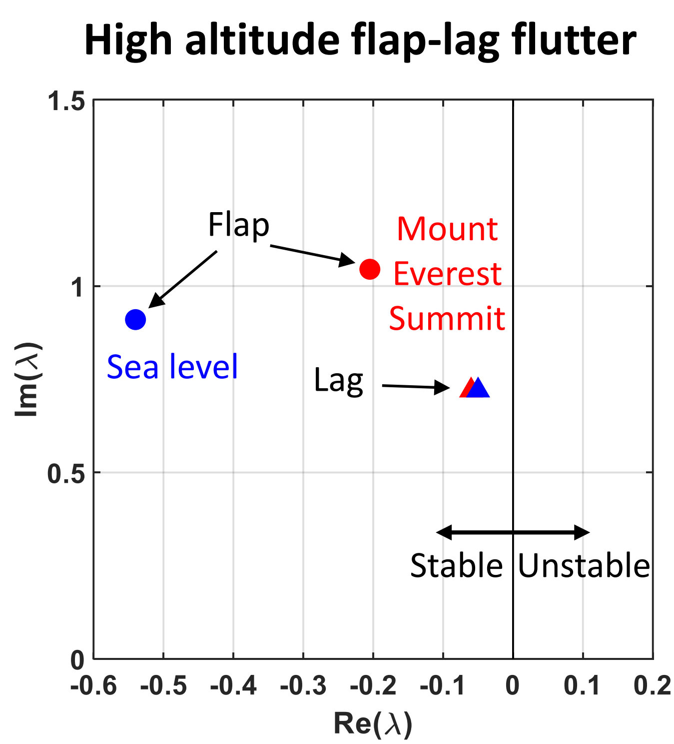
High thrust coefficient (C_T) at extreme altitude and possible snow landing presented challenges for aeroelastic stability and ground resonance. ***Caladrius's*** blades are designed to be free from any such instabilities.





Terrain Type	Terrain Damping	Lead-Lag Damper
Concrete	0.05	0.02
Mud	0.03	0.04
Grass	0.03	0.04
Snow	0.01	0.1

Elastomeric damper is selected for a possible **snow landing** which assures freedom from ground resonance for all terrain conditions.



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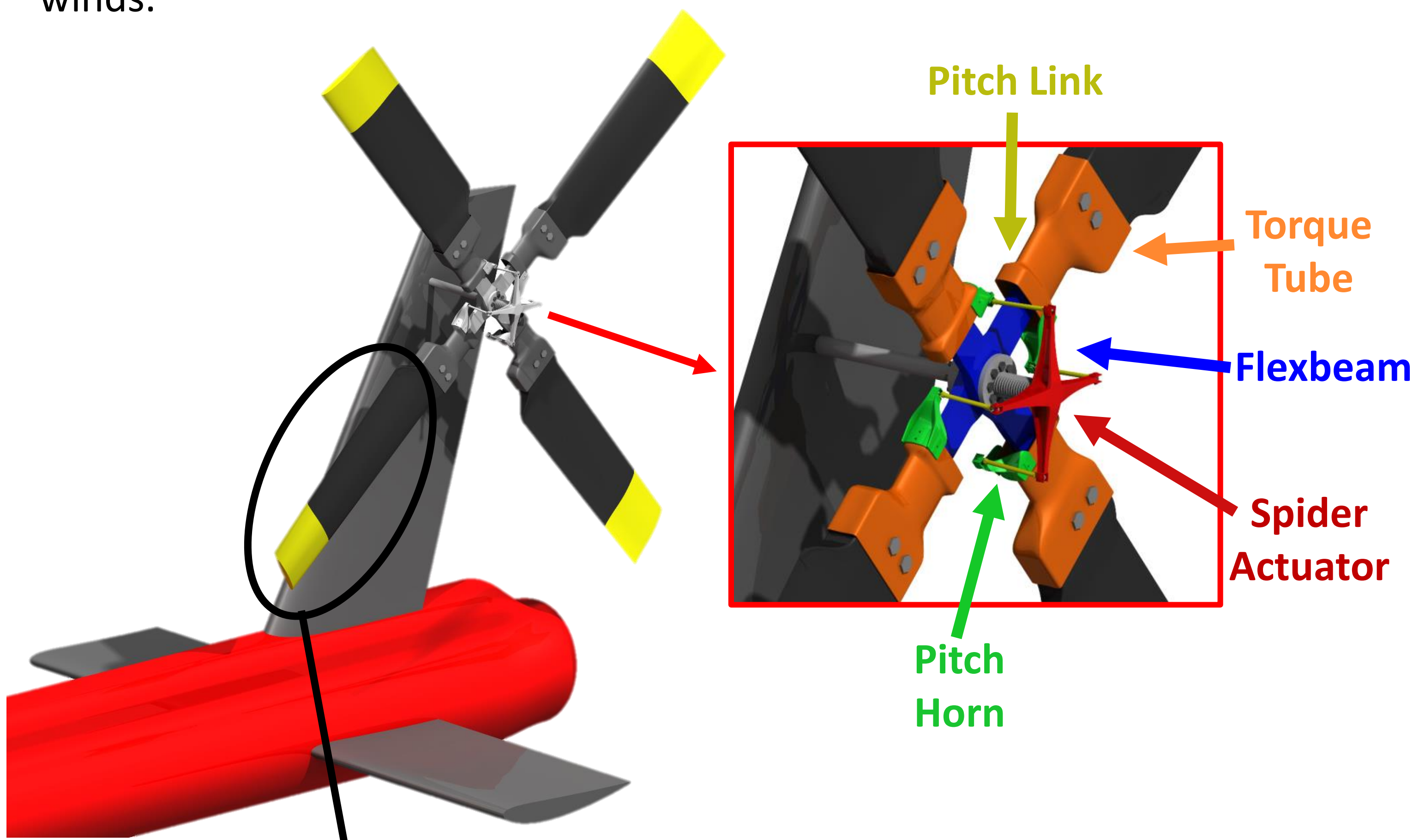
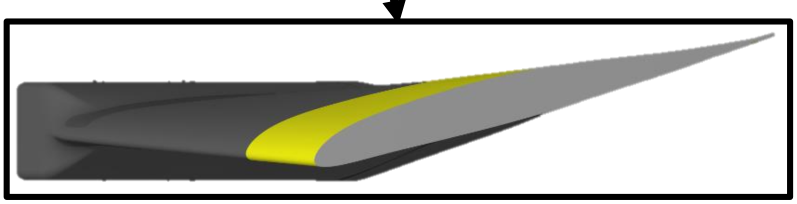
Special Bearingless Tail Rotor

Caladrius's 4-bladed tail rotor with twist prevents **loss of tail rotor effectiveness** and **vortex ring state** in winds up to **81 km/h (44 knots)** at 8870 m (29100 ft). The pedal control range was designed for high side winds.





Highly twisted blades

Parameter	Value
Diameter	2.80 m (9.19 ft)
Chord	0.27 m (0.89 ft)
Solidity	0.239
Rotor Speed (Hover)	139 rad/s (1328 rpm)
Twist	-20º linear
Airfoil	RC510

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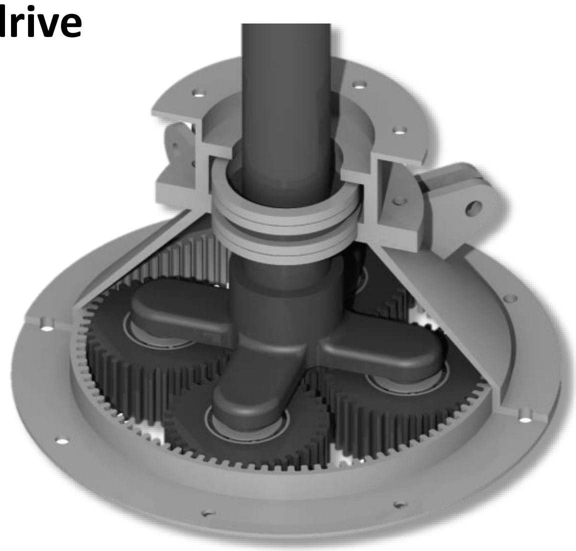
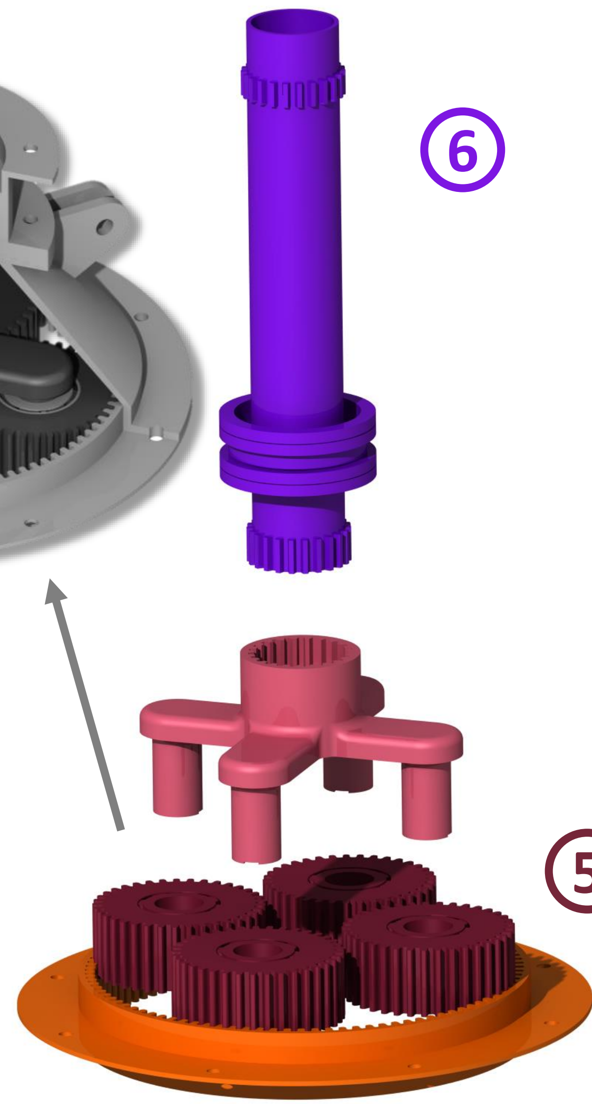
Lightweight Gearbox Design with 50 minute Dry Running Capability

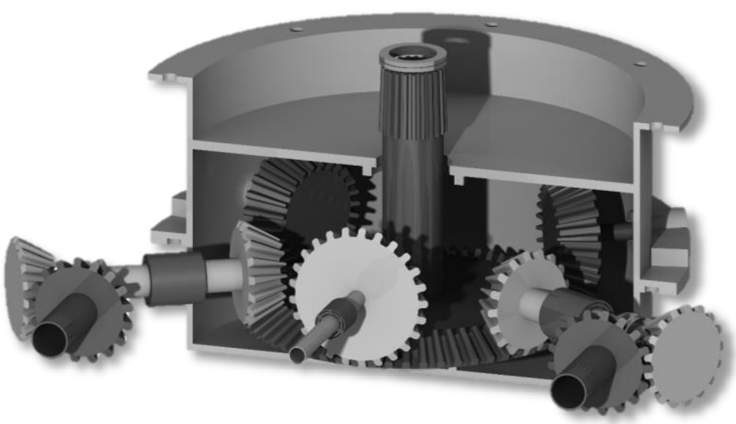
Weight minimized drive system

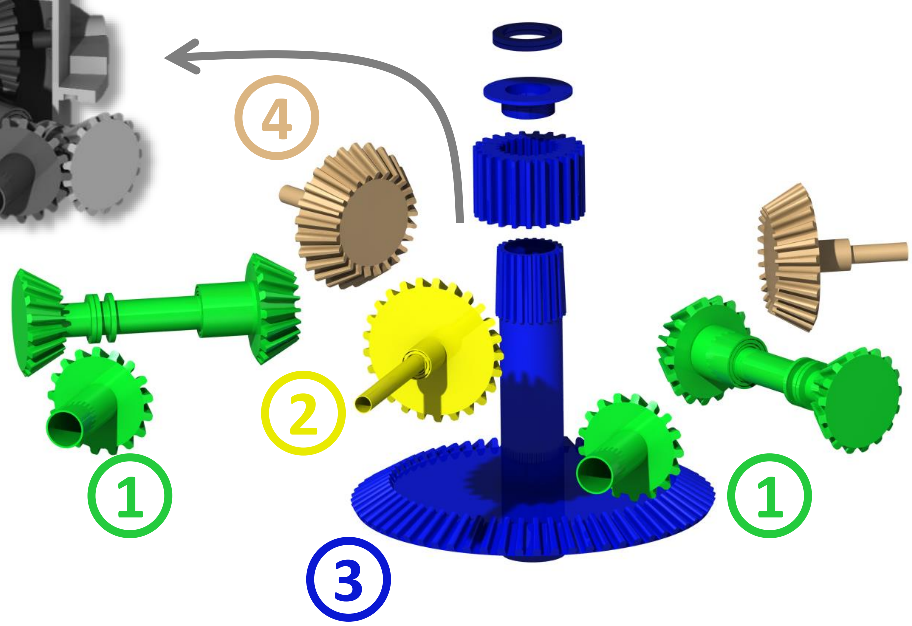
Reserved oil for 50 min dry running





1: Engine Inputs
2: Tail Drive Shaft
3: 1st Stage Bevel Reduction
4: Accessory Outputs
5: 2nd Stage Planetary Reduction
6: Main Rotor Drive Shaft





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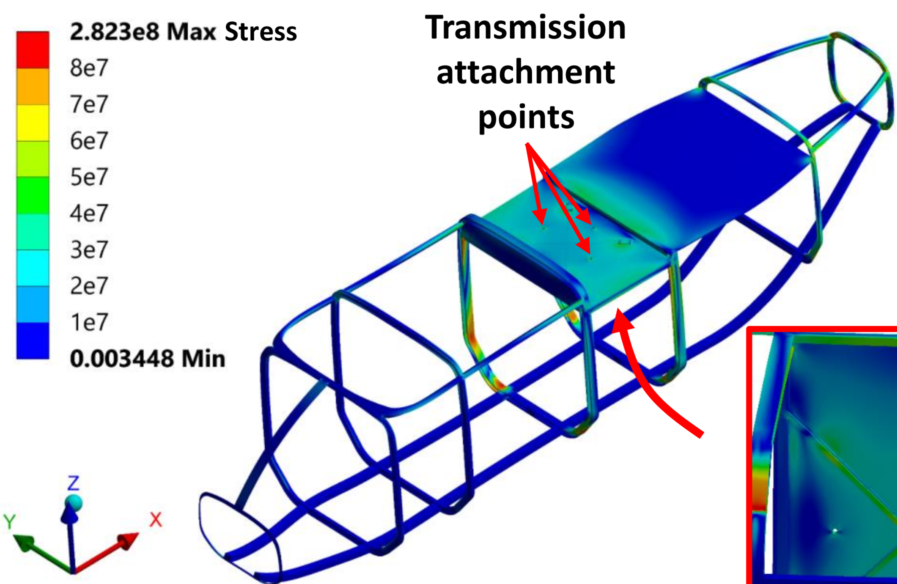
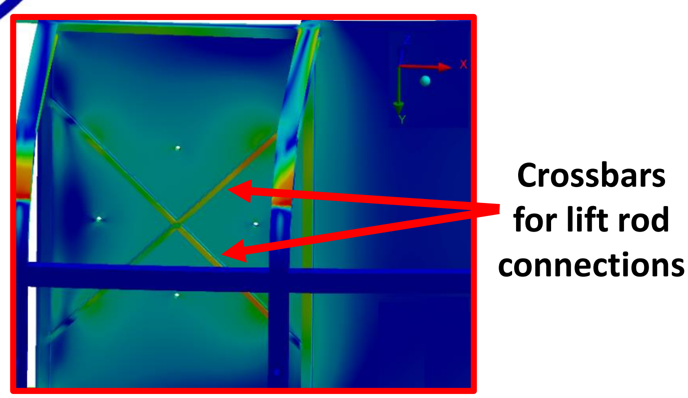
Airframe Sized for Extreme Conditions

Airframe was sized with high fidelity finite element tools to satisfy CS 29 requirements.

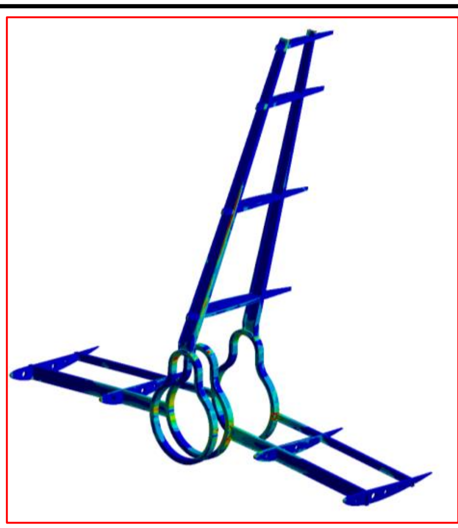
Combinations of **high tail rotor thrust** and **extreme side winds, updrafts, and downdrafts** were considered for maximum load cases.

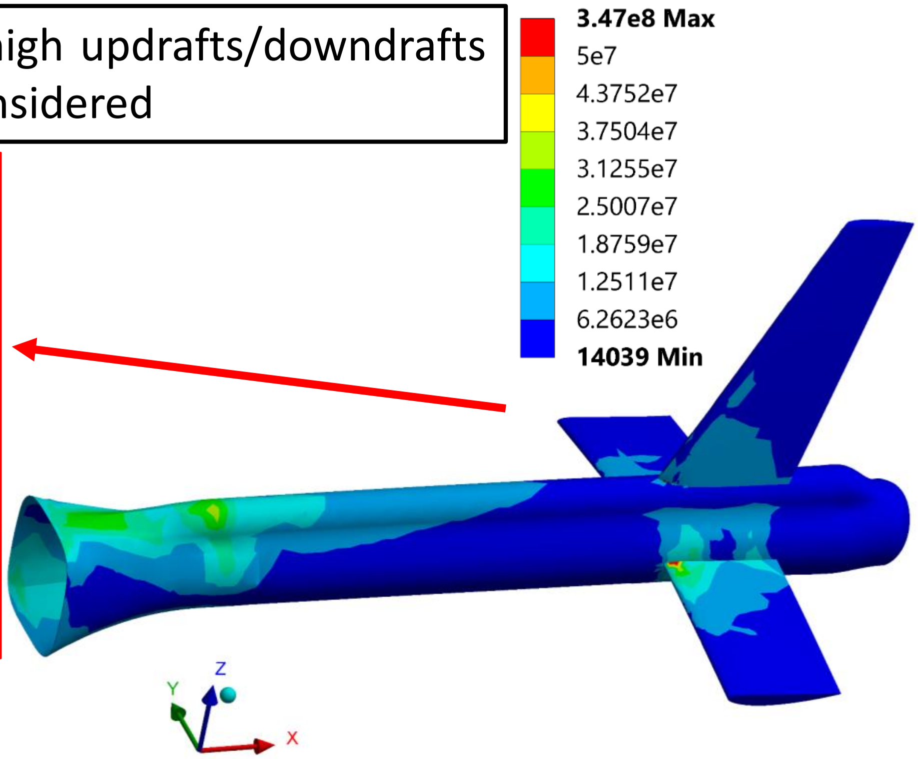


- 3.5 g load factor
- Maximum torque
- Factor of Safety = 1.8



CS 29 requirements and high updrafts/downdrafts at Mount Everest were considered





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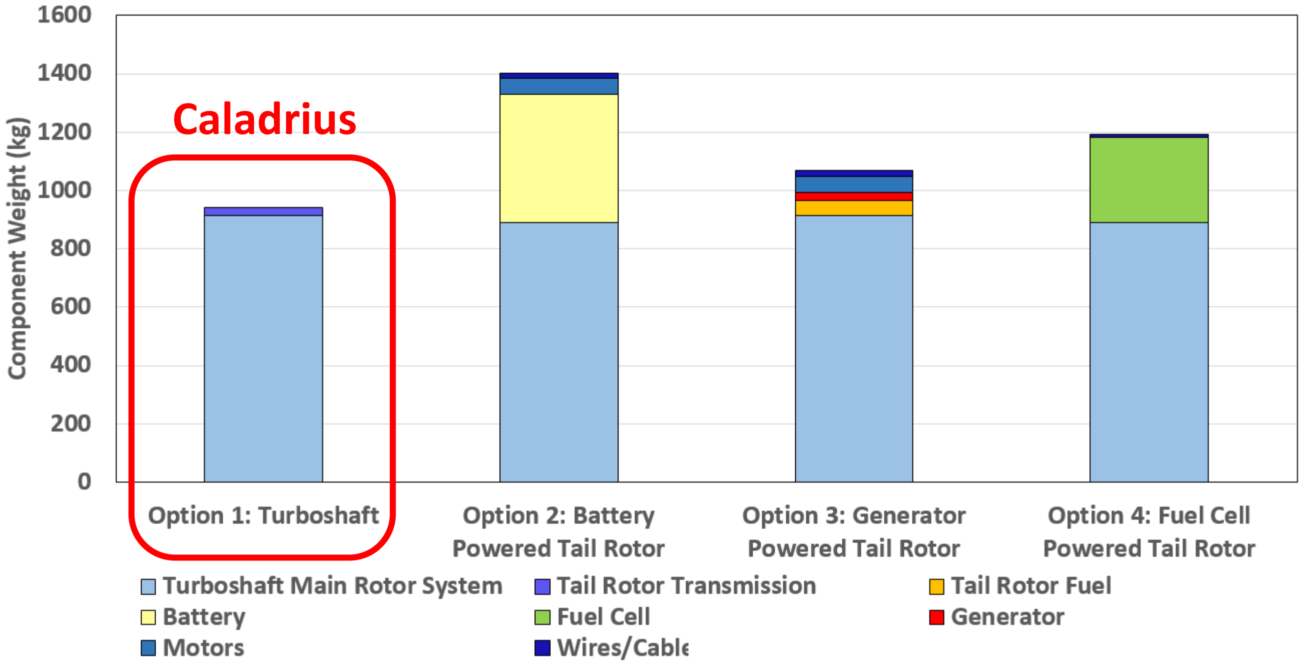
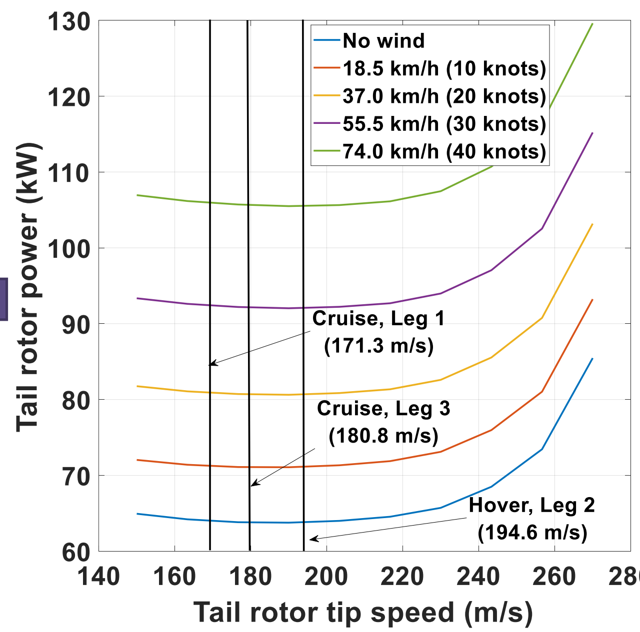
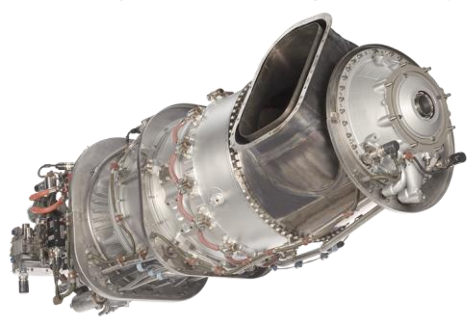
Twin Turboshaft Engines for Safety

Minimizing power consumption during rescue is critical for the mission. Trade studies were performed among several configurations to examine the pros/cons of an electric tail rotor.



- **Lowest weight:** Twin turboshaft engines with mechanically powered tail rotor
- Tail rotor operates in the drag bucket for each wind case
- No power benefit with electric tail rotor (variable rotor speed)
- **Twin engines** for high safety





2 X Pratt & Whitney Canada PT6C-67A

Power: 1447 kW (1940 hp) X 2
Weight: 190 kg (419 lb) X 2
SFC: 0.308 kg/kW/h (0.506 lb/hp-hr)

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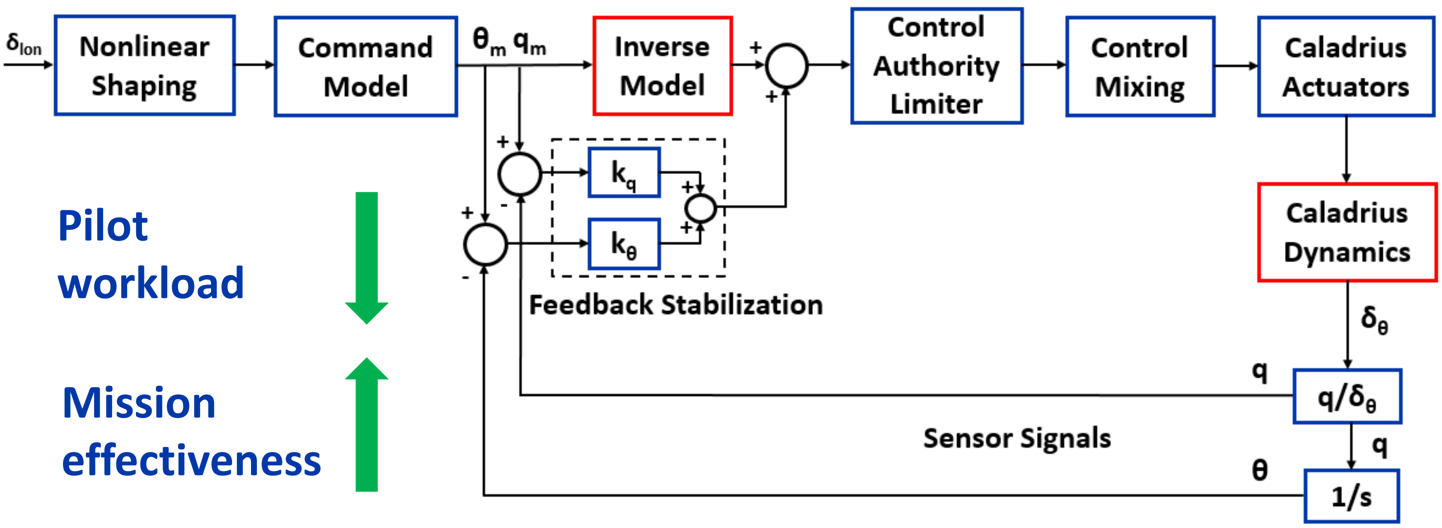
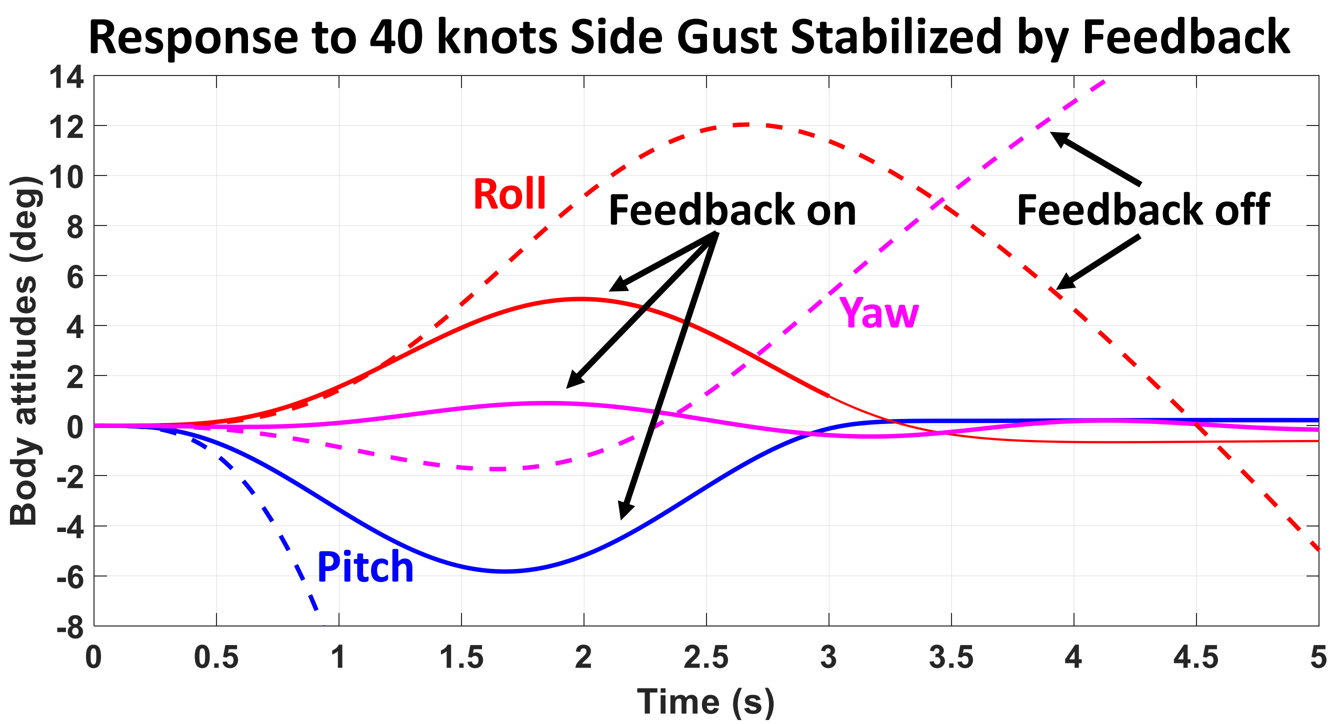
Flight Control System Designed for Extreme Gusts

Caladrius is equipped with a **Model Following Control System** and a triple redundant **four-axis autopilot** to ensure both **high gust tolerance** and **control authority.**





The flight control system **satisfies IFR requirements.**

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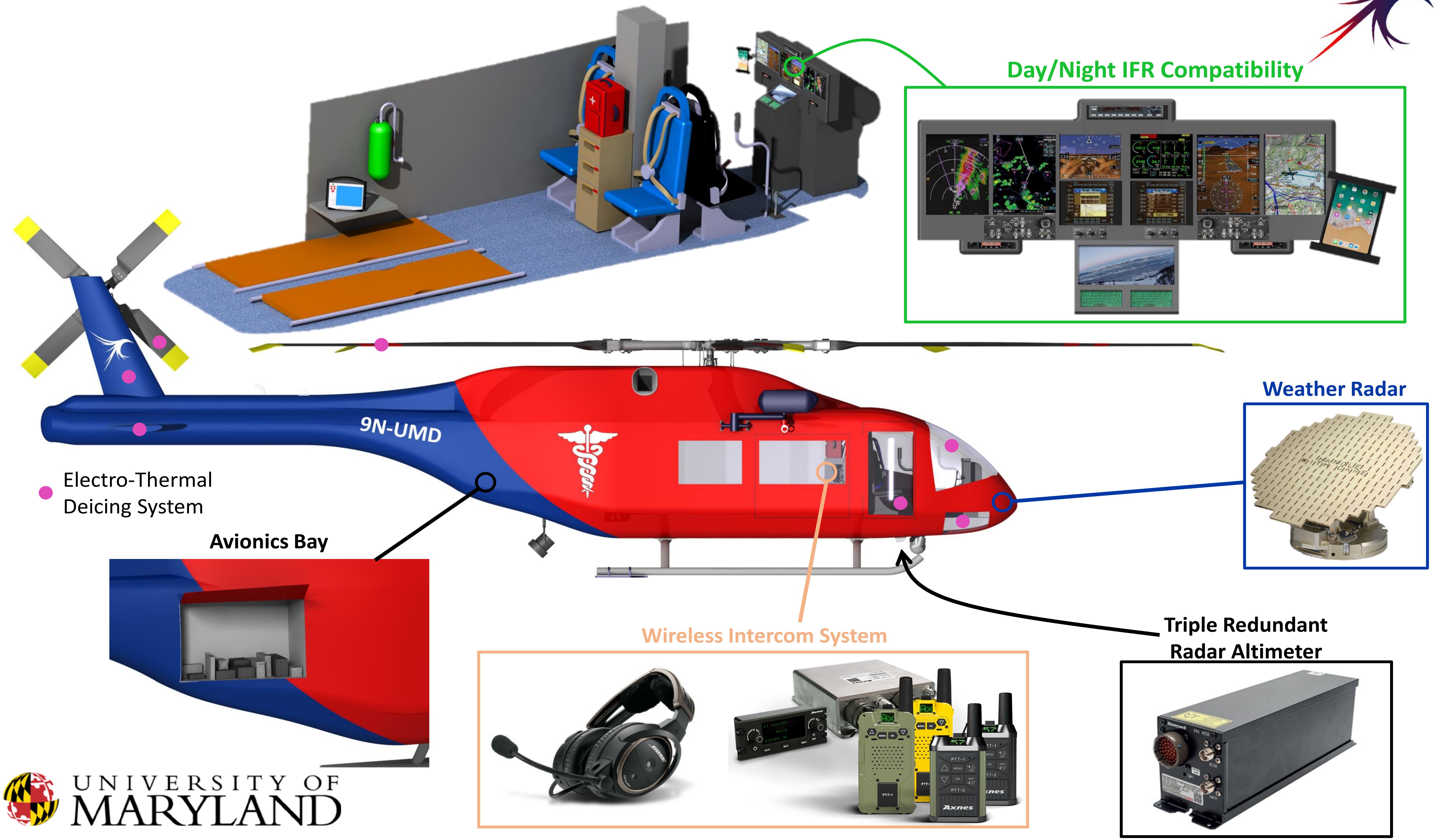
Avionics: Selected for High Safety and Low Pilot Workload



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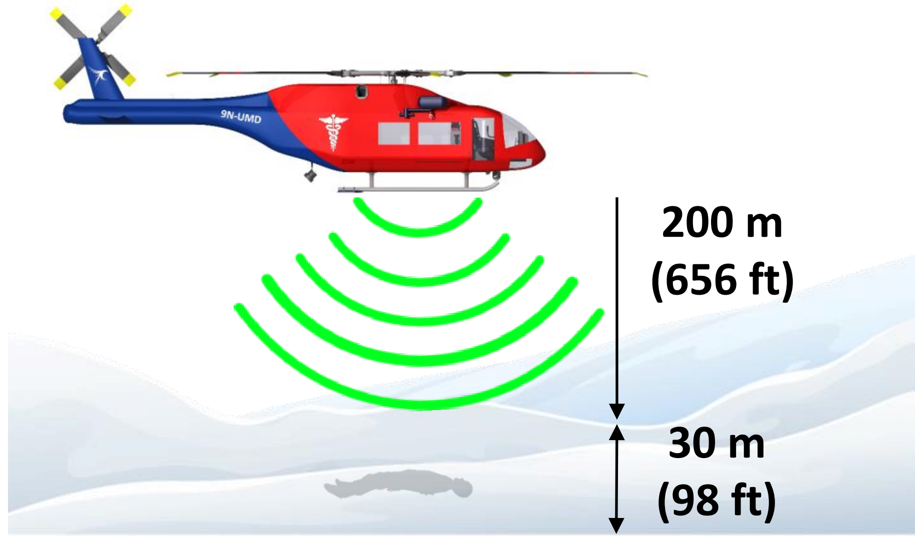
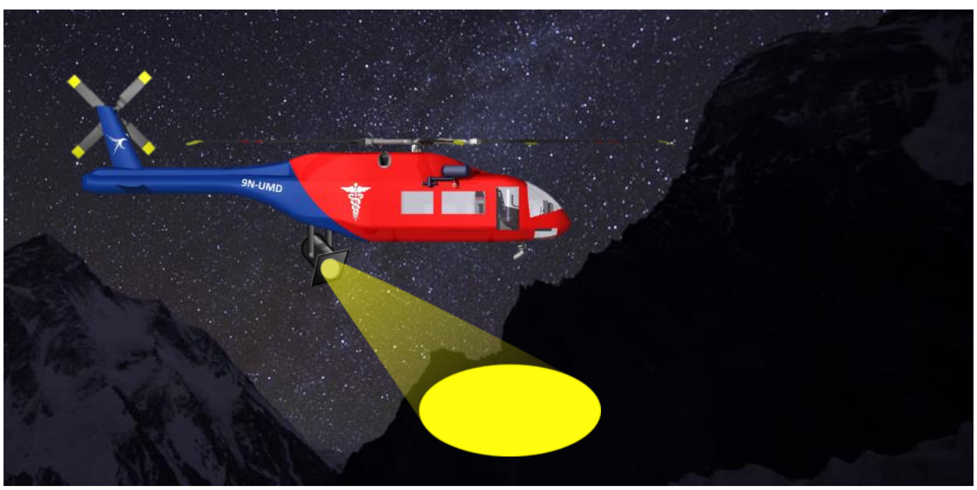
Mountain Search and Rescue Equipment for Day and Night, All Weather Conditions

State-of-the-art search and rescue equipment in order to reduce the **pilot workload** and **increase mission effectiveness.**

Recco avalanche detector to find the rescuees trapped **under snow**



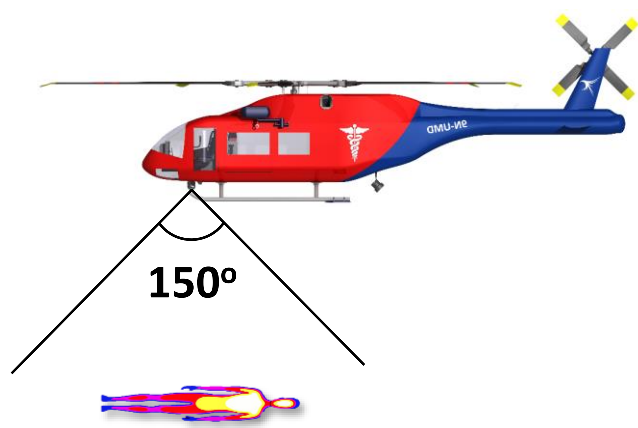


External searchlight with **25 million candlepower**

Electro-optical system with **thermal imaging** capabilities with coverage of

- 150^{o} elevation
- 360^{o} azimuth

to expeditiously locate the rescuees



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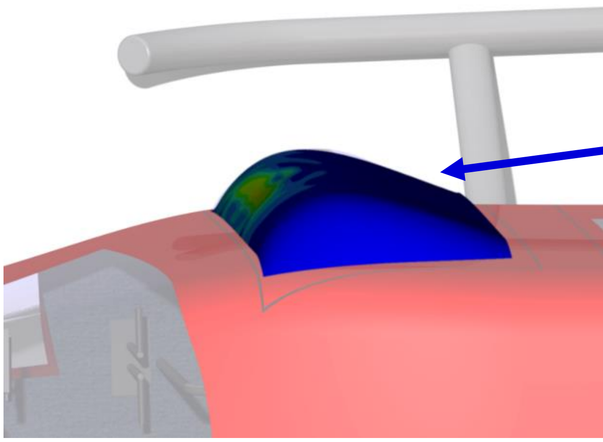
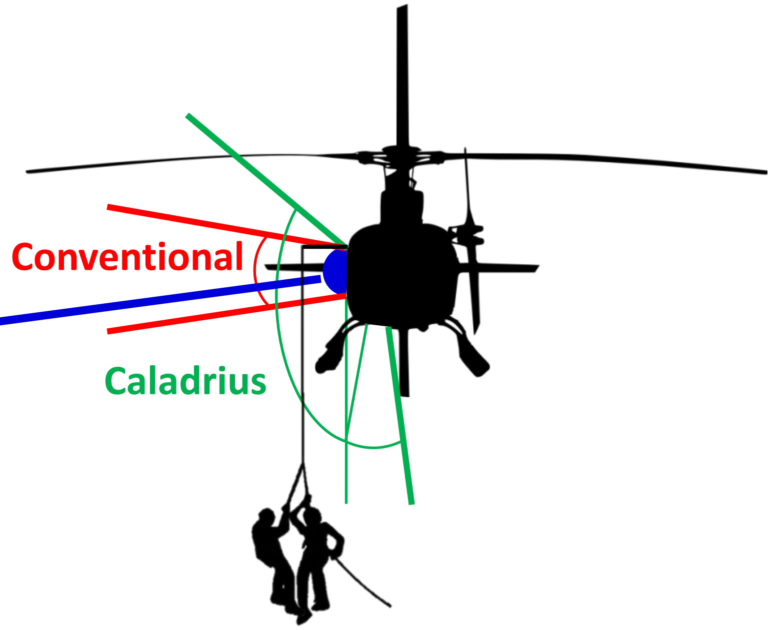
Wide Field of View for High Mission Effectiveness

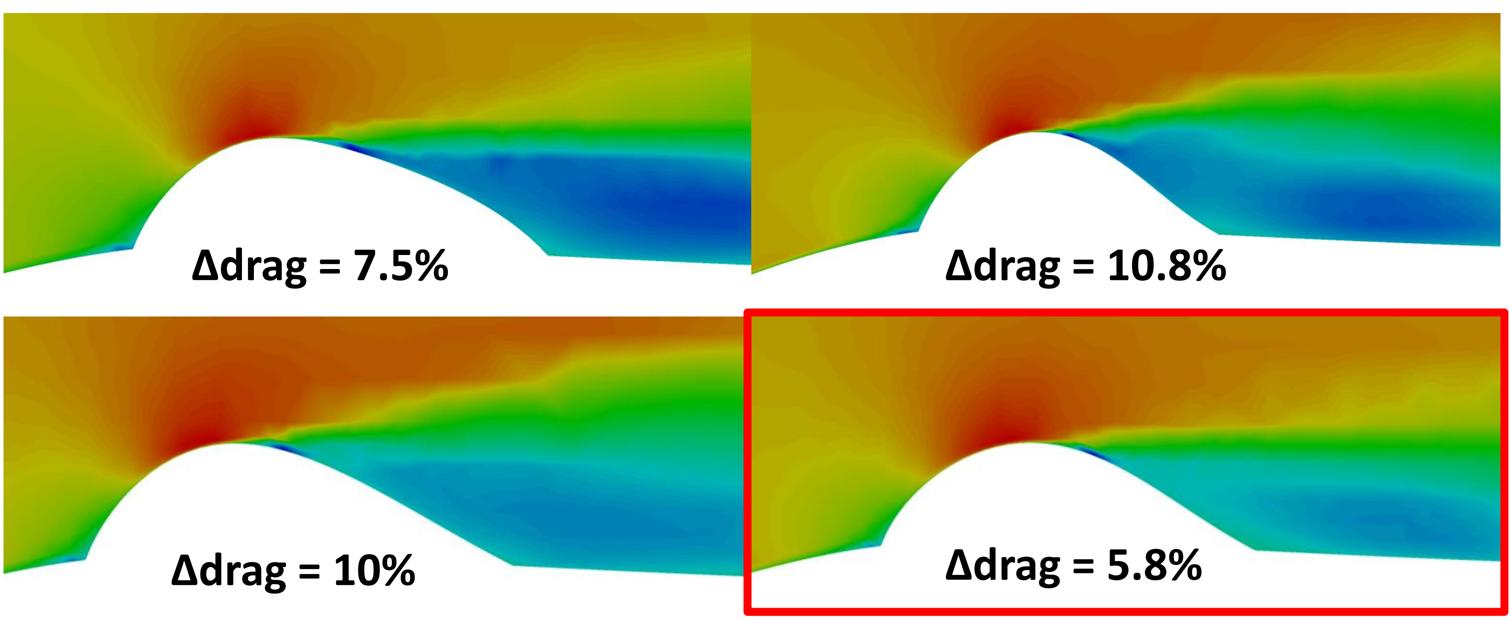
Bird strike resistant **windshield, side bubble window, and bottom windows** provide **excellent field of view**, which is especially important for the mountain rescue missions.

Bird strike analysis carried out using Altair





Bubble window geometry was designed after extensive aerodynamic studies for minimal impact in aircraft drag and increased lateral field of view



Design point for lowest airframe drag

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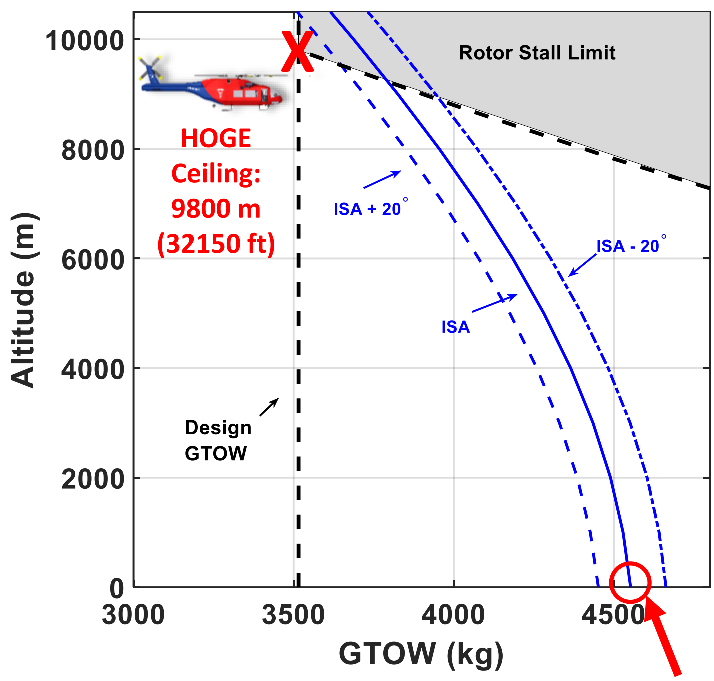
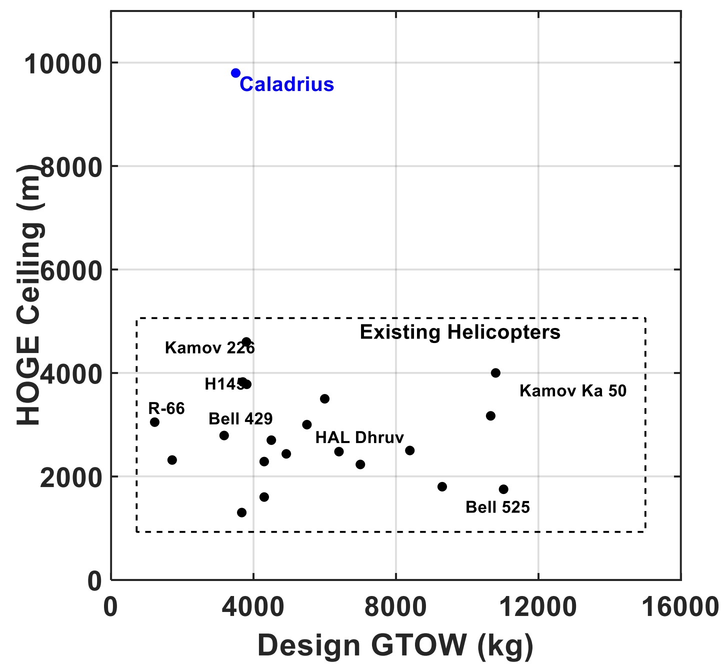
Unprecedented HOGE Ceiling and Efficient Cruise

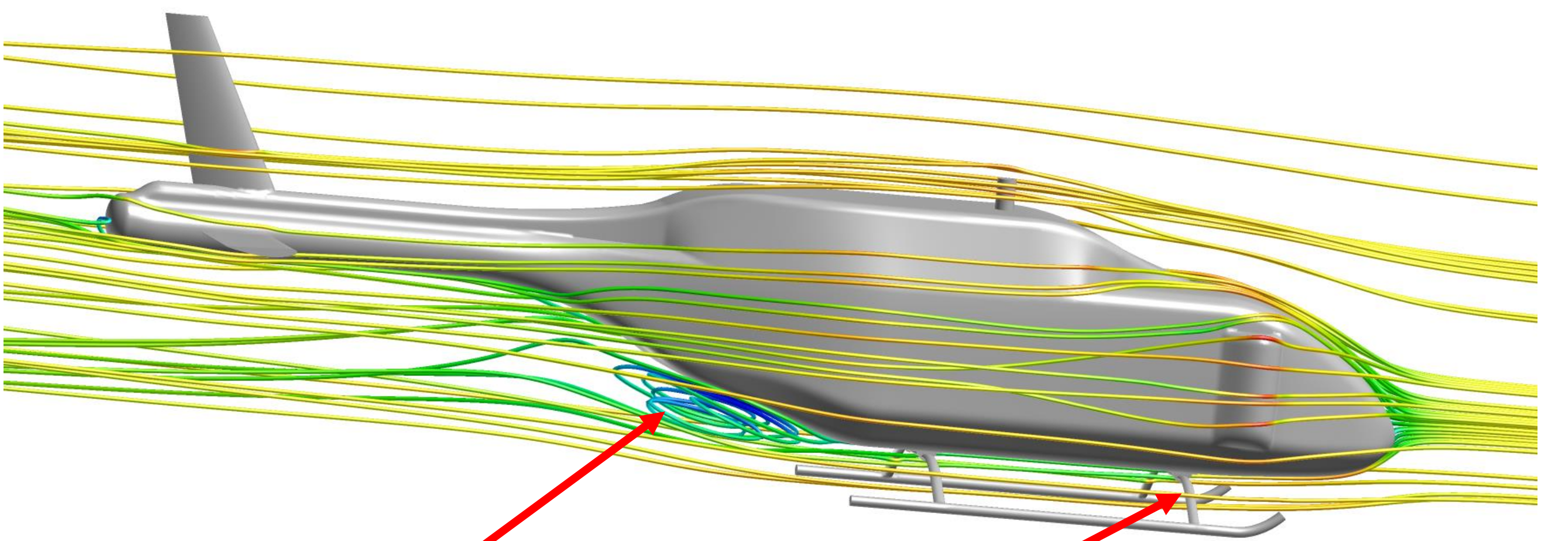
Only limited by transmission at low altitudes



Higher HOGE ceiling than any other helicopter by trading range and endurance



Greater than 1600 kg payload at sea level



Flow separation at upsweep was minimized

Elliptical cross-section crossbars

Flat plate area 1.2 m^2 (13 ft^2)

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Many Other Daring Missions

External Payload: 1200 kg
3 – 4 missions

Payload: 575 kg
Mission Radius: 120 km
Speed: 259 km/h

Mission Radius: 150 km
Endurance: 2.5 hrs

Endurance: 2.5 hrs

Payload: 600 kg
Mission Radius: 120 km

Payload: 680 kg
Range: 230 km

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