HUMA

41st Annual VFS Student Design Competition

Multi-Mission Modular UAS for Disaster Relief

Sponsored by: DEVCOM ARMY RESEARCH LABORATORY

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Alfred Gessow Rotorcraft Center
Department of Aerospace Engineering
University of Maryland
College Park, MD 20742 U.S.A.

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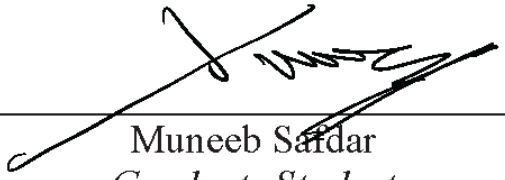
University of Maryland
College Park, MD 20742

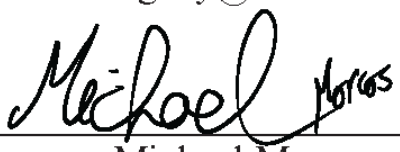
Vivek Uppoor
Graduate Student (Team Lead)
vvuppoor@umd.edu

Logan Swaisgood
Graduate Student
lswaiz@umd.edu

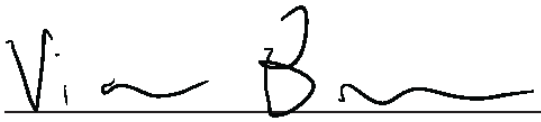
Batin Bugday
Graduate Student
bugday@umd.edu



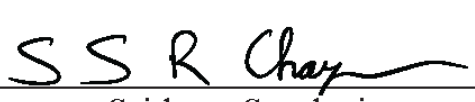
Muneeb Safdar
Graduate Student
msafdar@umd.edu



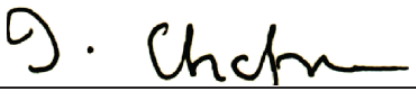
Michael Morcos
Graduate Student
mmorcos@umd.edu



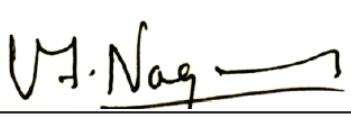
Victoria Britcher
Graduate Student
vbritche@umd.edu



Sridatta Satuluri
Graduate Student
satuluri@umd.edu



Dr. Inderjit Chopra
Faculty Advisor
chopra@umd.edu



Dr. Vengalattore Nagaraj
Faculty Advisor
vnagaraj@umd.edu

Dr. Anubhav Datta
Faculty Advisor
datta@umd.edu

Academic Course:
ENAE634: Helicopter Design (3 credits)

Alfred Gessow Rotorcraft Center
Department of Aerospace Engineering
University of Maryland
College Park, MD 20742 U.S.A.

To the Vertical Flight Society:

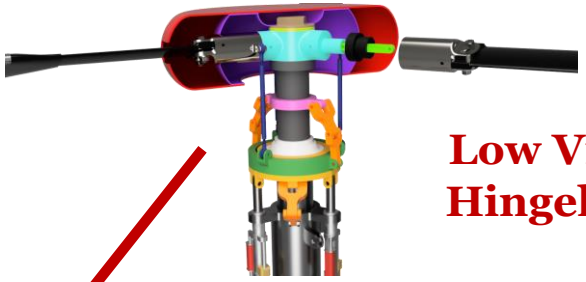
The members of the University of Maryland Graduate Student Design Team hereby grant VFS full permission to distribute the enclosed Executive Summary and Final Proposal for the 41st Annual Design Competition as they see fit.

Thank you,

The UMD Graduate Design Team

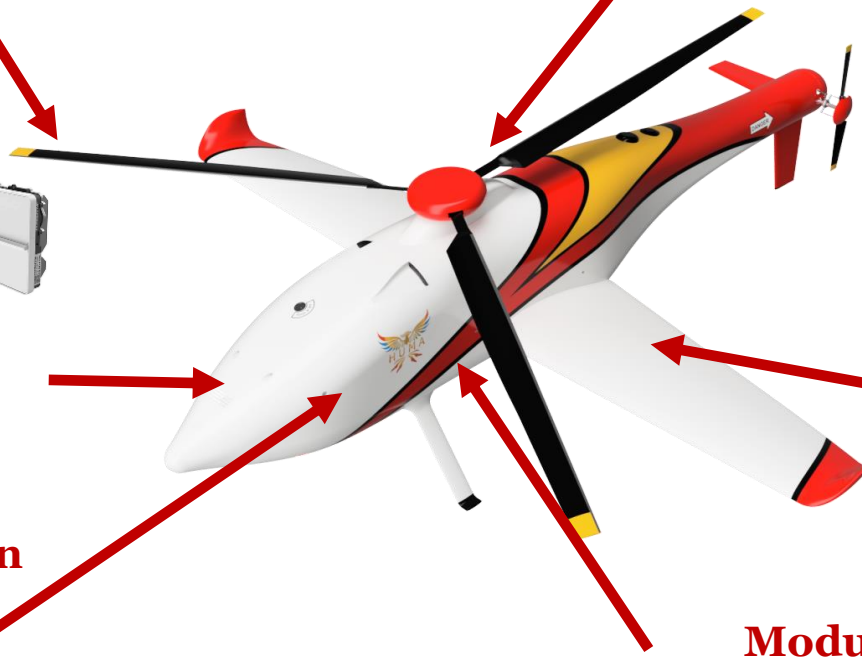
Huma: The Bird that Never Alights

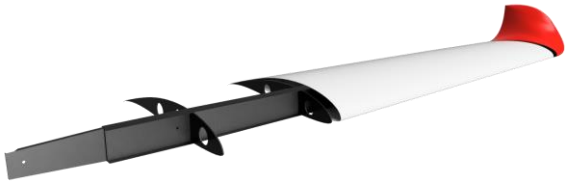
Optimized Main Rotor Blades



Low Vibration Hingeless Hub

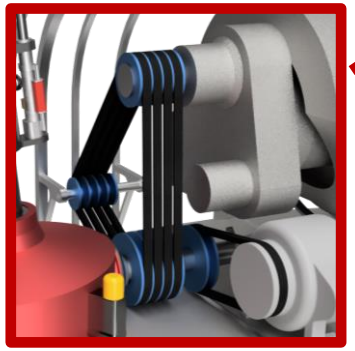
Robust Avionics and Controls





Lightweight Flutter-Free Modular Wing

Lightweight Belt-Driven Propulsion

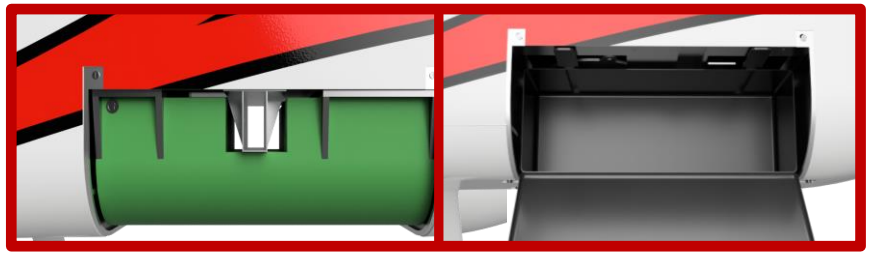


GTOW	160 kg (353 lbs)
Installed Power	37 kW (50 hp)
Rotor Radius	1.65 m (5.4 ft)
Disk Loading	203 N/m^2 (4.25 lb/ft^2)

Modular Center Body

Auxiliary fuel and wings enable 13 hour loiter

58 kg (128 lbs) split between two payload bays



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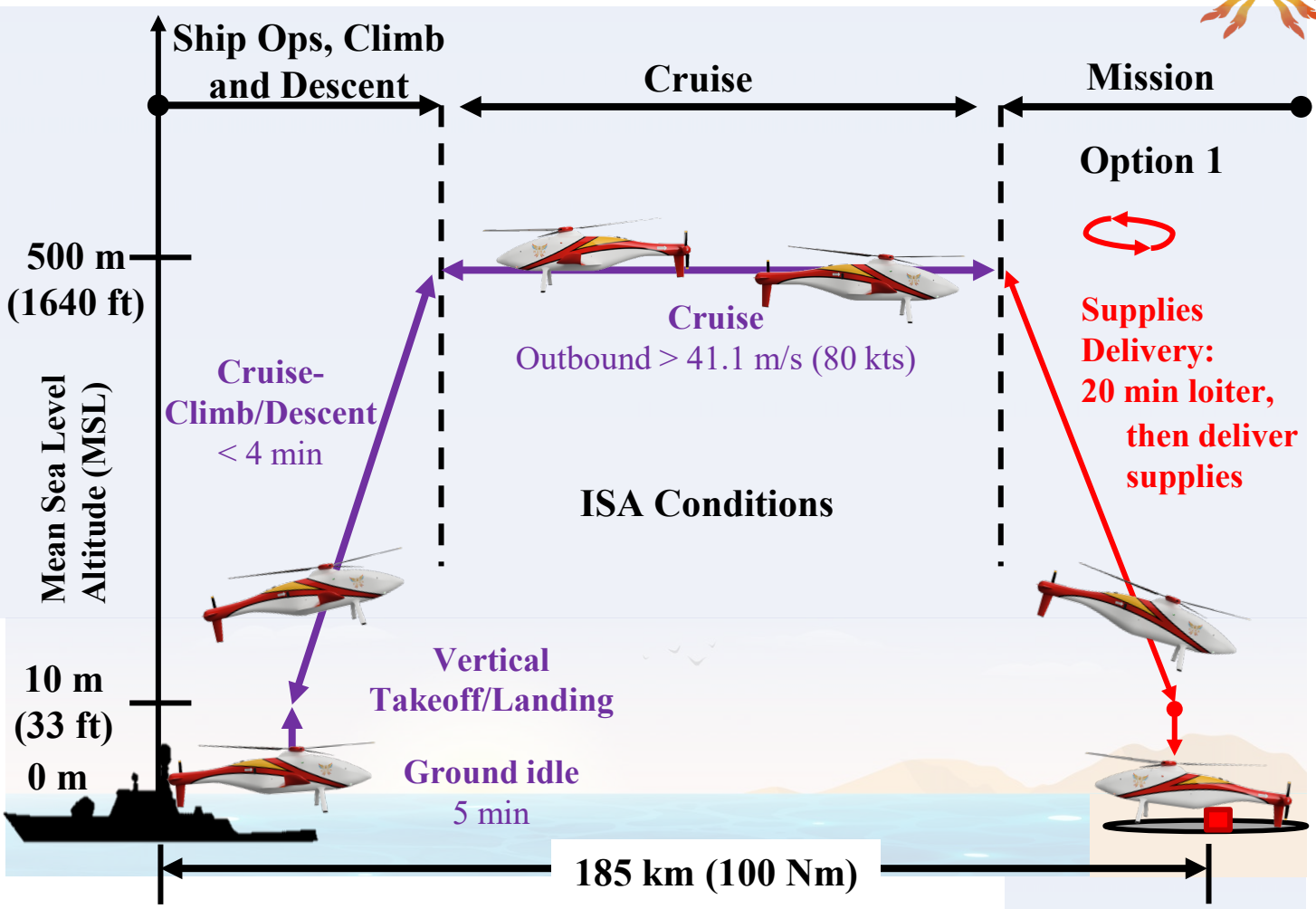
Huma: Modular Load and Loiter

Soaring high above all for eternity, spreading hope by a mere glimpse of its shadow, the legendary ***Huma*** bird provides aid to all in need. It offers assistance without reservation, showering those below with gifts, blessings, and the touch of fortune.

Huma, a reconfigurable **lift compounded single main rotor (SMR) helicopter**, developed by the UMD Graduate Design Team, is capable of exceptional flight time, able to loiter 185-km away from its takeoff point for **over 13 hours** before needing to return.

Huma is uniquely adaptable at 160 kg, able to quickly **remove its wings** and attach a heavy **55 kilograms** of lifesaving supplies to distribute to people in need. Huma can operate in challenging high-wind and gusty shipboard environments with a robust **hingeless hub**. Huma utilizes a **lightweight belt-driven transmission** and **low-drag three-point fixed landing gear** to maximize payload and minimize Jet-A fuel burn. An advanced flight control system with a **dynamic inversion** architecture, **error-resistant avionics suite**, and **vision-based ship deck landing** algorithm ensure situational awareness, stability, and reliability in all phases of flight. Whether at sea or over land, flying a long mission, or carrying a heavy payload, Huma remains steadfastly dependable and capable of successfully fulfilling any undertaking.

Exigent Dual Missions



	RFP Requirement	Huma
Long Endurance Loiter	10 Hours	13 Hours
Supplies Payload	50 kg (110 lb)	58 kg (128 lb)
Fuel Type	Jet-A	Jet-A
Empty Weight	-	Long endurance: 96.5 kg (213 lb) Supplies delivery: 92.5 (204 lb)

Option 2

Long Endurance: 10 hour loiter

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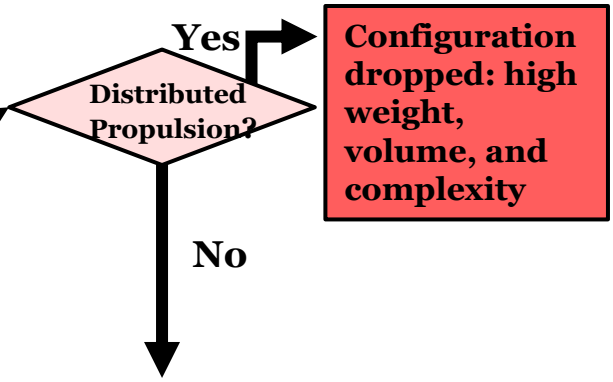
Configuration Selection

12 Configurations Considered

Preliminary Analysis

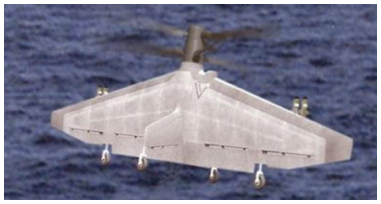


Qualitative Downselection for Detailed Analysis

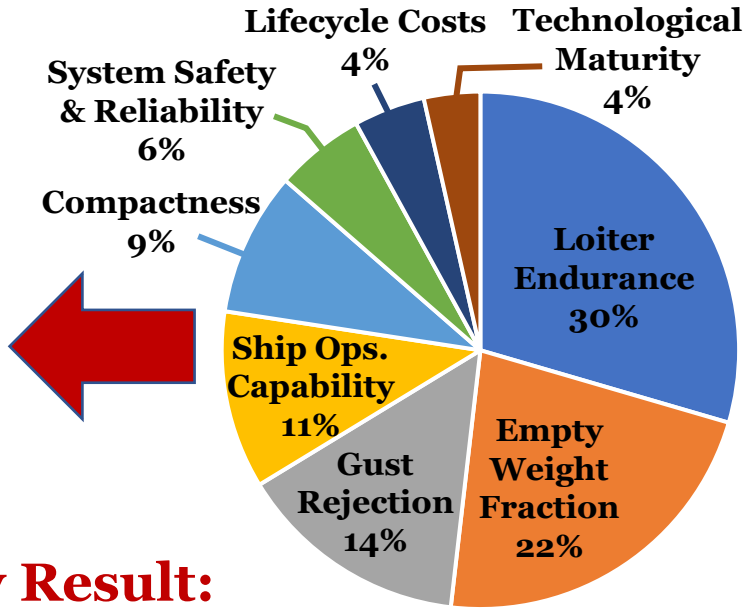
Single Main Rotor

Lift+Thrust Compound

Lift Compound



Coaxial Winged Tailsitter



Comprehensive Trade Study Result:

Reconfigurable Lift Compounded SMR

- Modular center body
- Removable wings
- High cruise L/D
- Low empty weight fraction
- Optimized dual-mission rotor blades

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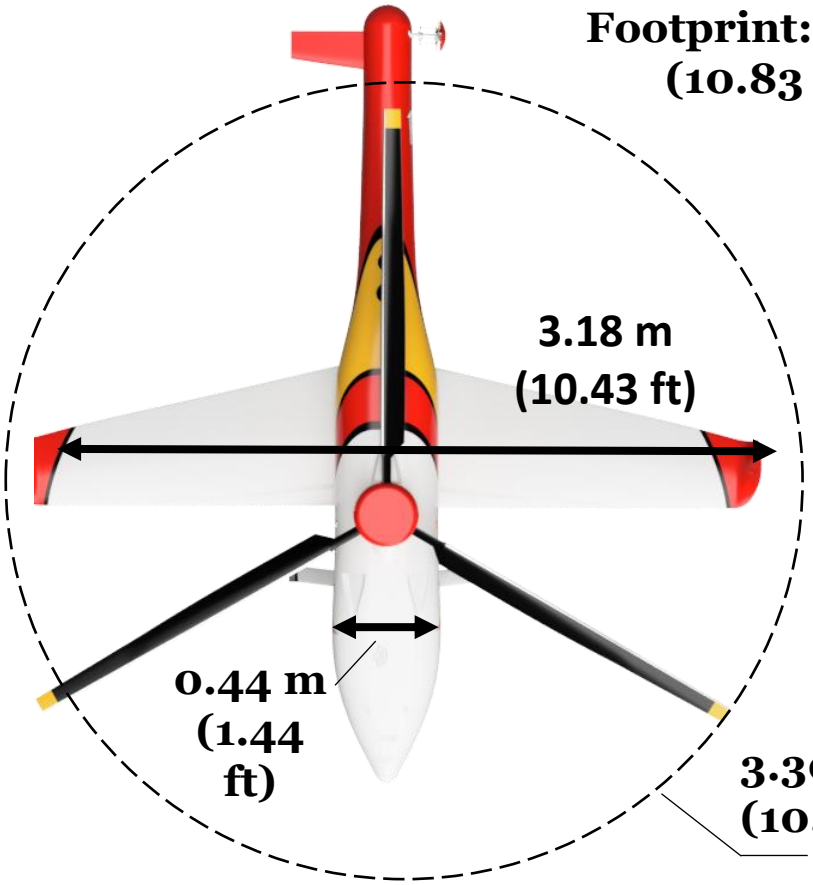
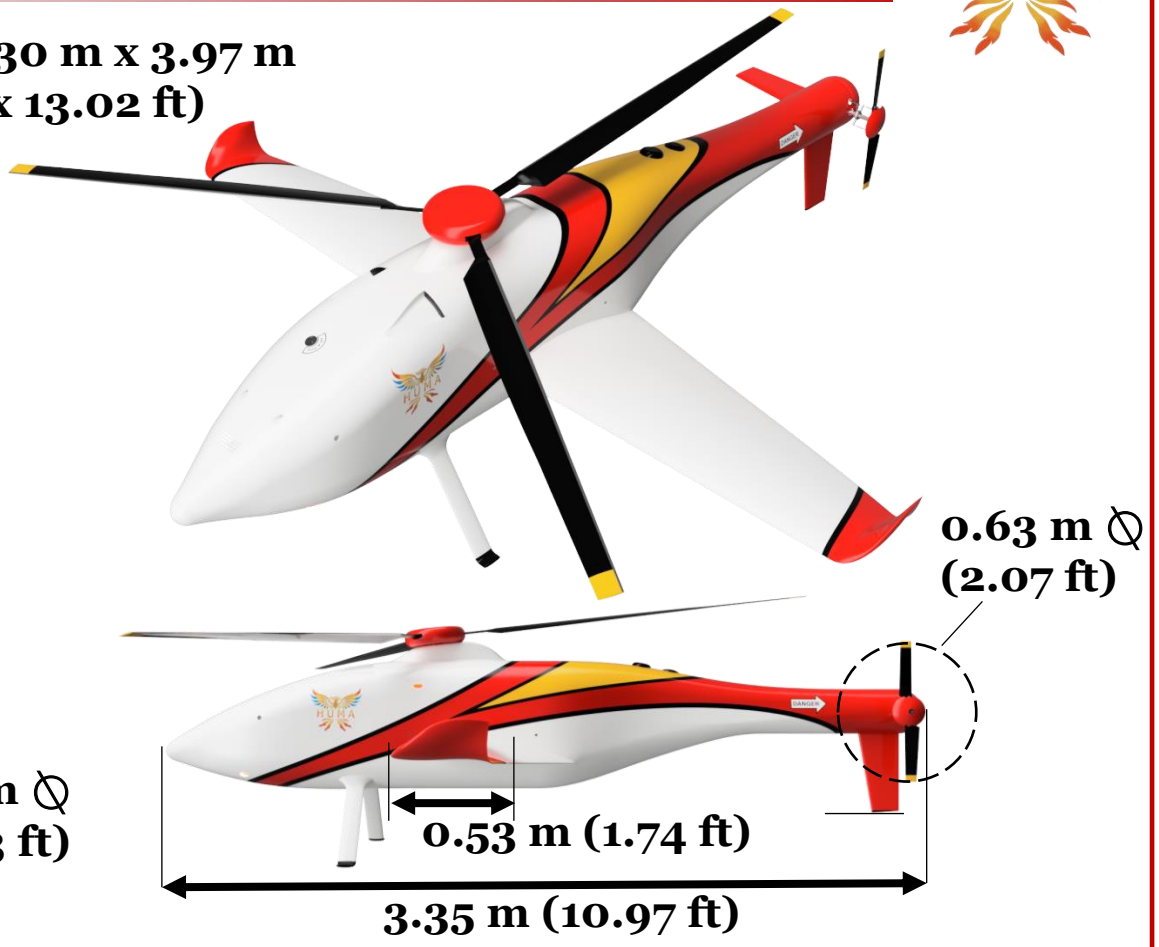
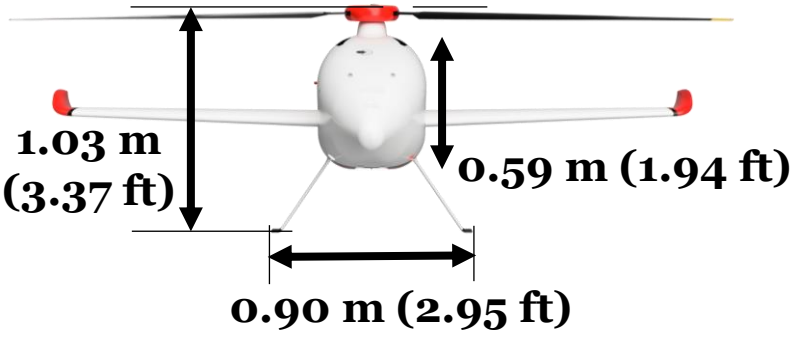
Huma: Size and Characteristics







Characteristics	Huma
GTOW	160 kg (352 lbs)
Installed Power	37 kW (50 hp)
Disk Loading	203 N/m² (4.25 lb/ft²)
Payload	58 kg (128 lbs)
Loiter Endurance	13 hours

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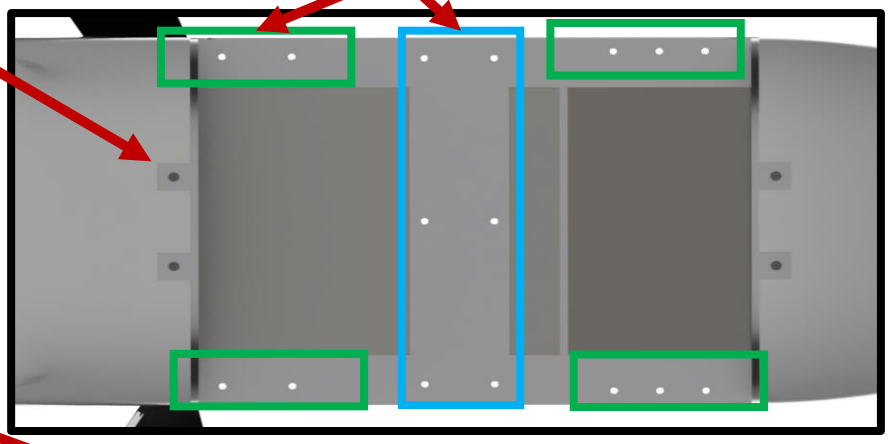
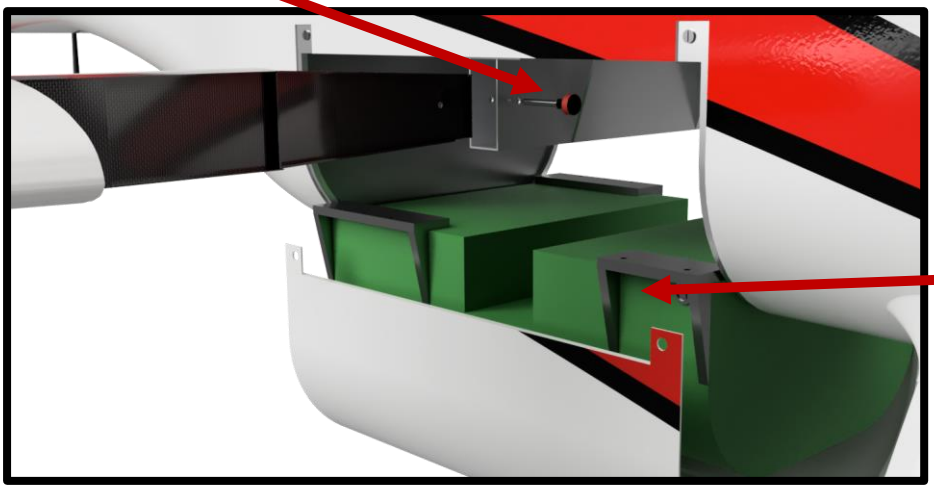
Modular Lift Compounding

Enclosure skin attachment using quarter turn screws

Mounting hardpoints located in the center body bay

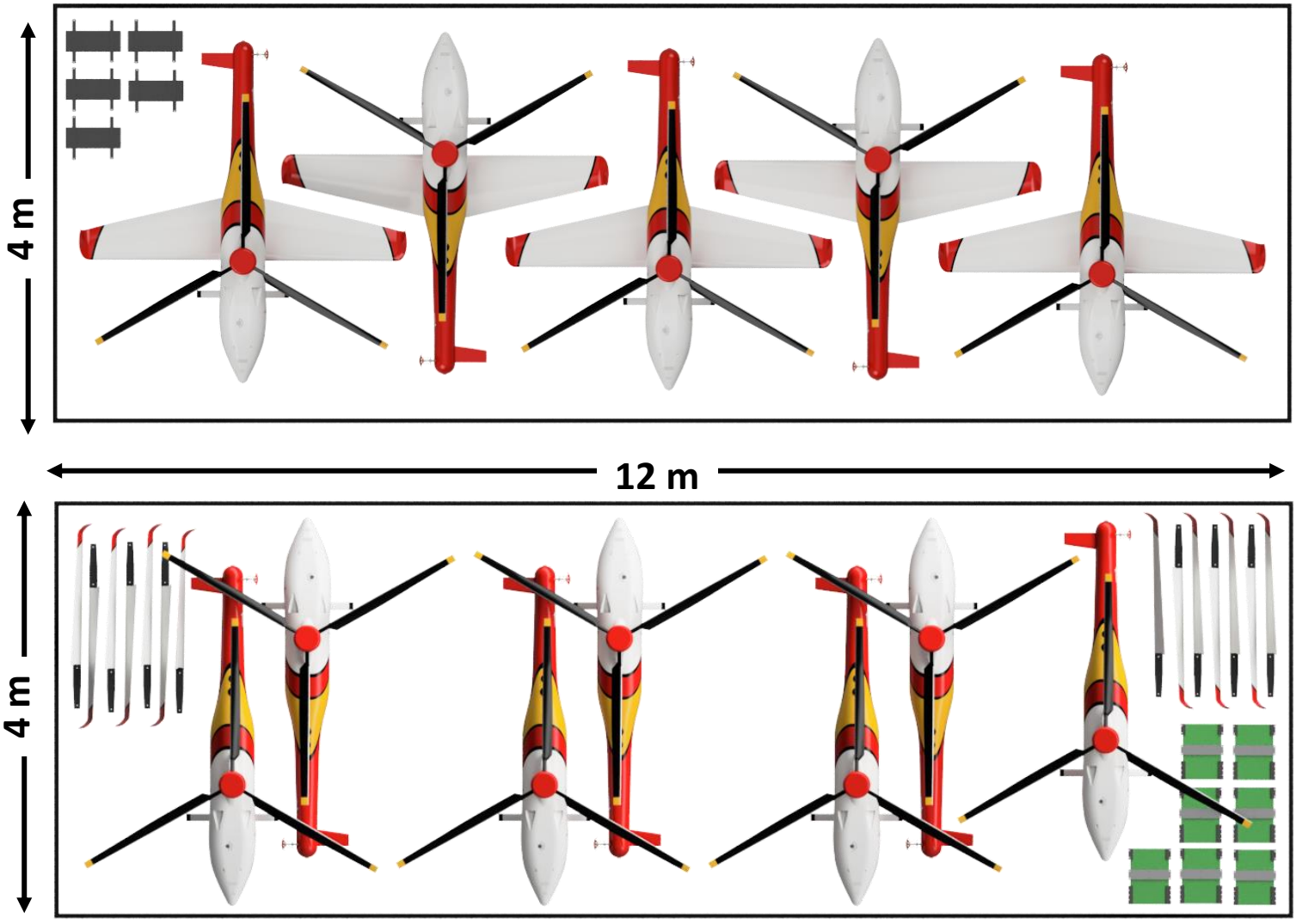


Detachable wing slots into mounting box



Add-on fuel tank (35.4 L, 9.35 gal) with mounting frame

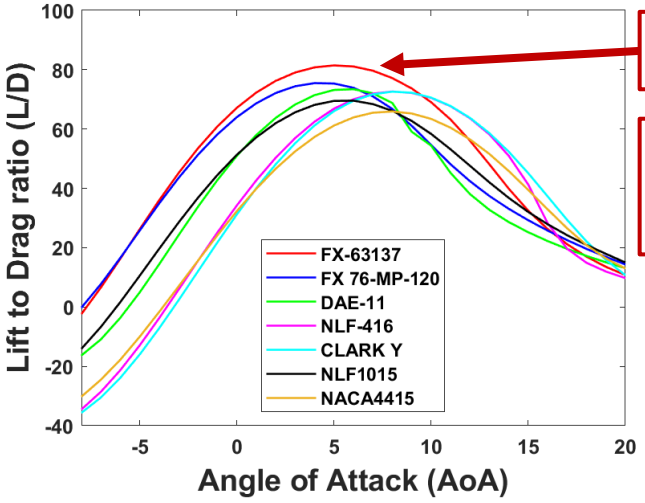
Compact and Portable



5 with wings &
7 with wings on exterior racks

Loading & refueling requires only one kneeling person

Slender Flutter-Free Detachable Wing



14% t/c FX-63137 Airfoil

Wing Weight: 1.97 kg (4.43 lb)

Winglets decrease recirculating vortices

2:1 taper

2° dihedral enhances stability

Wing Spar Root Attachment

Wings safe from flutter up to 104 m/s (202 knots)

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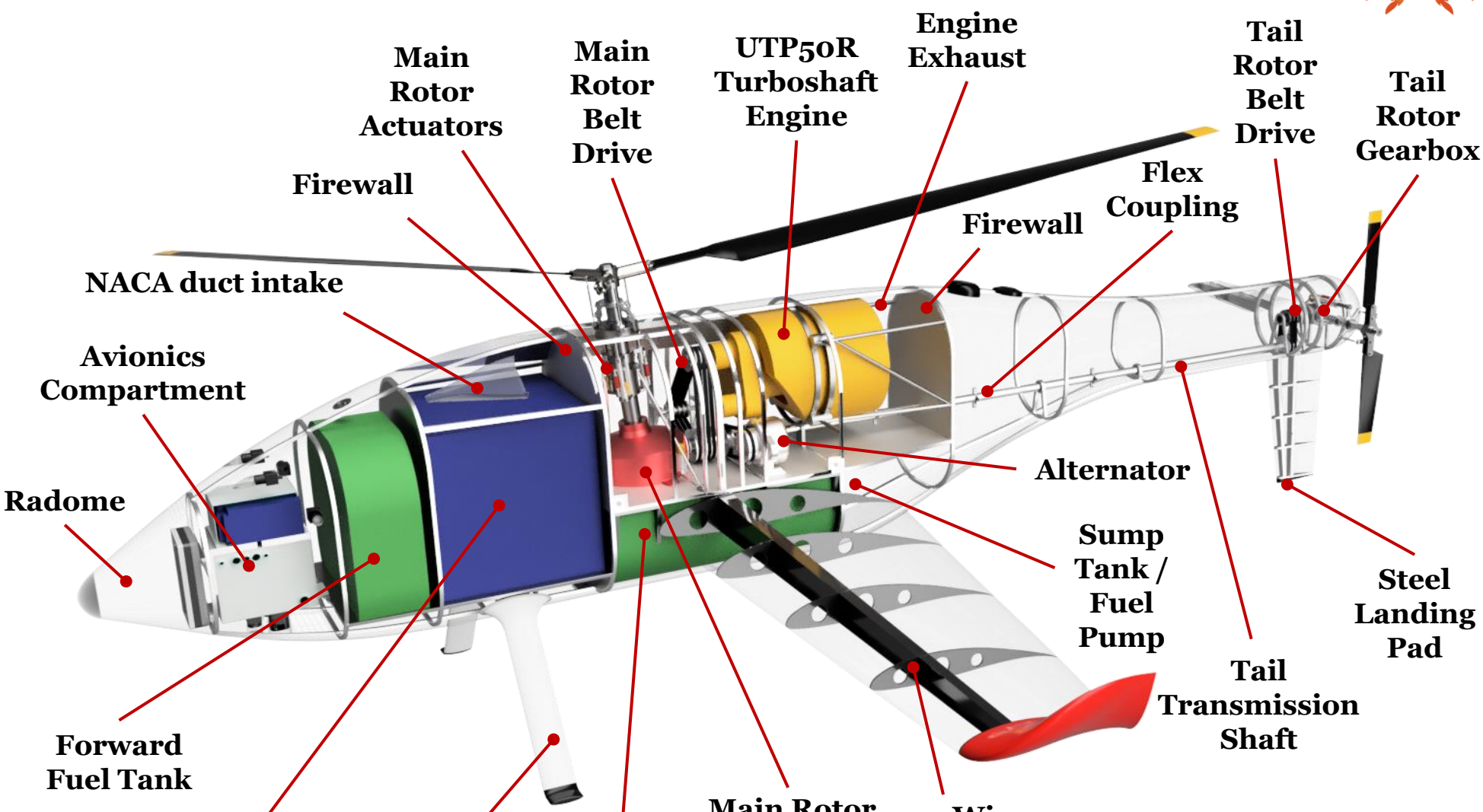
Huma Internal Layout



Center Body Bay Contains:

- **Wing Attachment and Fuel Tank**
- **Payload Carrying Case**

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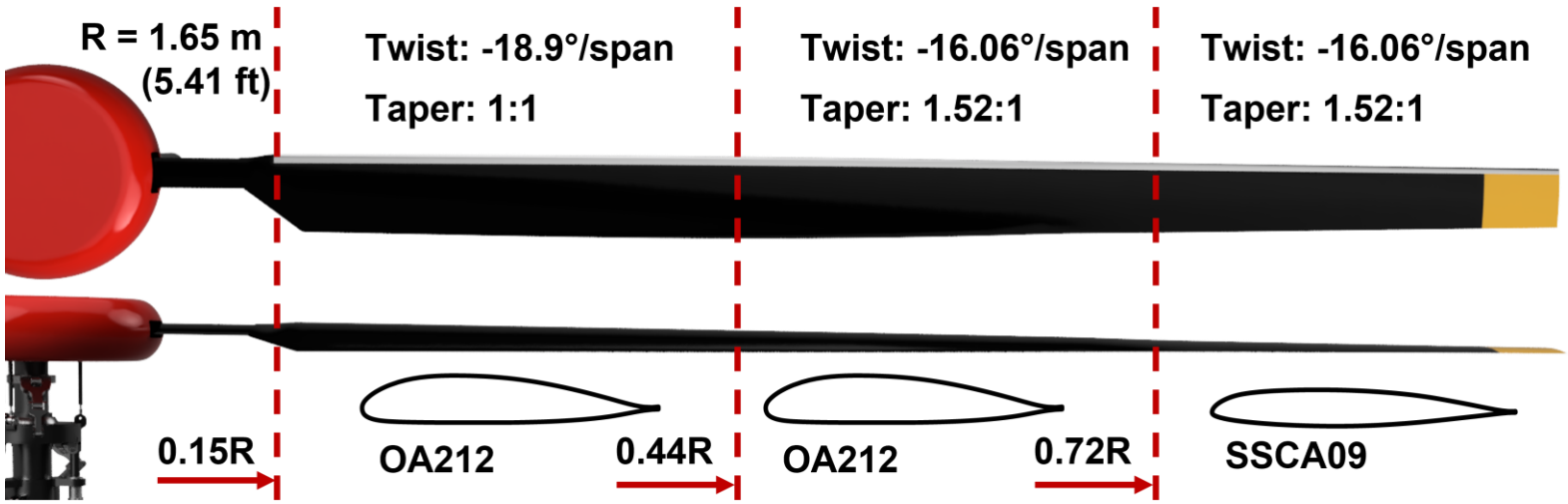
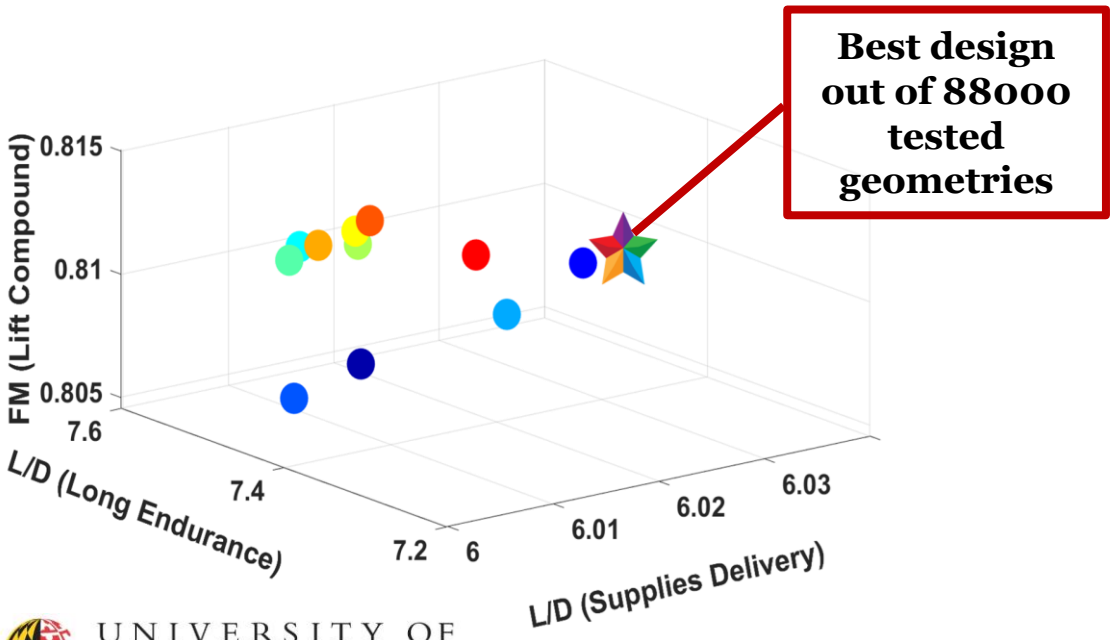
Main Rotor Blade Design



An Innovative Methodology
Genetic Algorithm to optimize blade for: hover, loiter and cruise



Mission	Segment	Performance	
Single Main Rotor	Hover	FM	0.81
		PL	15 lb/Hp
	Cruise	L/D	6
Lift Compound	Hover	FM	0.80
		PL	15 lb/Hp
	Loiter	L/D	7.5

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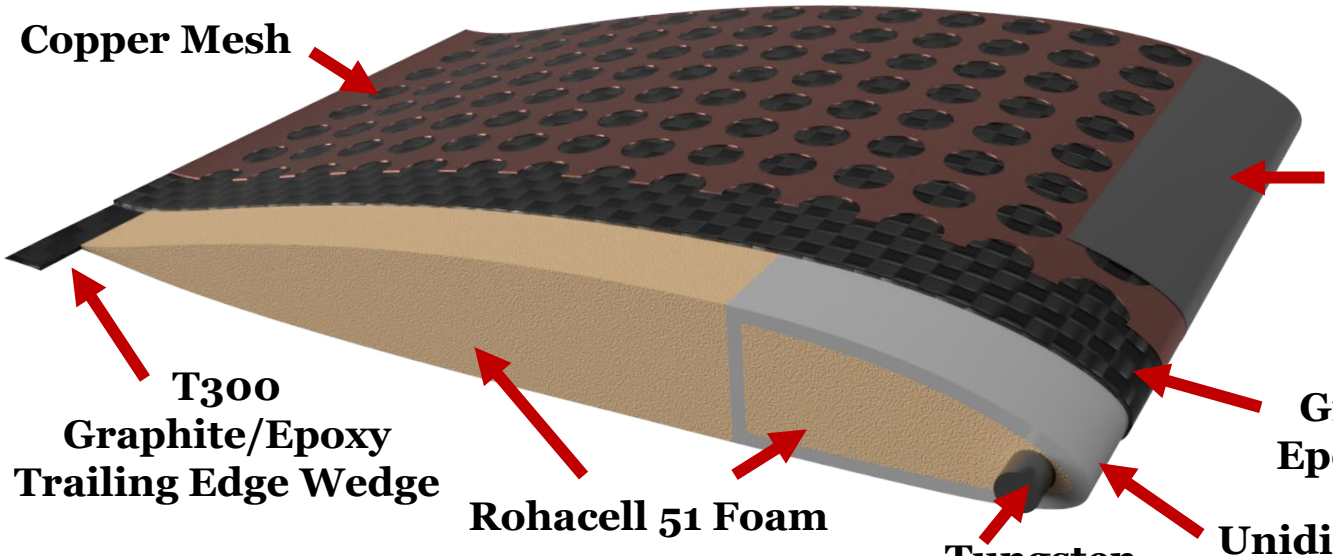
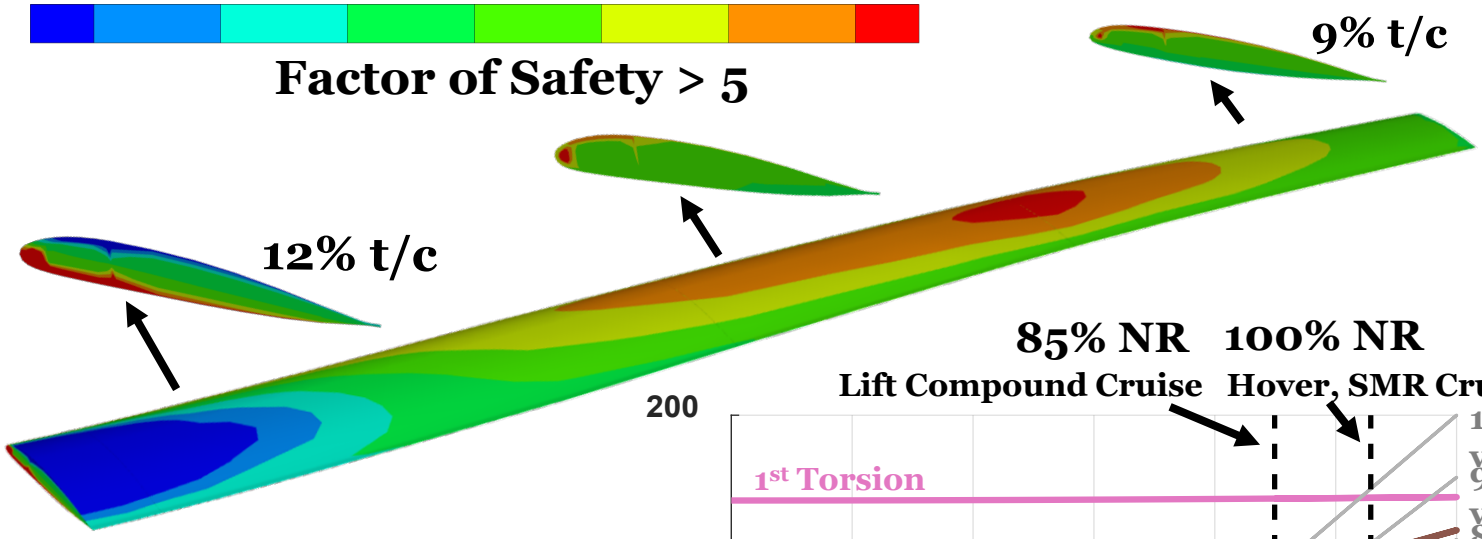
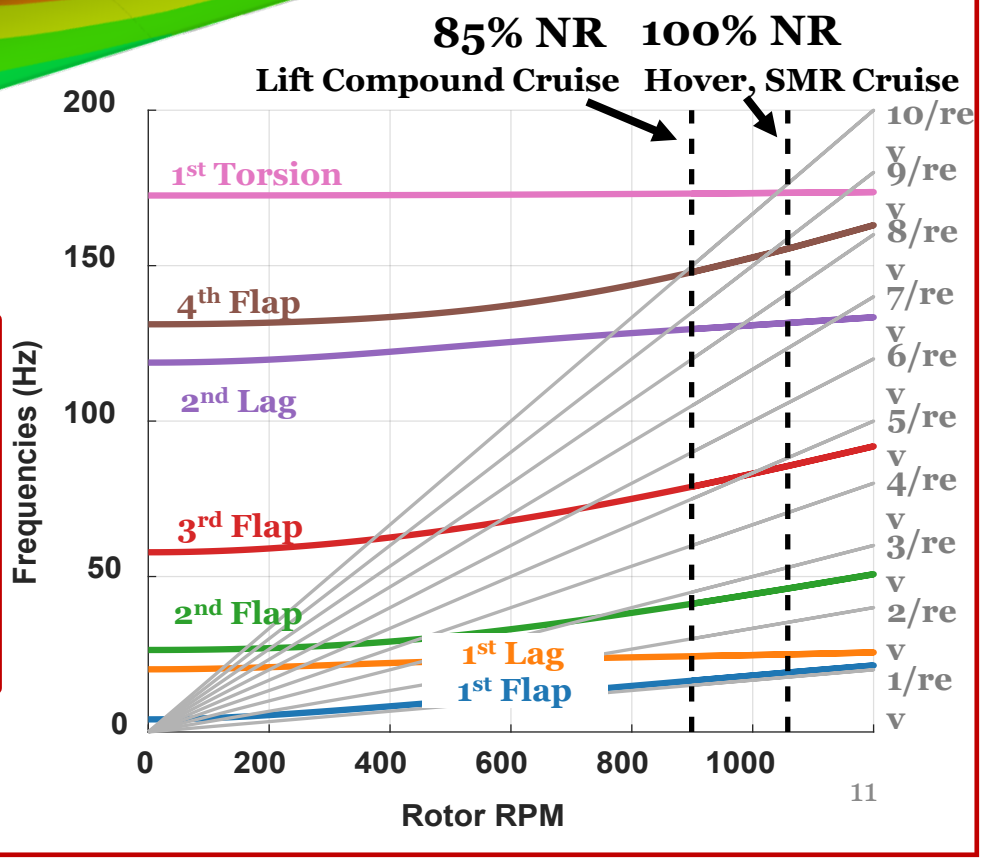
Blade Structural Design



3D Dynamic Stresses, σ_{11} [MPa]

Factor of Safety > 5





Hover
Flap: 1.08/rev
Lag: 1.42/rev
Cruise
Flap: 1.10/rev
Lag: 1.63/rev

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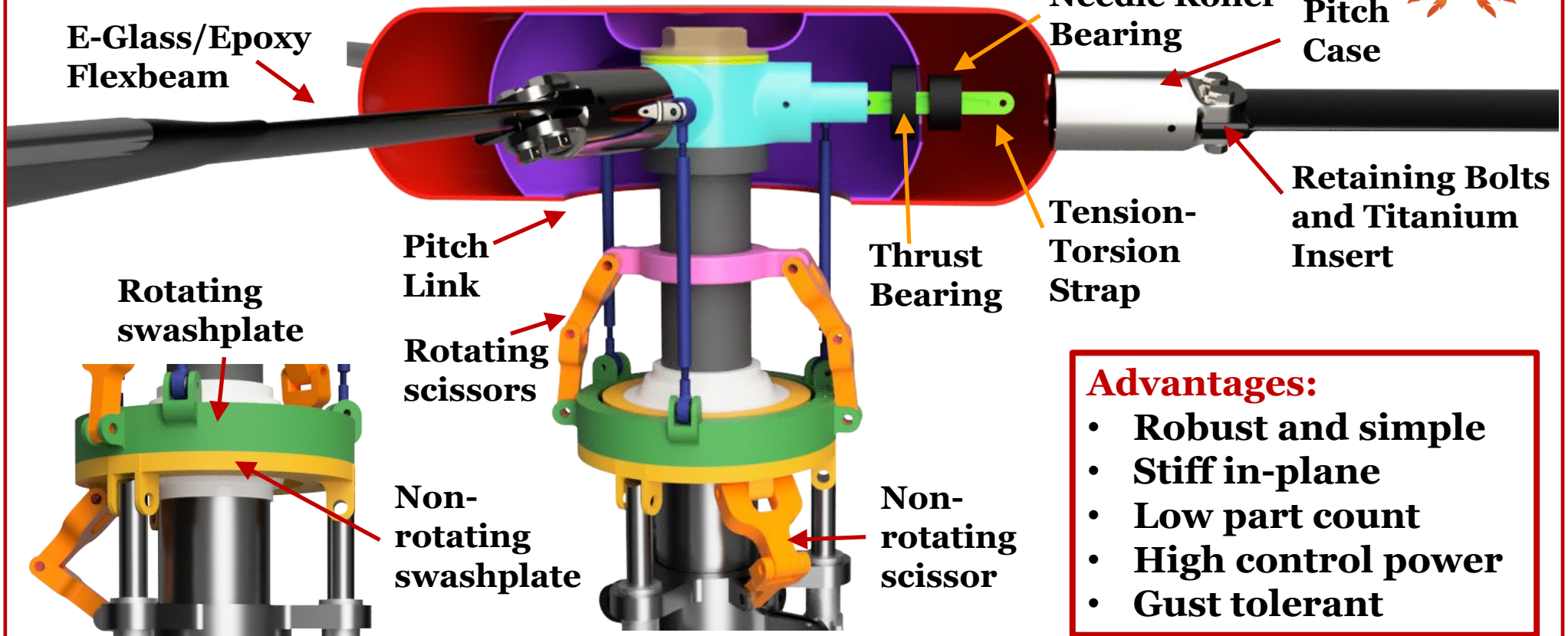
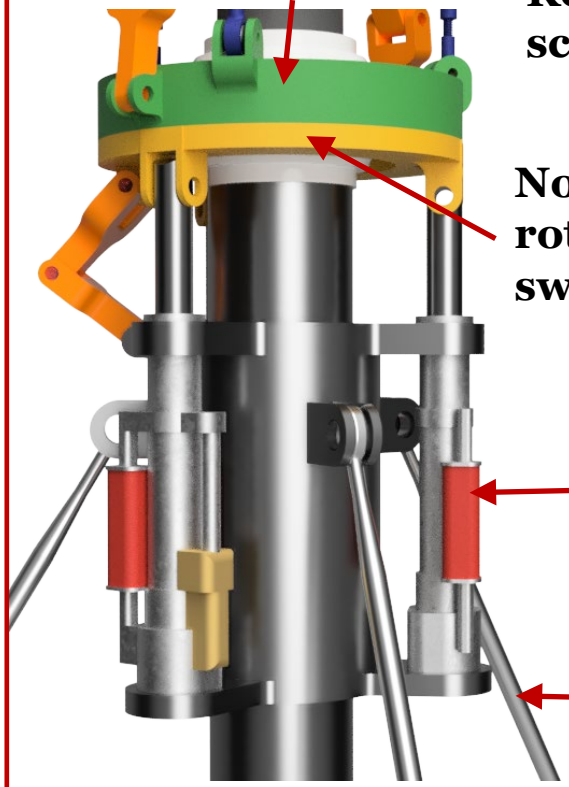
Low Vibration Hingeless Hub





Light weight Electro-Hydraulic Actuators

Lift rods sized for 3.5 g loading

Advantages:

- Robust and simple
- Stiff in-plane
- Low part count
- High control power
- Gust tolerant

Hub fairing significantly reduces hub profile drag

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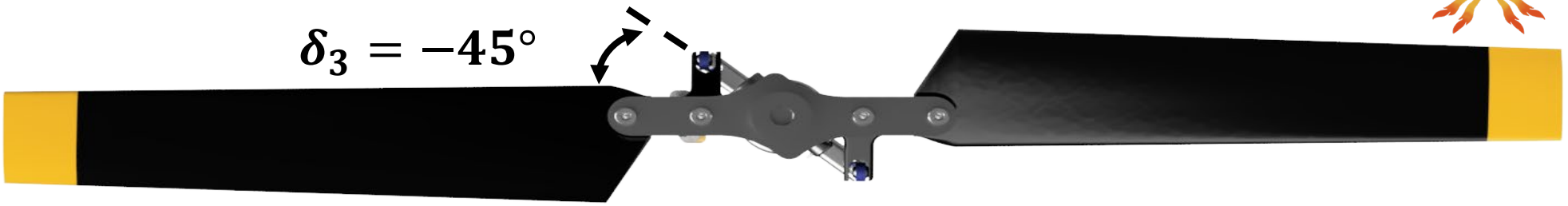
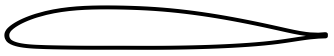
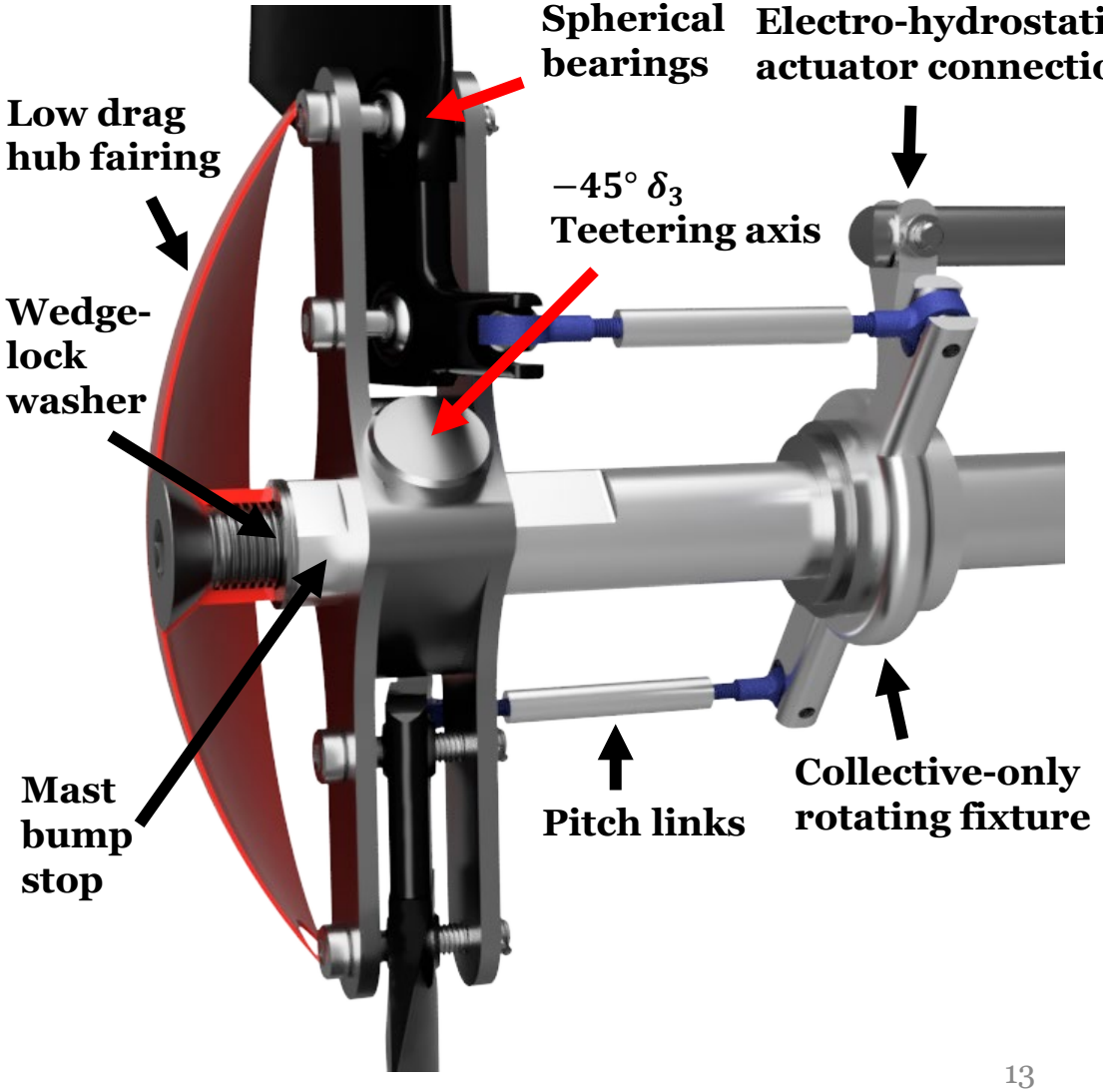
High Gust Tolerant Tail Rotor





OA212 Airfoil

R = 0.31m (1.02 ft)



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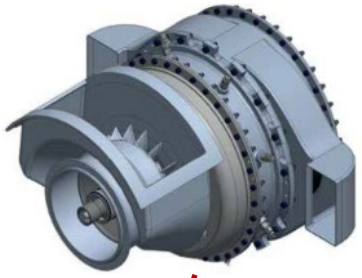
Compact Belt-Driven Transmission

4x Optibelt XPZ-9JX belts with a reduction of 1:1.43



UTP50R Turboshaft: 37.23 kW (50hp)

Idler pulley tensioner

Shaft supported by bearings along tail

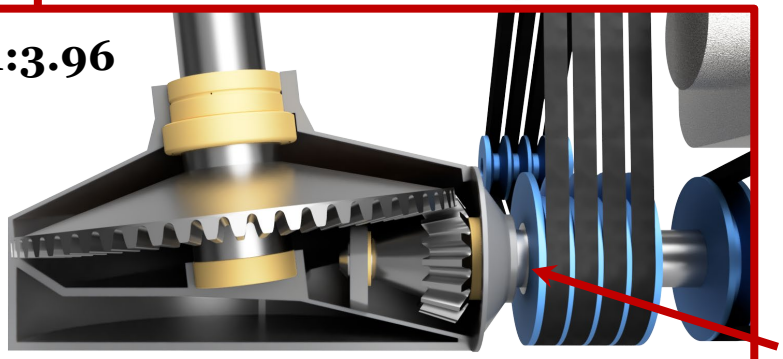
Flex couplings

Alternator driven by belt on main drive shaft

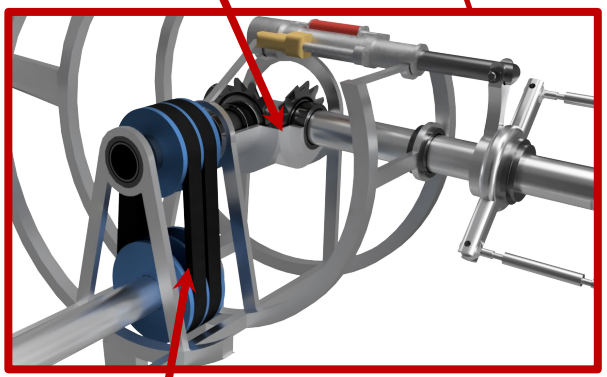
1.07:1 lightweight bevel gearbox

Main Gearbox

1:3.96



Sprag clutch inside driver pulley



1.22:1 belt reduction reduces transmission weight

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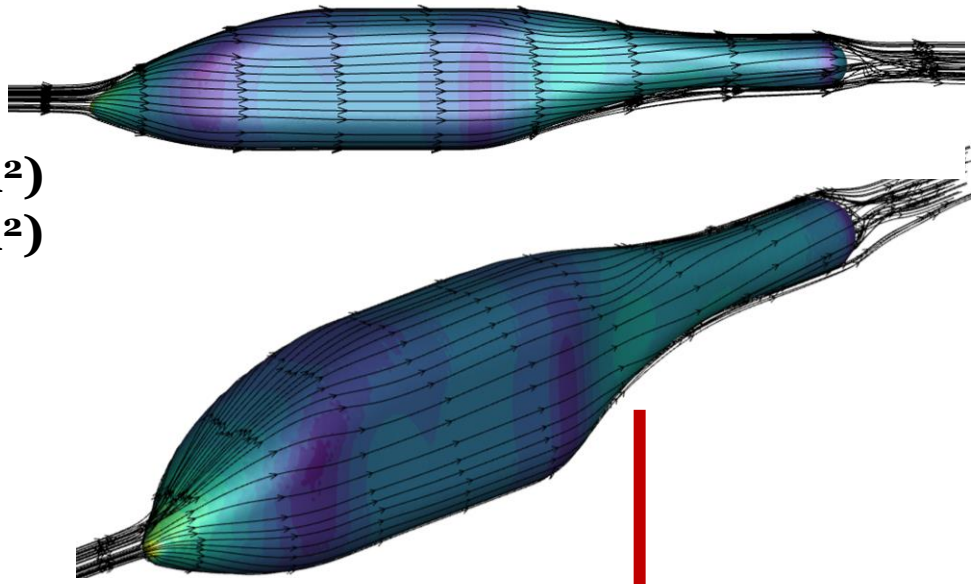
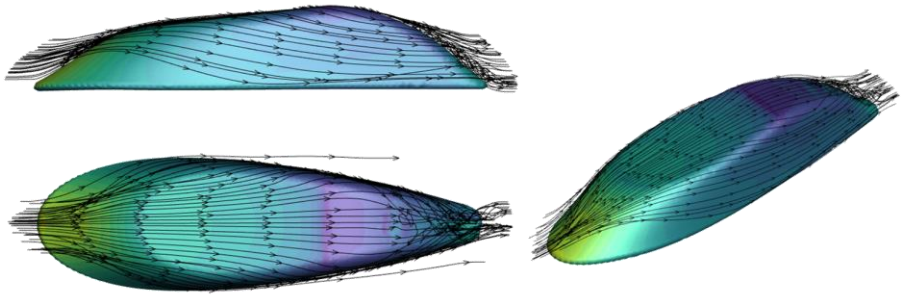
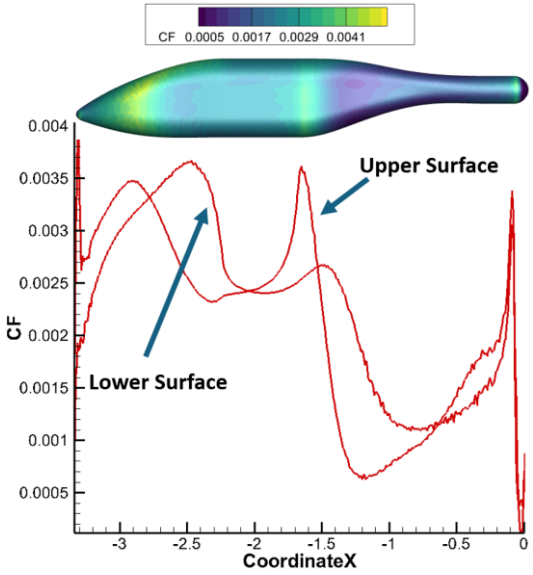
RANS CFD Based Aerodynamic Design

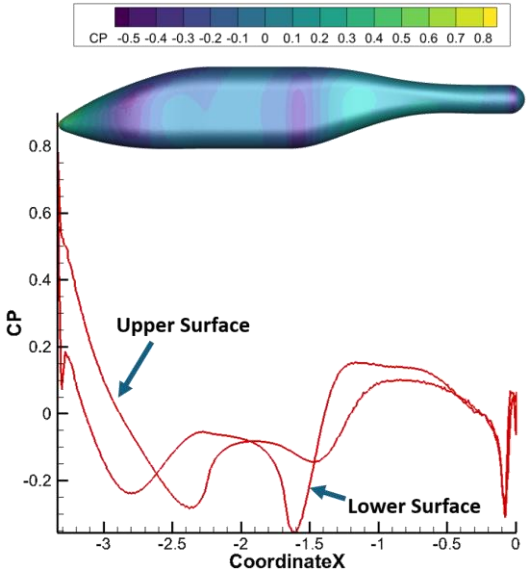
- A streamlined design for fuselage, hub fairing, and landing gear
- Low Flat Plate area
  - Supplies Delivery 1.31 ft² (0.1218 m²)
  - Long Endurance 1.53 ft² (0.1424 m²)





Hub Fairing





Low adverse pressure gradient

No flow separation

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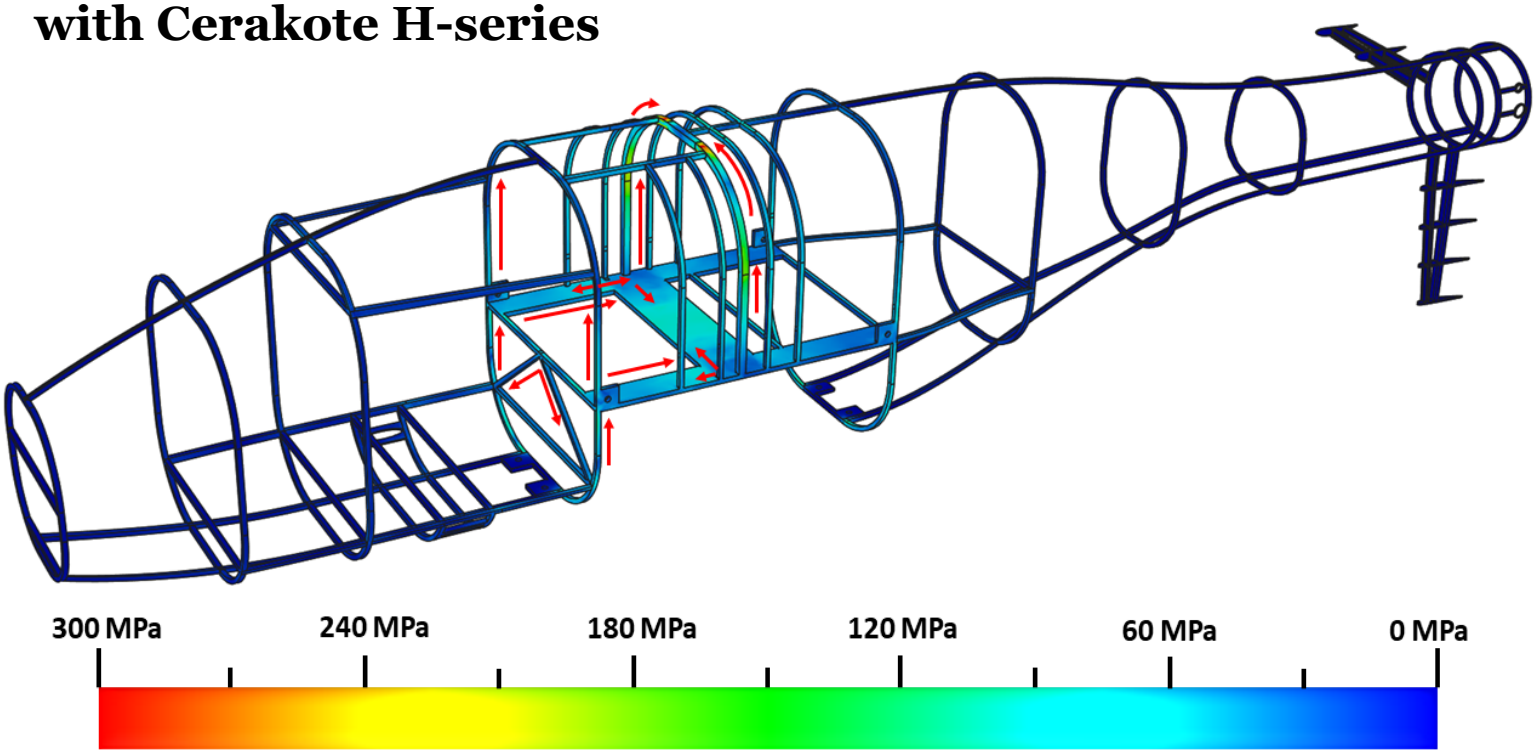
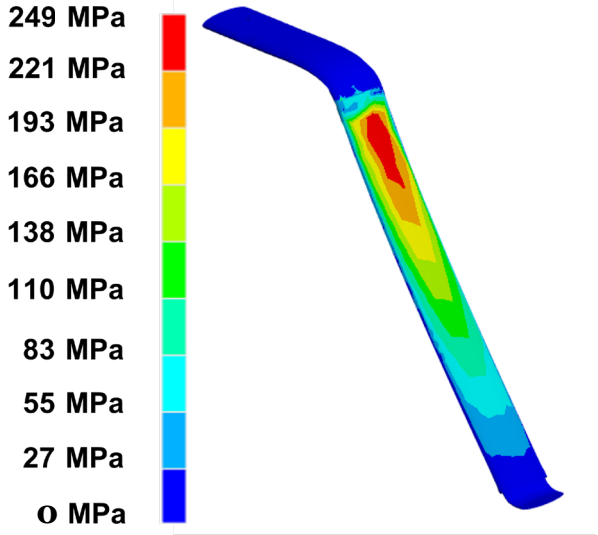
Airframe and Landing Gear

Designed according to NAVY AR56 requirements

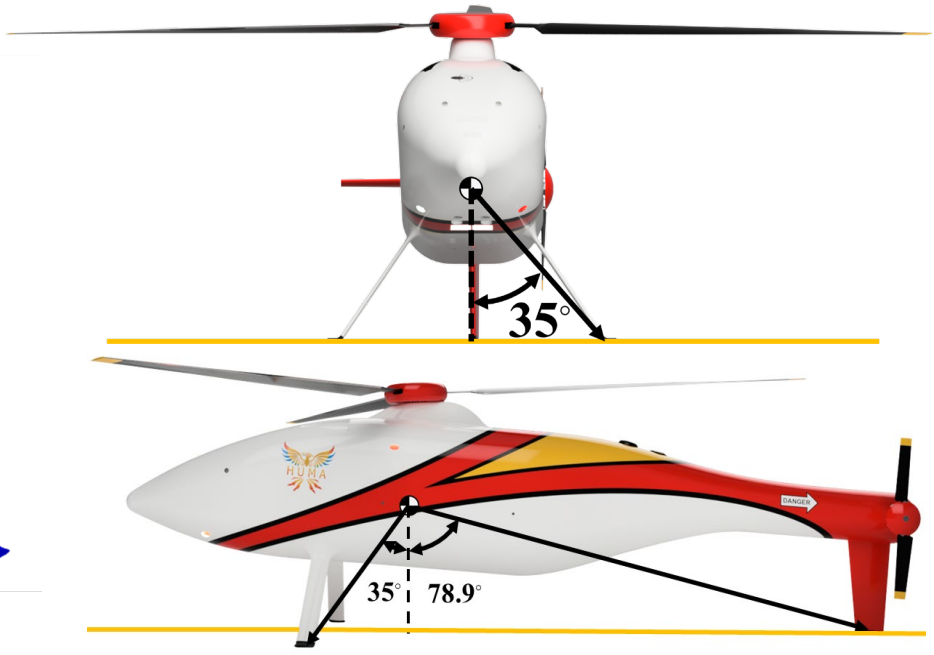
Marinized corrosion-resistant airframe coated with Cerakote H-series



High Factor of Safety (1.71)



Three-point landing gear stable from dynamic rollover



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Avionics Tailored for Shipboard Operations

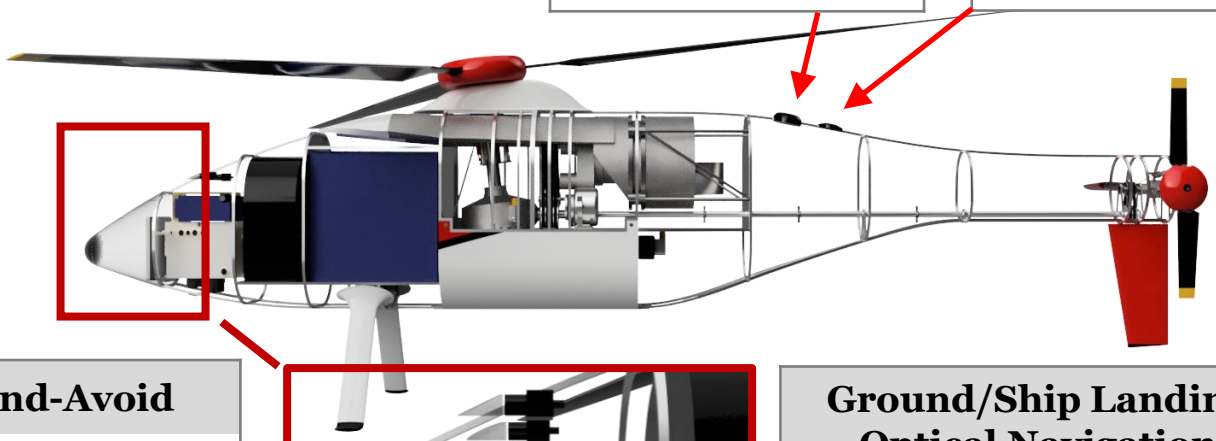
Multiple sensors and onboard processing support full autonomy

SATCOM

Communication beyond line-of-sight

GNSS

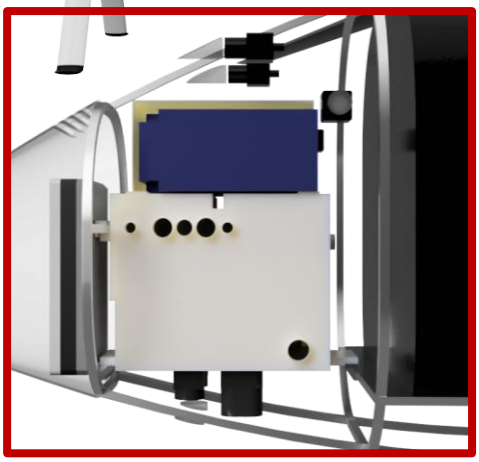
< 2.5 m position accuracy



Sense-and-Avoid

Front- and side-facing cameras

Radar



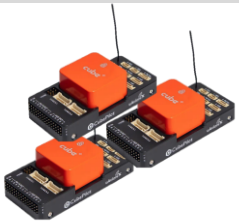
Ground/Ship Landing Optical Navigation

Downward-facing cameras

Thermal cameras

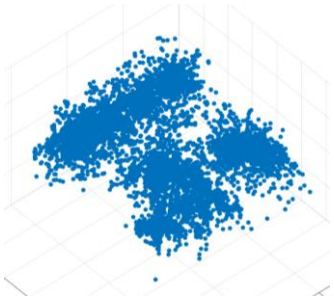
Internal Processing Components

Jetson AGX Orin embedded computer

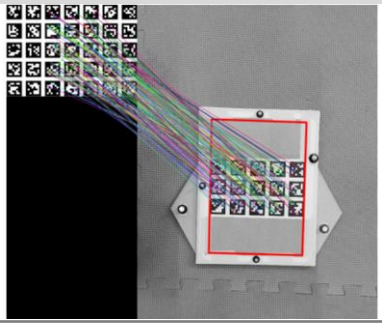


Triple-redundant flight controllers

3D cloud of features



Vision based featured detection



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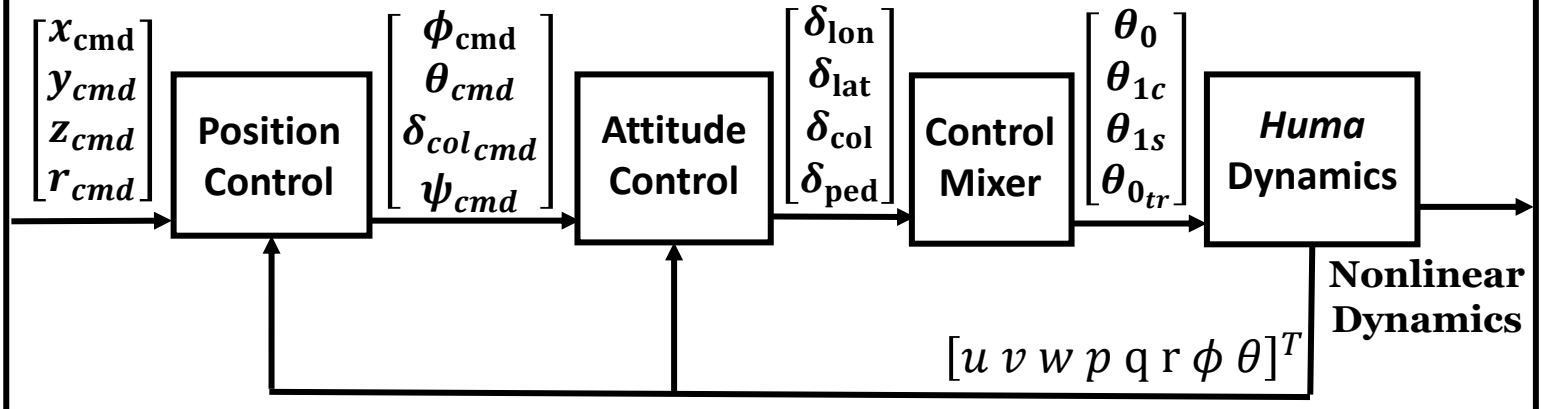
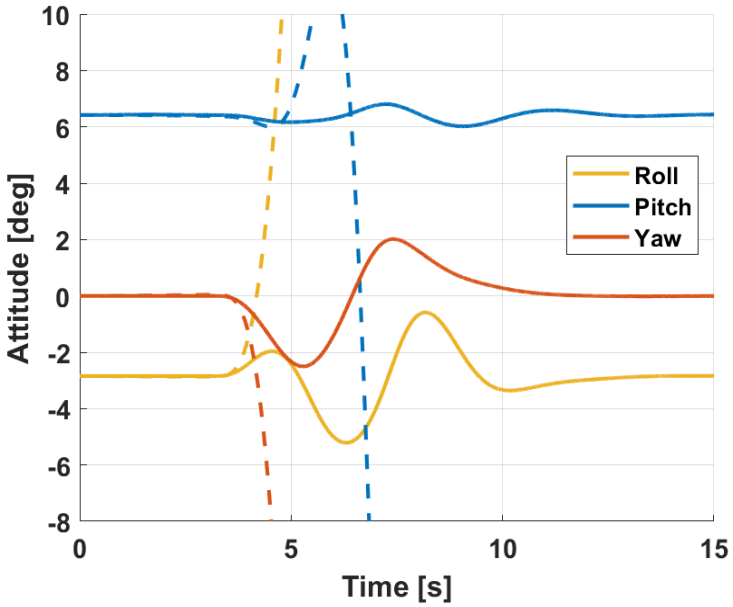
Multi-layered Dynamic Inversion Flight Controller

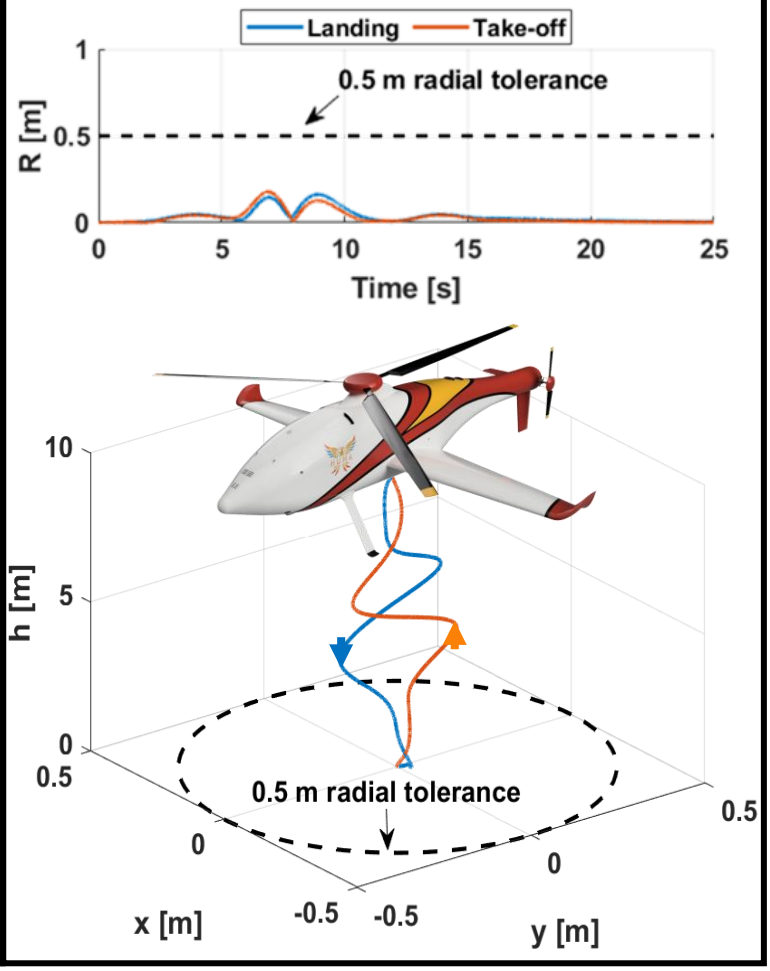
- **Position control with Attitude Command Attitude Hold (ACAH) controller in hover**
- **Translational Rate Command (TRC) with ACAH controller in cruise**



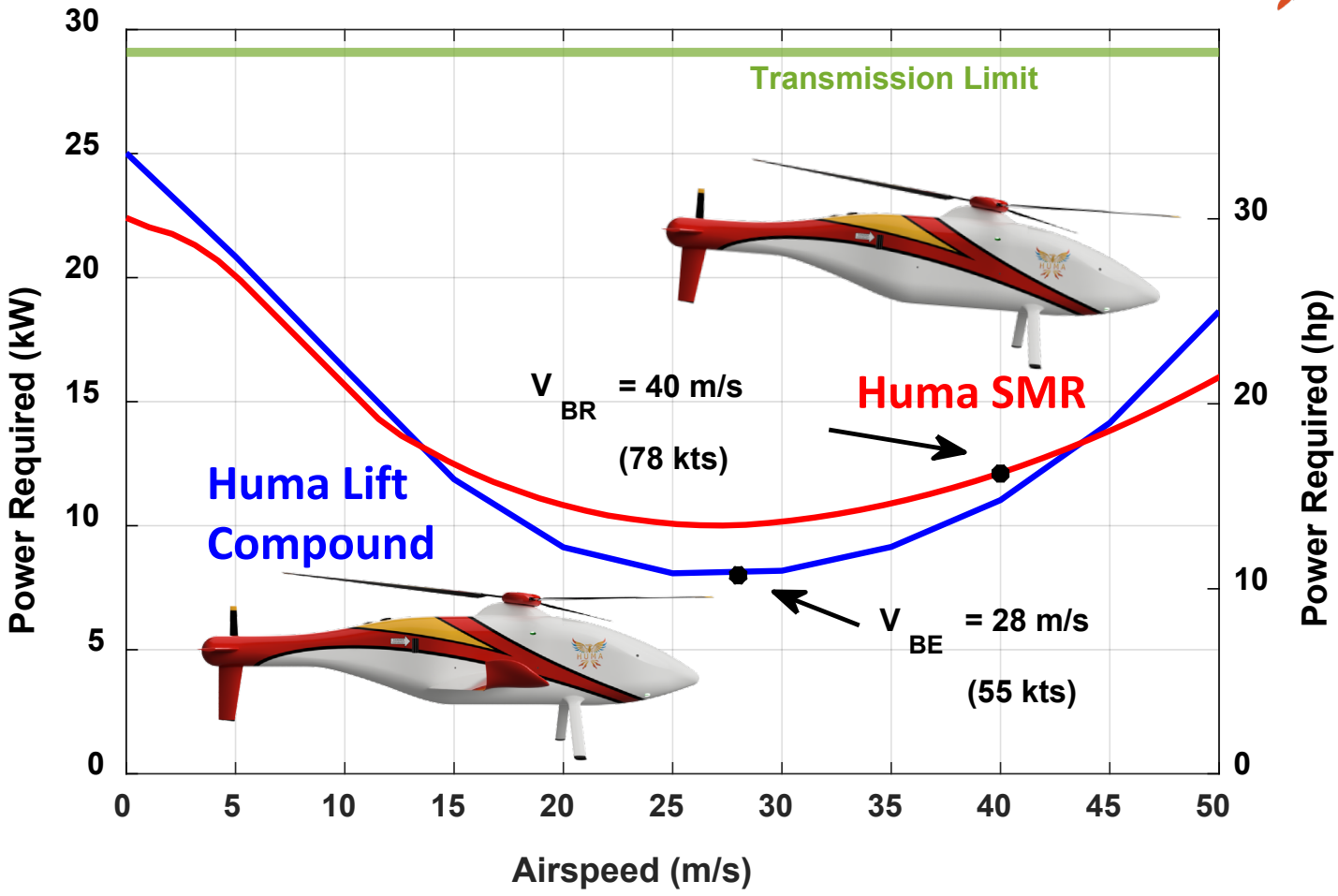
Dynamic Inversion Controller Architecture

Gust rejection **with stability augmentation, attitude and position control for** ***launch and recovery***

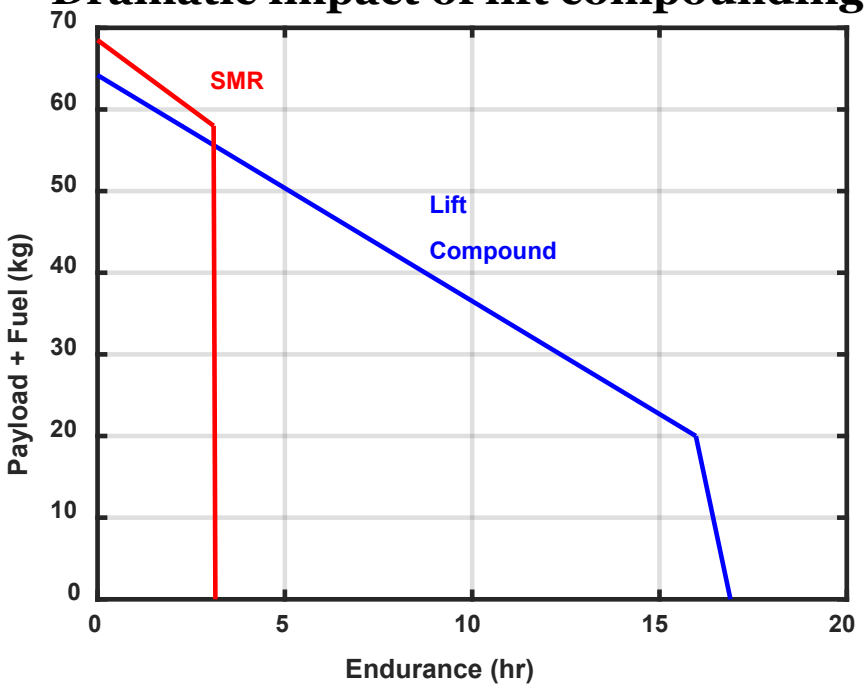




Unprecedented Dual Mission Performance



Dramatic impact of lift compounding



Lift compound:

- **Exceptional 13 hour loiter**
- **Maximum of 16 hour loiter without any payload**

SMR:

- **Heavy maximum payload of 69 kg (152 lb)**

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Multi-Mission Capability

Huma: A Modular UAV With Superior Dual-Mission Performance

Exceeds Mission Requirements

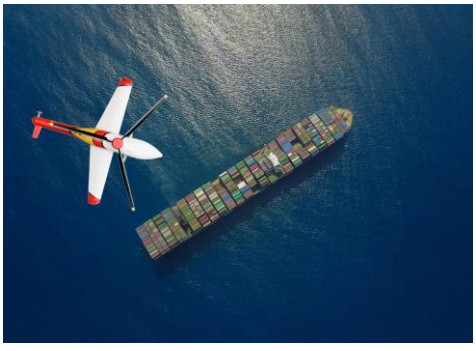
- 13 hour loiter endurance in long-range configuration
- 58 kg (128 lbs) payload capacity in supplies-delivery configuration

Affordable

- 187,000 USD estimated purchase price
- 205 USD maintenance and operational cost per flight hour

Applications for myriad missions

Maritime Surveillance and Reconnaissance



Agricultural Monitoring

Medical Delivery