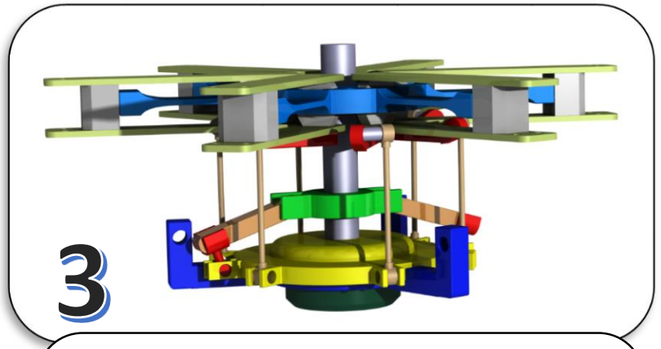
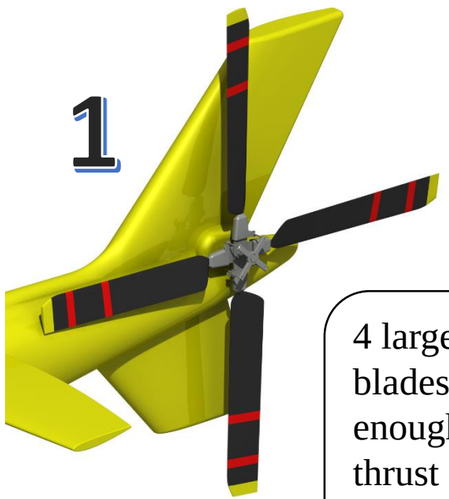
Overview

6 RC4-10 blades are optimized for efficient hover at high altitudes

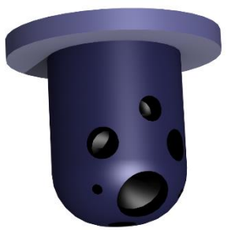


Hingeless rotor hub allows for a simple, low-maintenance design. Rotating components are covered by a drag-reducing fairing that is simple to remove for maintenance

Large windows give pilots a wide FOV



4 large Clark-Y blades provide enough tail rotor thrust for good control authority



Camera system lets pilots have eyes on the rescue directly on the MFD

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Introduction

High on the most inhospitable slopes of mountains around the globe, the Himalayan Tahr makes itself at home on the smallest crags. It deftly navigates the treacherous terrain and adapts to the ever-fluctuating environmental conditions with ease. This adaptability and maneuverability allows the Tahr to reach the unreachable.

Tahr over Mt. Everest

Inspired by this fleet-footed animal, the undergraduate team from the University of Maryland and Universidad de Carlos III designed *Tahr,* an **extreme high-altitude search and rescue** rotorcraft in response to the 2018-2019 VFS Student Design Competition sponsored by Airbus.

Tahr is a **6-bladed single main rotor** helicopter designed to hover at altitudes over **8870 m** (29100 ft.). Its **high forward flight speed** capabilities and **efficiency in hover** due to its **state-of-the-art twin turboshaft engines** make it an effective search and rescue vehicle. *Tahr* was also designed to be **pilot-friendly** to maximize **safety**. These capabilities allow the *Tahr* to operate in environments currently unreachable with available rotorcraft.

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Tahr Highlights

2.6 m (4.3 ft) diameter tail rotor with good control authority

13.2 m (43.3 ft) diameter rotor for high altitude hover

Aerodynamic fairing around rotor hub to reduce drag

Longer and taller cabin than the H145 gives EMS workers plenty of space

Rigid skid landing gear may be equipped with skis for snow landings

Notable Features of the *Tahr*

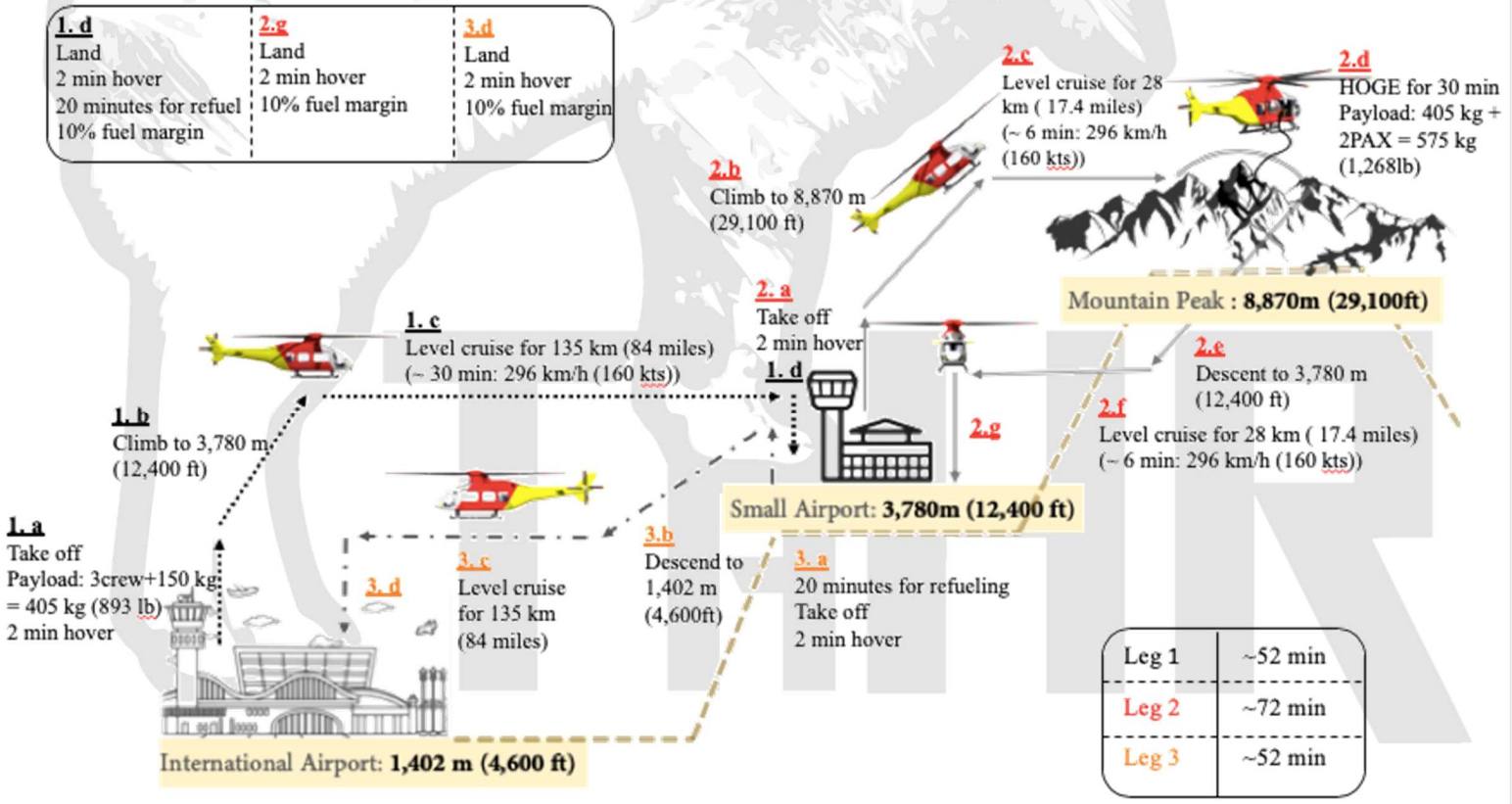
- Large 6-bladed rotor designed for **HOGE at 8870m (29100ft.)** for **30 minutes**, can also haul heavy loads at sea-level
- Large tail rotor for control authority in winds of **74 km/h (40 kts.)** allows for missions in high winds
- State-of-the-art engines provide **3200 kW (4300 hp)**, vital for extreme high altitude hover
- 75 minute hover endurance at 8870 m (29100 ft.)

Parameter	*H145*	*Tahr*
MGTOW	3800 kg (8380 ft)	3600 kg (7940 lbs)
Hover Ceiling (OGE)	2667 m (8750 ft)	9200 m (30200 ft)
Cruise speed	240 km/h (130 kts)	300 km/h (160 kts)
Cabin Space	6.03 m^3 (213 ft^3)	6.51 m^3 (230 ft^3)

Mission Profile

The mission profile is divided into 3 separate legs. The details of each leg are shown in the graphic. The mission must be completed in 3 hours or less

- Leg 1
  - Initial cruise leg to arrive at the stopover airport for refuel
- Leg 2
  - Rescue leg involves climb, hover, rescue and descent back to the stopover airport
  - Weight increases with more passengers and payload
- Leg 3
  - Patients are transported back to the initial airport for medical aid



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Configuration Selection

Evaluate RFP Requirements

RFP was thoroughly evaluated to determine the voice of the customer.

Analytical Hierarchy Process

19 Design drivers were narrowed down to 11 drivers, assigned a relative importance to each other in the Analytical Hierarchy Process.

Pugh Matrix

18 unique design configurations were separated into 4 categories for comparison. Using the weighted drivers from the AHP, configurations were assigned scores. The top scoring configuration in each category was selected for further consideration.

Final four configurations

- Single Main Rotor
- Coaxial with Pusher Propeller
- Synchropter
- Single main rotor with pusher propellers

4 groupings

- Single Main Rotors
- Coaxial Rotorcraft
- Multiple Rotors
- Transition rotorcraft

- Disk loading kept low for efficiency in hover and low downwash for safety of those on the ground
- Fast forward flight increases survival chances of trauma patients
- Wide pilot field of view and large doors make *Tahr* safe during rescue operations

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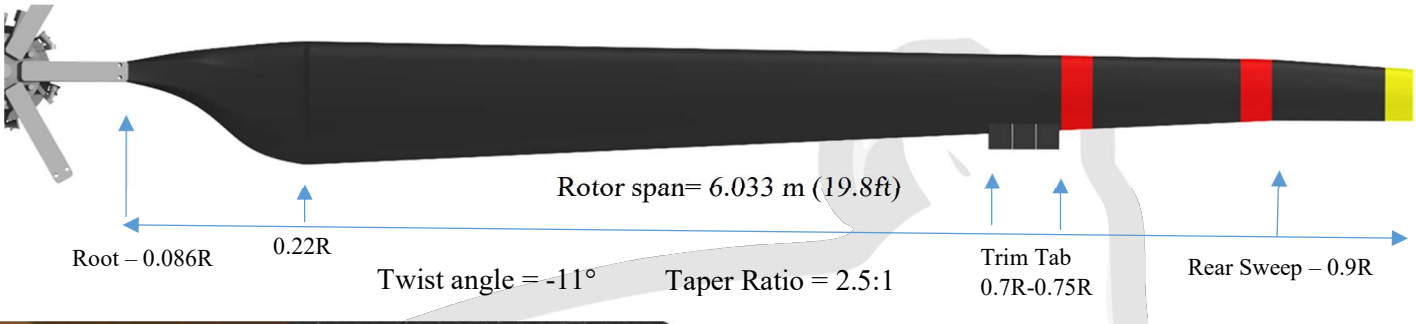
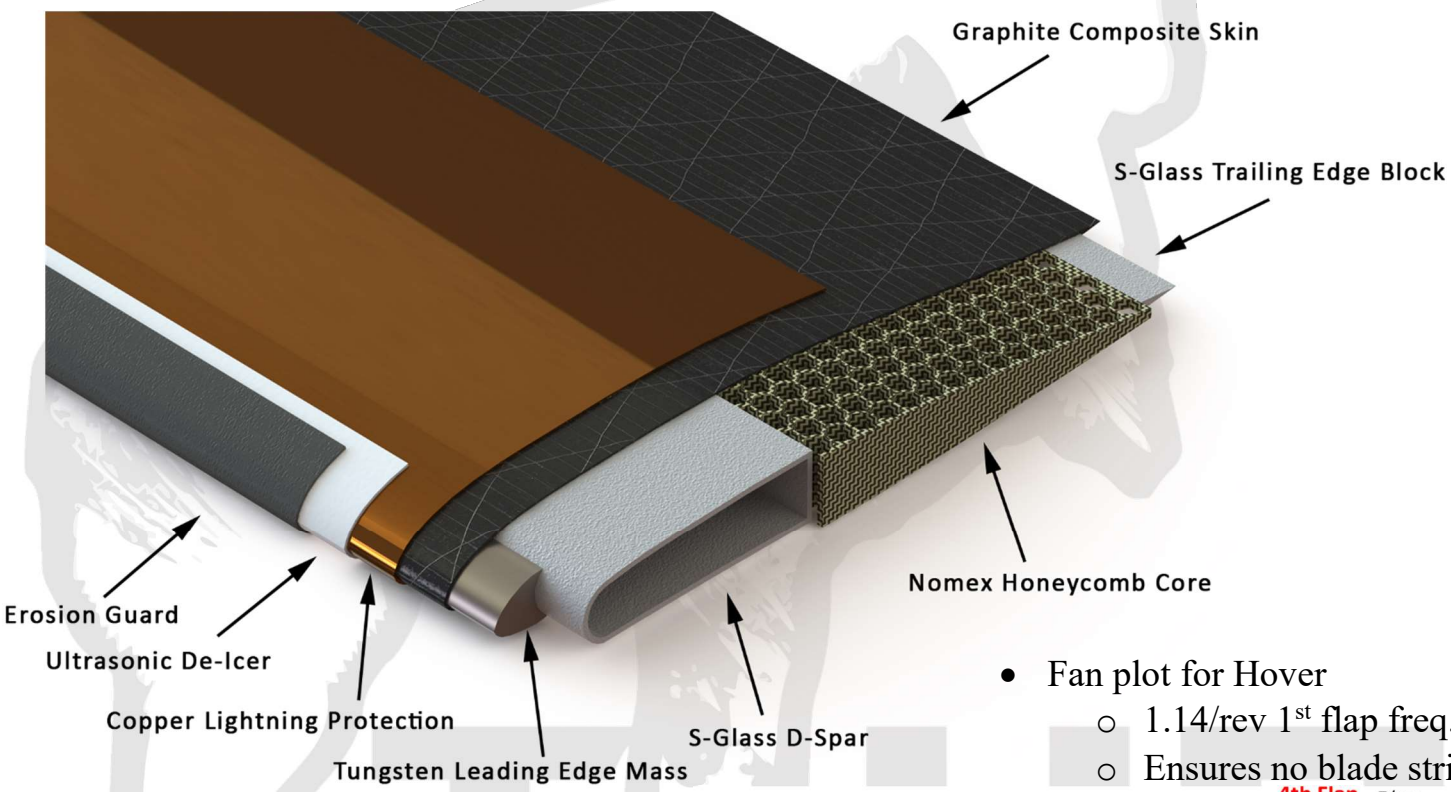
Rotor Blades

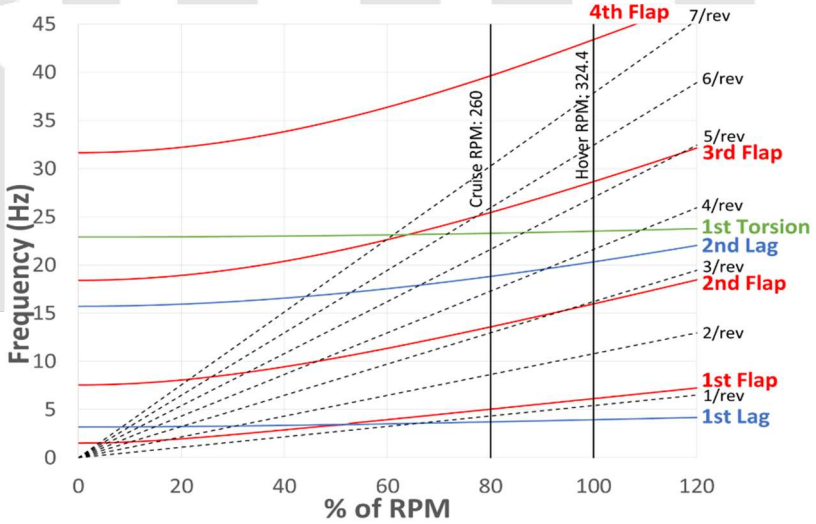
As the most difficult task in the RFP is the high altitude hover, *Tahr's* rotor blades were optimized for efficiency in hover.





Rotor Performance Characteristics	
Figure of Merit @ 8870 m	**0.807**
Figure of Merit @ Sea level	**0.667**
Disk Loading	259 N/m^2 (5.4 lb/ft^2)
Power Loading	28 N/kW (8.5 lbs/hp)
Hover Tip Mach Number	**0.72**

- Fan plot for Hover
  - 1.14/rev 1st flap freq.
  - Ensures no blade strike



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Tail Rotor Assembly

Tail Rotor

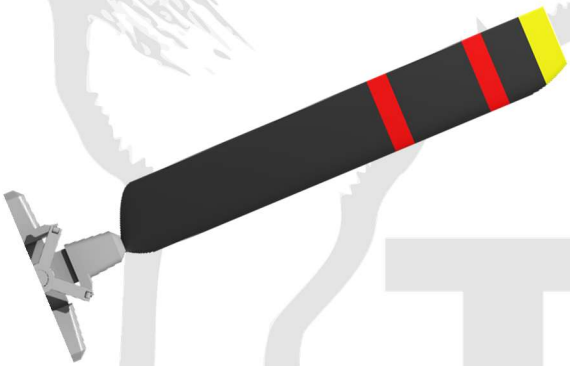
- Maximized anti-torque for **stable hover** in gusts
- Aerodynamically **optimized** tail rotor **blades**
- Effective **tractor configuration**

Empennage

- **Efficient** yet **simple** design
- **Anti-torque** & **pitch stability** in forward fight

Empennage Considerations

- **Symmetric** vs. **asymmetric** horizontal stabilizer
- Vertical stabilizer **camber**, **sweep**, and **aspect ratio**



Tail Rotor Trade Study

1. Comparison of **coaxial** and **single rotor** using momentum theory
2. Airfoil selection using BEMT
   a. Considered aspect Ratio, taper & twist

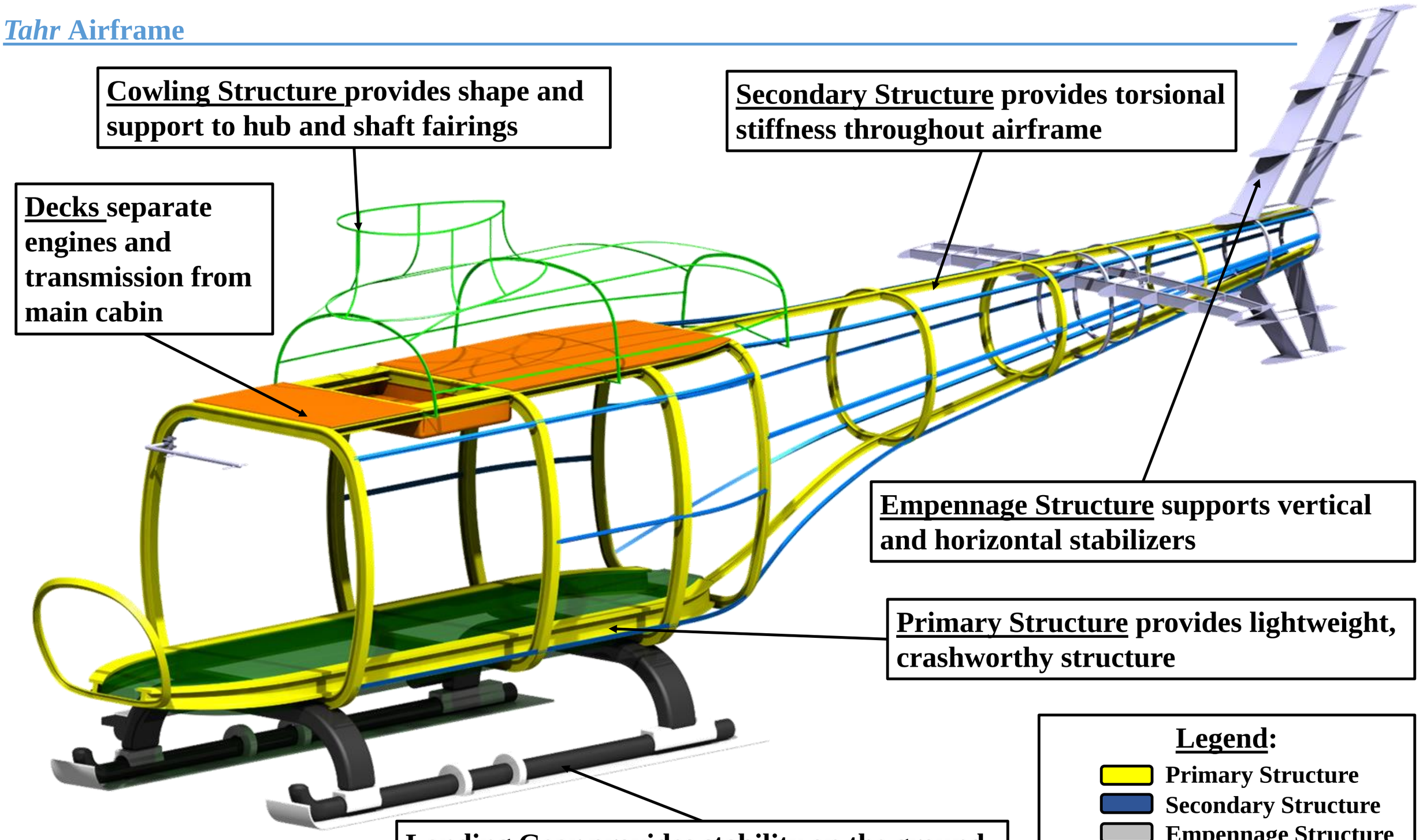
Tail Rotor Summary

Parameters	Final Choice
Airfoil	Clark-Y
Diameter	2.65 m (8.69 ft)
# of blades	4
Aspect Ratio	7.0
FM (sea level)	0.752
FM (8,890 m)	0.845

Empennage Summary

Parameter	Vert. Stab.	Horiz. Stab.
Airfoil	NACA4418	NACA2412
Area	2.4 m^2 (26.3 ft^2)	1.2 m^2 (12.8 ft^2)
Aspect Ratio	1.70	4.86
Sweepback	40°	0°
Taper Ratio	1.5	1.5
Incident Ang.	0°	−5°

Tahr Airframe



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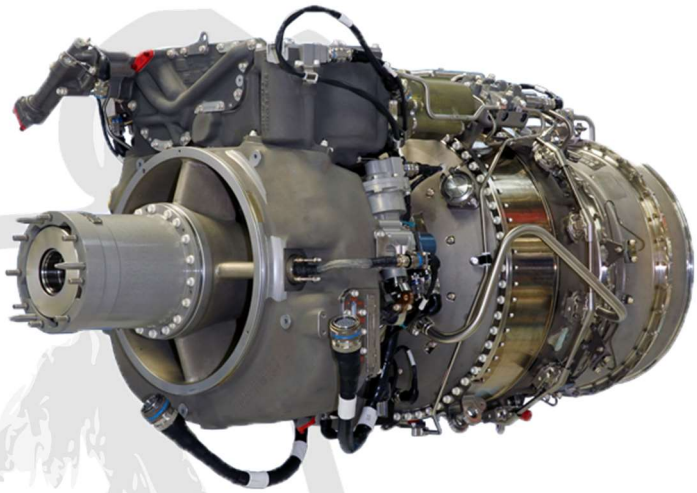
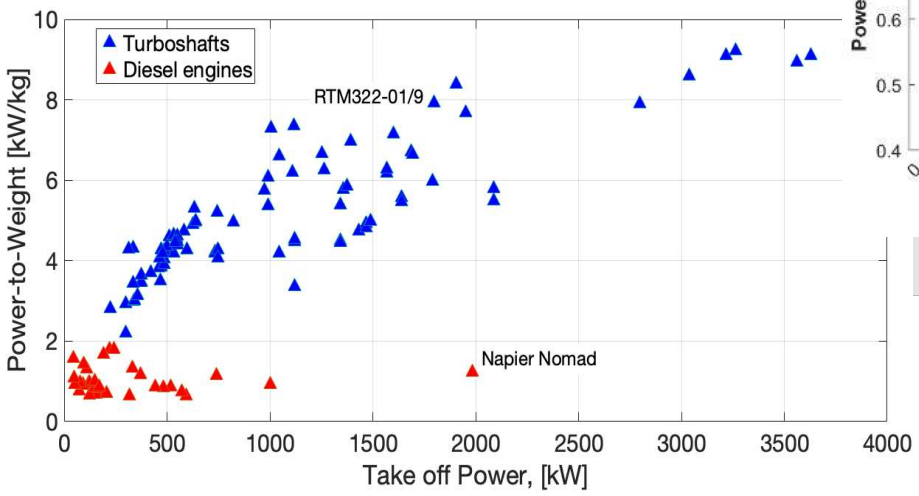
Powerplant

Tahr's propulsion system utilizes a **twin Rolls Royce Turbomeca RTM322** with a total power output of **3200 kW (4300 hp)**. This is to allow **HOGE at 8870 m (29100 ft.)** for **30 minutes.**



Rolls Royce RTM322 01/9A

- Inlet particle separator on intake protects engine from ice, water, and other debris
- Proven reliability on rotorcraft such as the Apache and AW101
- Turboshaft selected for good SFC and power to weight ratio as shown below
- Lapse rate shows that the power supply is reduced by about 55% at altitude, driving the high power requirement



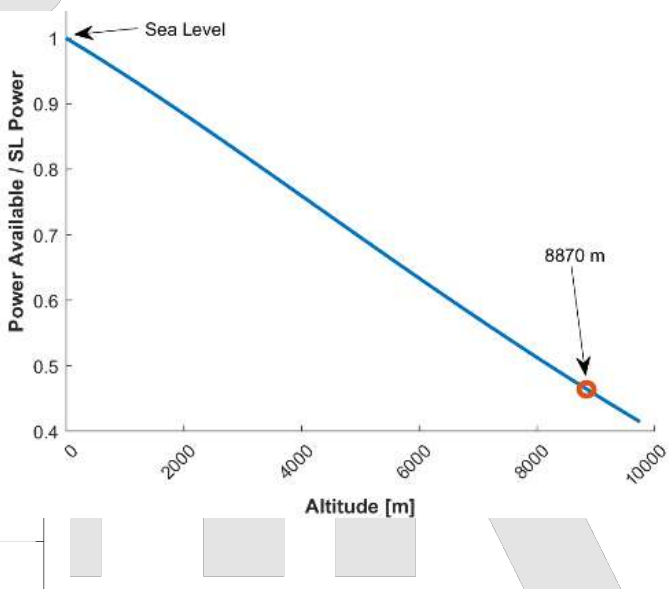
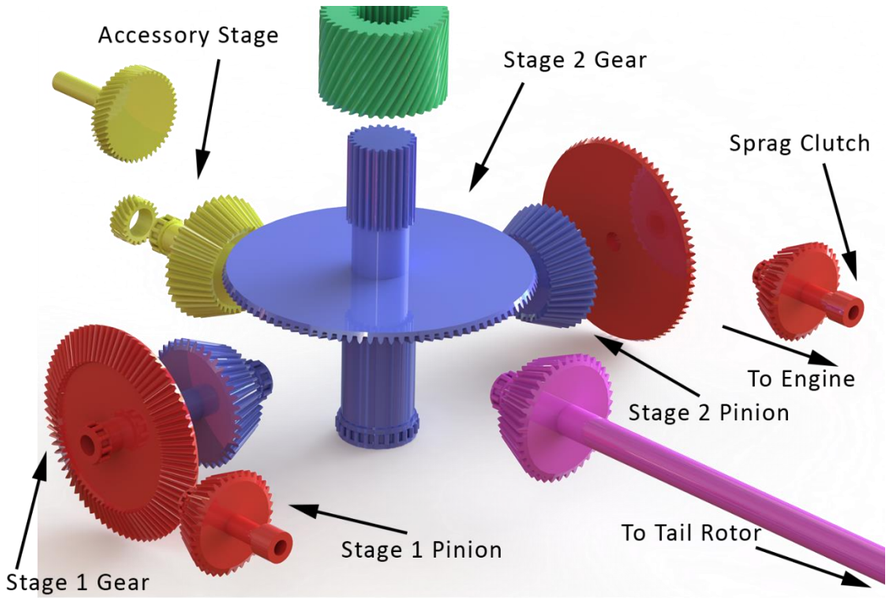
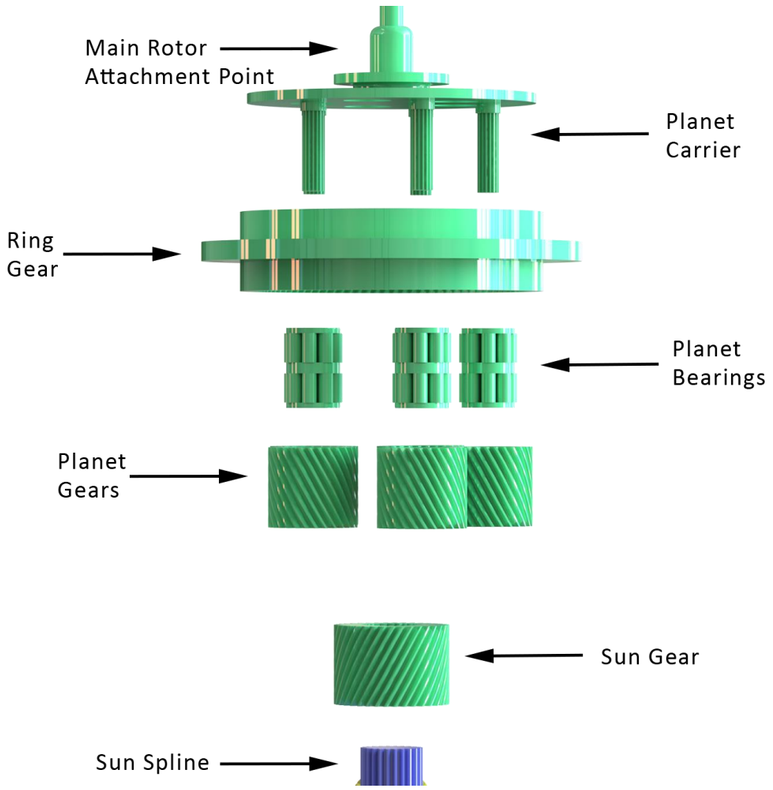


Figure showing turboshafts better power-to-weight ratio compared with diesel

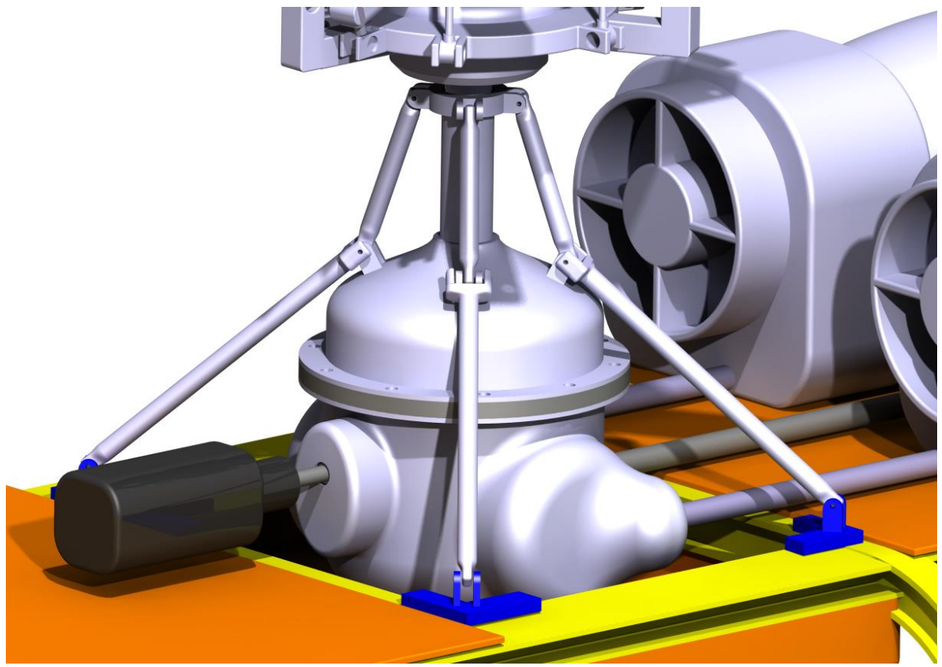
Transmission



A dual input bevel gear reduction module for 90 degree power transference and efficient accessory and tail connections...



A helical planetary system for reduced noise, vibrations, weight, and size...



A transmission housing designed to reduce noise and be as light as possible...

All combine to make the best designed transmission for the *Tahr.*

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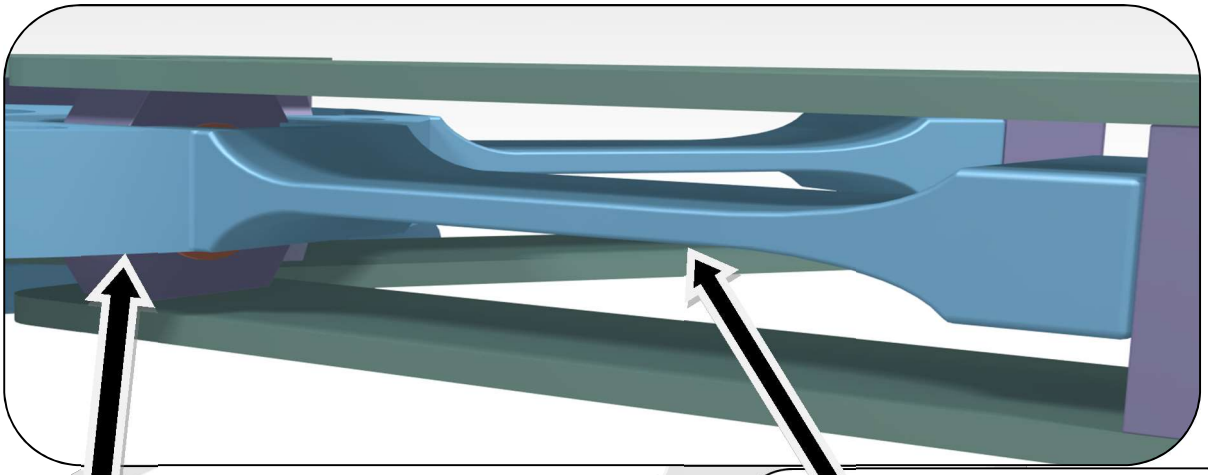
Hub design

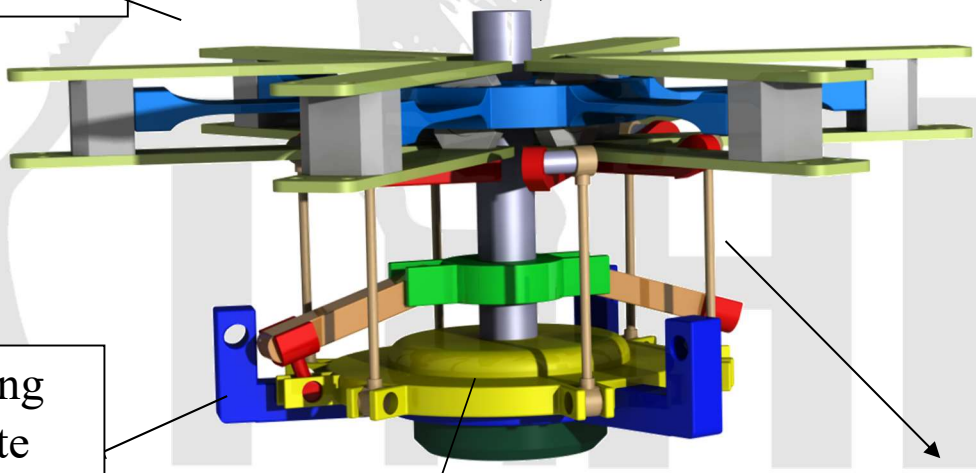


Conical elastomeric bearing provides pitch articulation to the hub

Flex beam with tailored bending stiffness provides virtual flap and lead-lag articulation

Blade Retention Fork

Main Rotor Shaft



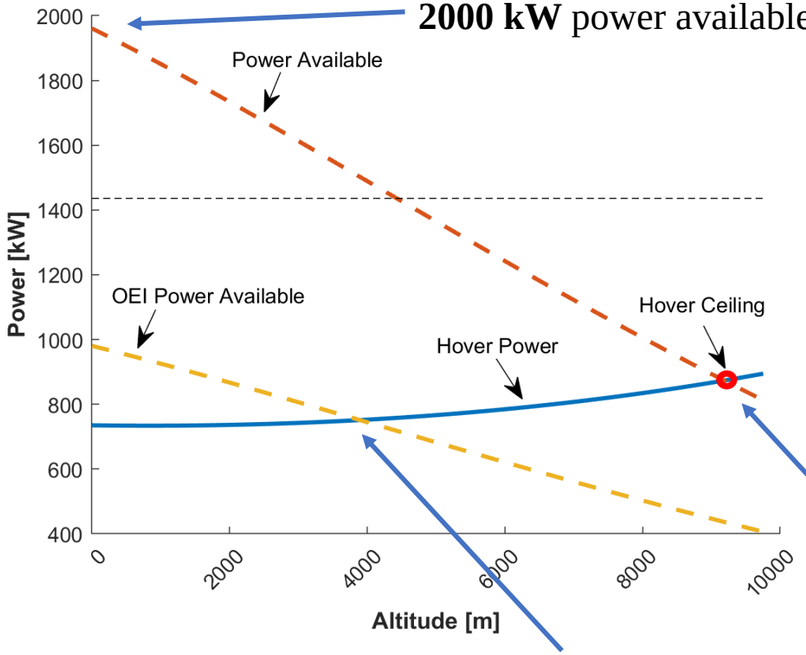
Non-rotating Swashplate

Pitch Link

Rotating Swashplate

Performance

Hover capability anywhere on Earth



2000 kW power available at sea level

- 9500 m **service ceiling**
- 9200 m **hover ceiling**
- **Max cruise speed** 170 knots
- 1.2 hours **hover endurance** at 8870 m
- **Cruise range** of 450 km
- **Cruise endurance** of 2.5 hrs

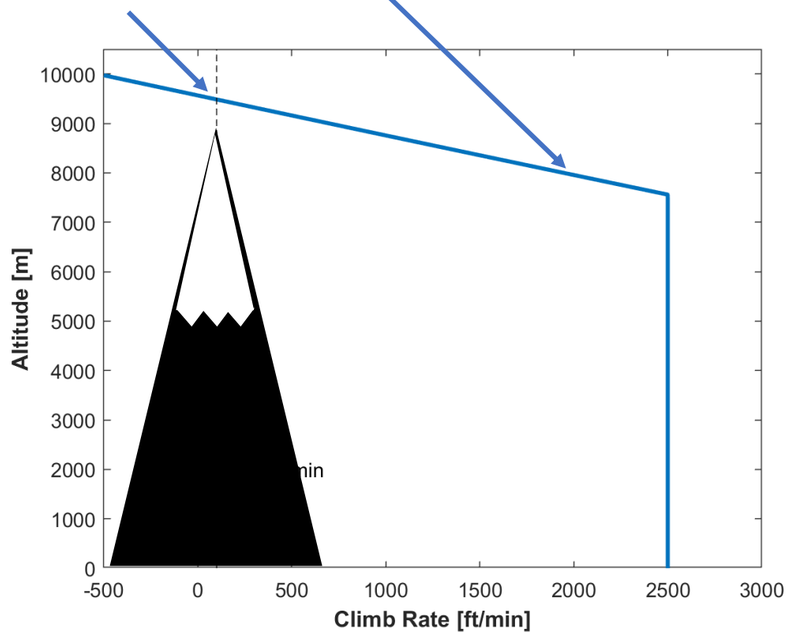
9200 m hover ceiling

OEI Hover up to **4000 m**

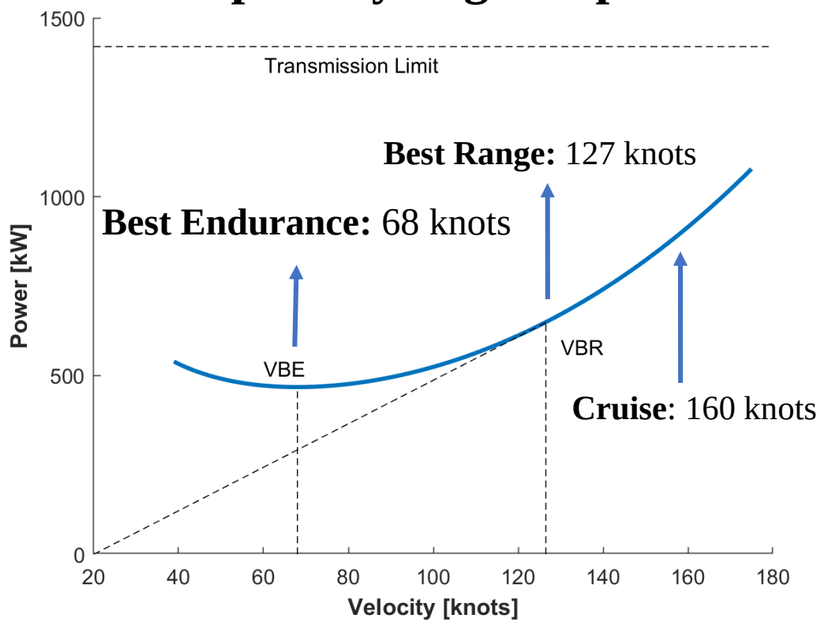
High RoC for faster rescue missions

Over **2000 ft/min RoC** up to 8000 m

9500 m hover ceiling



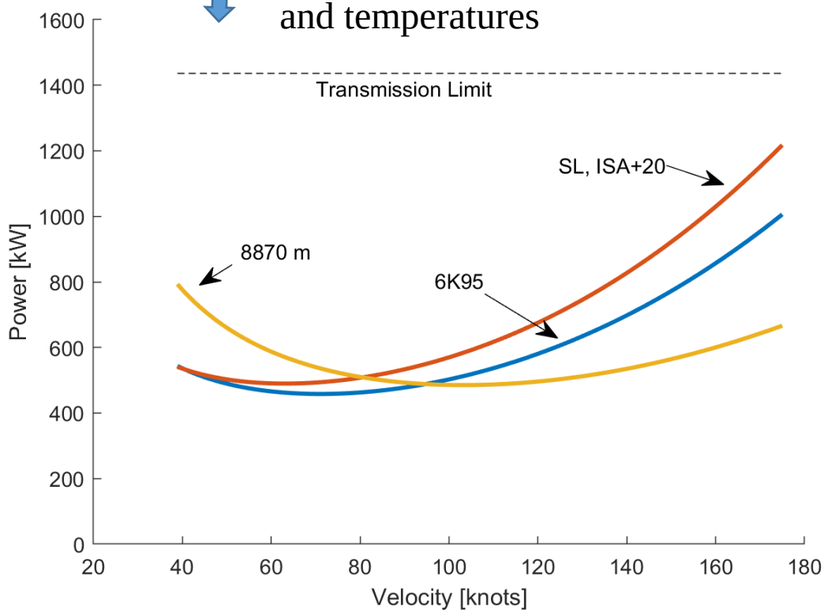
Fast cruise capability to get to patients in time...



… in any setting ...

There is a large power margin for operations at **6k95** conditions. For the graph on the right, the power available exceeds the transmission limit.

160 knot cruise at all practical altitudes and temperatures



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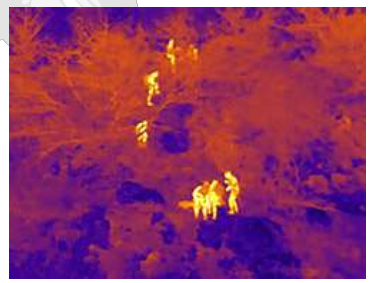
Avionics and Equipment

Tahr's avionics suite was designed to minimize the workload of the pilot and maximize the safety of the crew members. *Tahr* surpasses current service envelopes and is capable of handling the most difficult of operating conditions.

Helicopter Terrain Awareness System
High resolution terrain maps

De-icing of
Antennae, Pitot tubes, and wind shield

Searching for Hikers
Beacon locator, Advanced Imaging, RECCO



Smart Hoist
Embedded Sensors and reduced maintenance time

Medical Care
Medical cabinet providing Advanced Life Support

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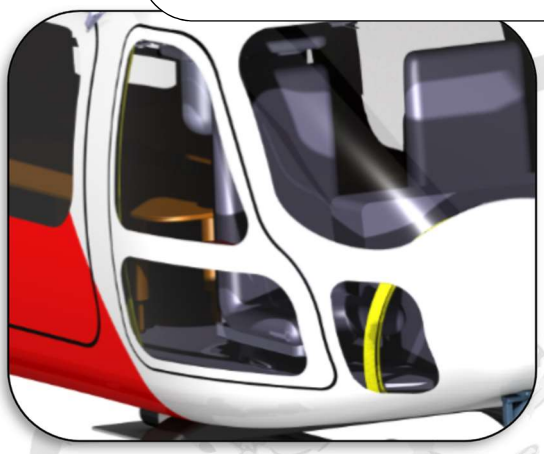
Pilot-Friendly Design

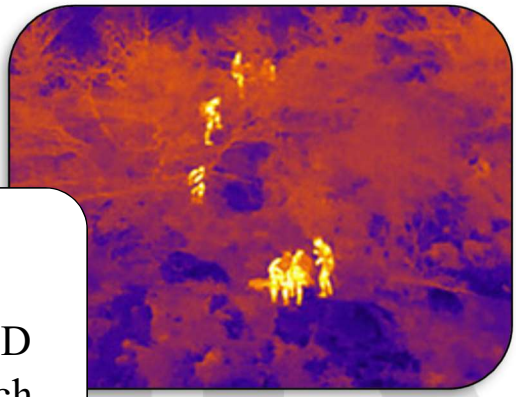
Tahr's cockpit was designed to give pilots a wide field of view to ensure the safety of the crew and patients



MFD's provide pilots only the essential information as they need it

Hoist camera allows the pilots to observe the end of the rescue hook directly on the MFD

Wireless headsets allow easy communication between pilots and rescue workers without the need for wires



Infrared and night vision cameras displayed on the MFD aid pilots in the search.

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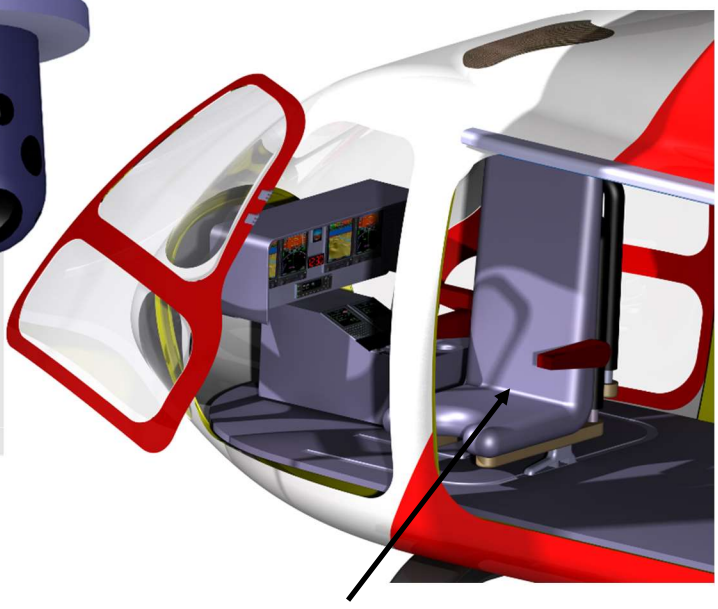
Concept of Operations

Tahr is designed for three crew members during rescues. The crew breakdown is 1 pilot, 1 copilot/rescue worker, and 1 EMS worker. *Tahr* is designed specifically for flexibility as the situation demands.

The concept of operations for *Tahr* is as follows:

- Fly to the rescue site with a standard 2-person cockpit.
- As the operation transitions into search and rescue, the copilot's seat can swivel into the cabin for them to assume a rescuer role
- The pilot determines whether to employ the hoist or make a soft touchdown on the snow for direct loading
- During the rescue, crew members communicate wirelessly and the pilot has a camera focused on the hoist hook
- As *Tahr* delivers the patient to the hospital, the copilot may return to the cockpit or remain in the cabin

Tahr's internally mounted hoist swings out for rescues



Tahr's swivel seat for easy cabin access

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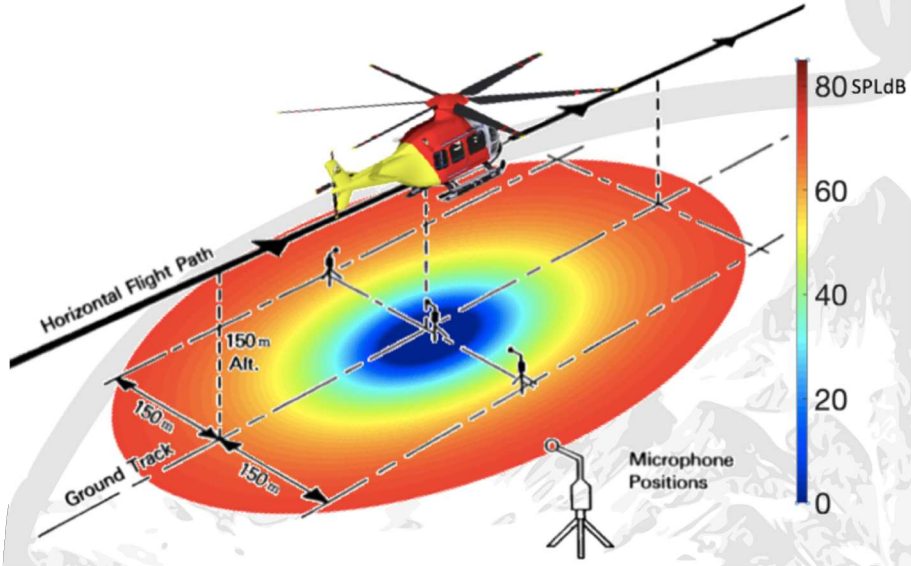
Acoustics

The *Tahr* is designed to reduce its acoustic signature to combat noise pollution, detection, and certify its use in all fields.



VERSATILE

Forward Flight acoustic analysis at Sea Level altitude was performed to demonstrate the versatility of the *Tahr* in terms of Sound Pressure Level (SPL) in all fields.

PATIENT FRIENDLY

An acoustics analysis during the hover rescue at one of the highest peaks of the world, 8,870m (29,100 ft), assures that the *Tahr*'s acoustic levels are not harmful for the patients.

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Multi-mission Capabilities

Heavy Lift

- Powerful engines and high thrust margins allow for lifting heavy payloads at sea level
- Applications include logging, aerial crane, and firefighting

Executive Transport

- *Tahr's* quiet rotor and roomy interior make it ideal for comfortable transportation

Military and paramilitary

- Effective for troop transport, search and rescue, covert ops, and high altitude missions
- Excellent power margins for 6k95 conditions

High wind environments

- Robust flight controls allow for applications including wind turbine and cell tower maintenance

Summary

In response to the 2018-2019 VFS Student Design Competition, the University of Maryland and Universidad de Carlos III design team has designed *Tahr*. The *Tahr* is specifically designed for extreme high altitude hover to be an effective search and rescue rotorcraft. Additionally, the large rotor and high power margins make *Tahr* a versatile, high endurance and heavy lift rotorcraft.

Designed with pilots in mind, *Tahr* is a dream to fly. With state of the art rescue equipment and only essential information displayed on MFD's, the pilot workload is greatly reduced. While specifically designed for search and rescue, *Tahr* is a workhorse well-suited for missions ranging from firefighting to executive transport.