AERO INDIA– 2019
The Runway to a Billion Opportunities

DRUTA

The Rapid Eagle

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team garuda

About Druta

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Druta translates to rapid or quick. Druta is a variable diameter coaxial tiltrotor with span wise adaptive wings for use in megacity type environments and is able to fit in between narrow streets and confined spaces. Span wise adaptive wings provide compactness in Hover configuration. The variable diameter coaxial tiltrotor provides required thrust with lower disk loading in hover configuration and increases the efficiency in forward flight configuration. A unique combination of 5+3 coaxial rotor blades in rotor is present to prevent noise.

With a combination of turboshaft and two turbojet engines, Druta can reach to a max speed of 535 km/ hr. At the same time, it is efficient in both forward flight and hover with cruise range of 498 km at 3000 m altitude and hover time of 78 minutes with 50% fuel capacity at SLS.

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5+3 Retractable coax tiltrotor

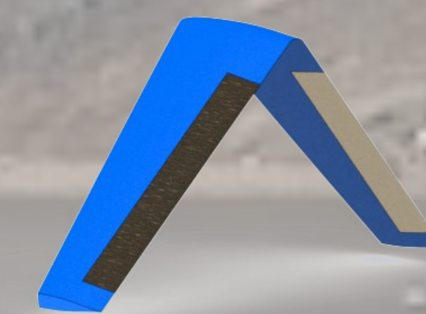
Rotors save the Anti Torque system power loss, providing better propulsion efficiency in forward flight and better acoustics at the same time.

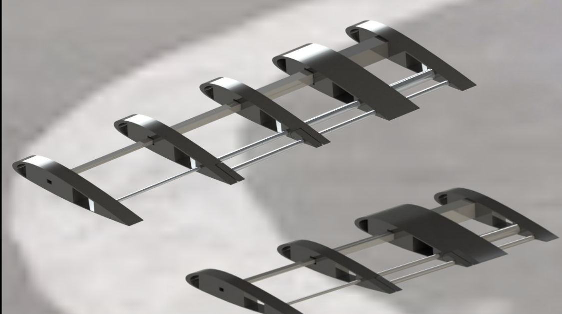
Dual Propulsion System

Simultaneously cruise speed efficiency and high dash speed is achieved with a better control over transition

V tail for control

Provides proverse roll-yaw coupling, reduced interference drag and a lower control surface count





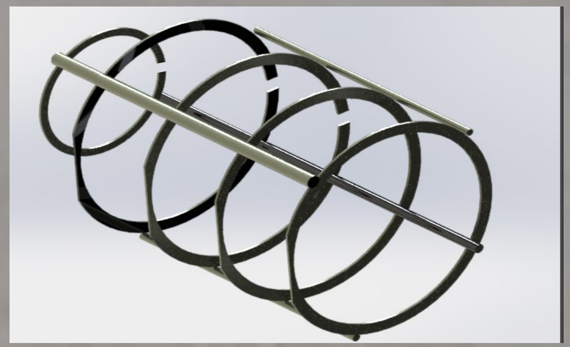
Span wise adaptive wings

Unique high lifting device well suited for both low speed flights and gliding capabilities for high range mission

MGTOW	600 kg
Payload	100 kg
Figure of Merit	0.75
Rotor Radius in Hover configuration	1.5 m
Rotor radius in forward flight configuration	1 m
Installed Power	167741 W

Airframe Structure

Aluminium Lithium (Al-Li) lightweight airframe with four primary bulkheads maximizes space for payload while maintaining a low drag shape



Sample Mission Profile

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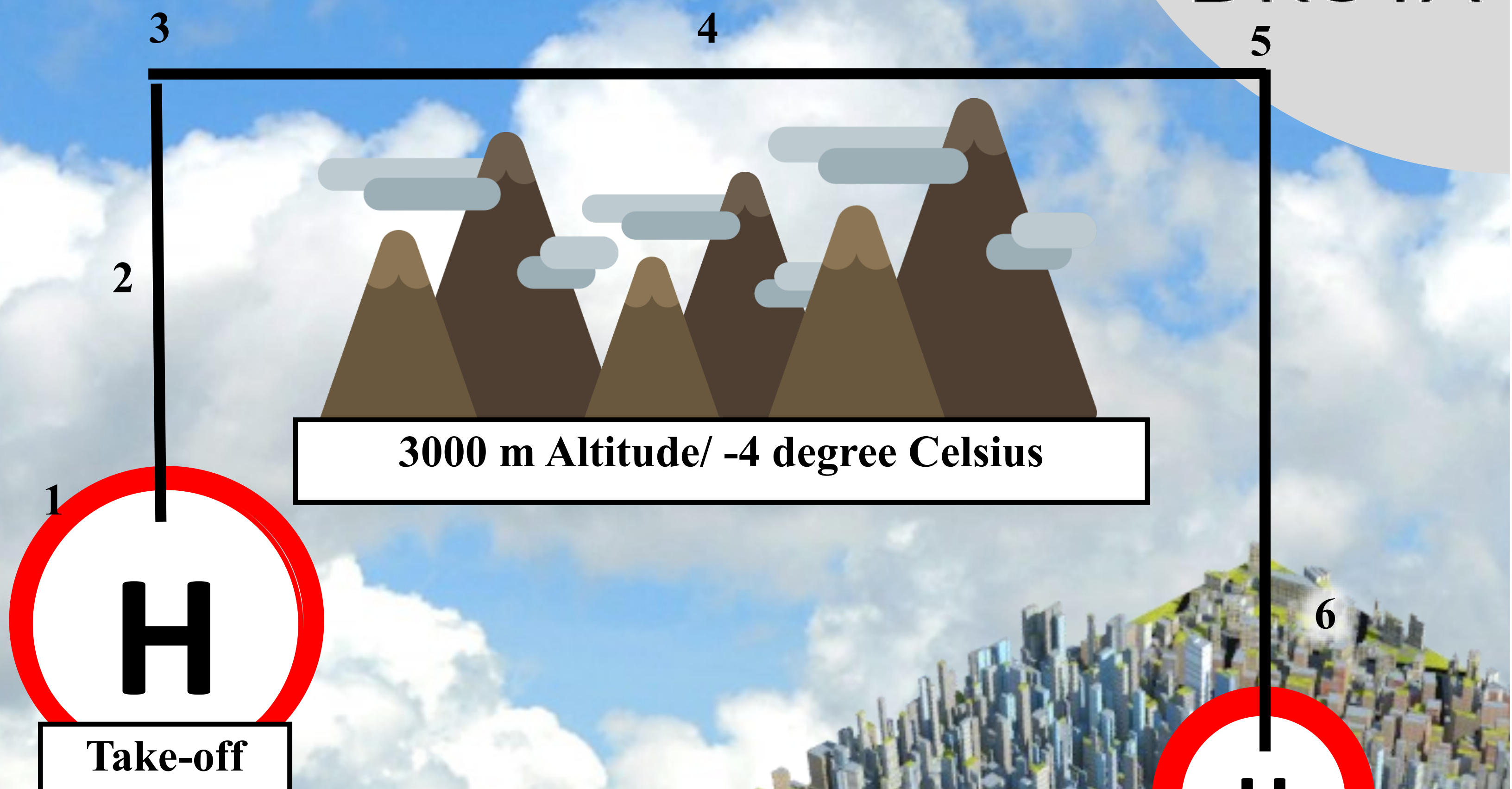

Segment	Requirement
1	Vertical Take-off
2	Ascend to 3000 m altitude
3	Reconfigure to forward flight configuration
4	Cruise
5	Reconfigure to hover configuration
6	Descend and surveillance in Megacity-type-environment
7	Vertical Landing

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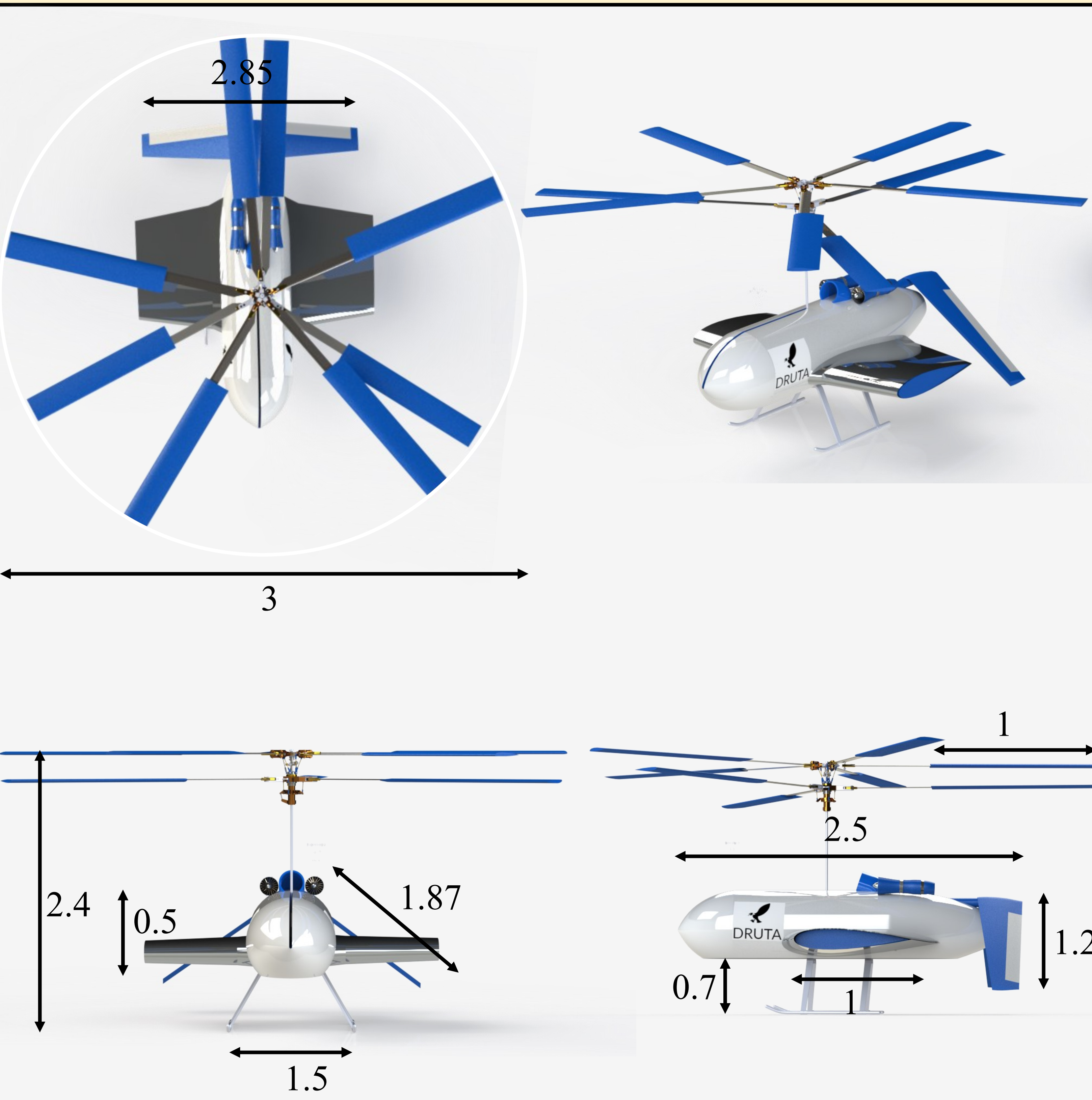
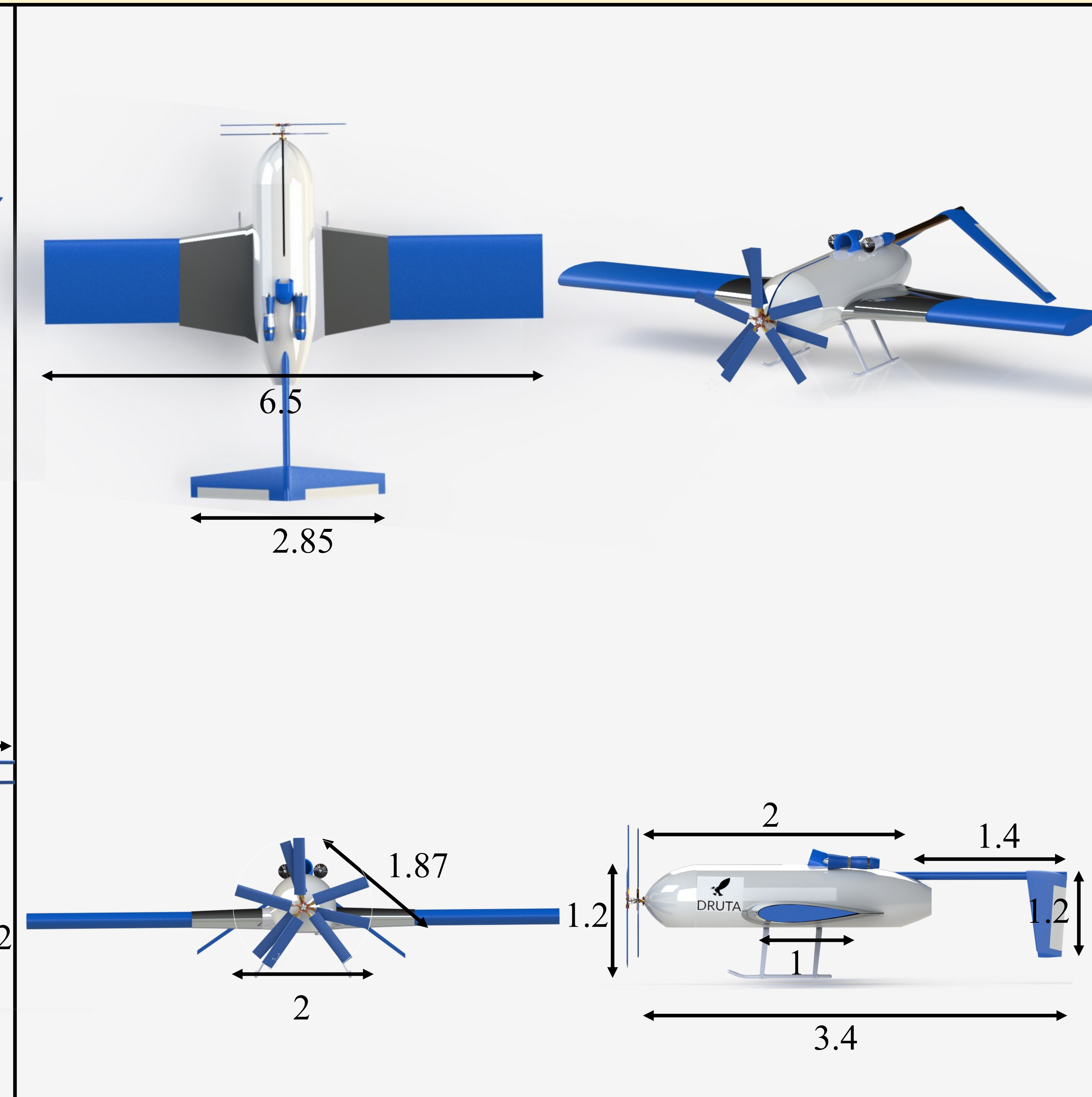
Druta Four-View

Hover

[All Dimensions in meter (m)]

Forward Flight



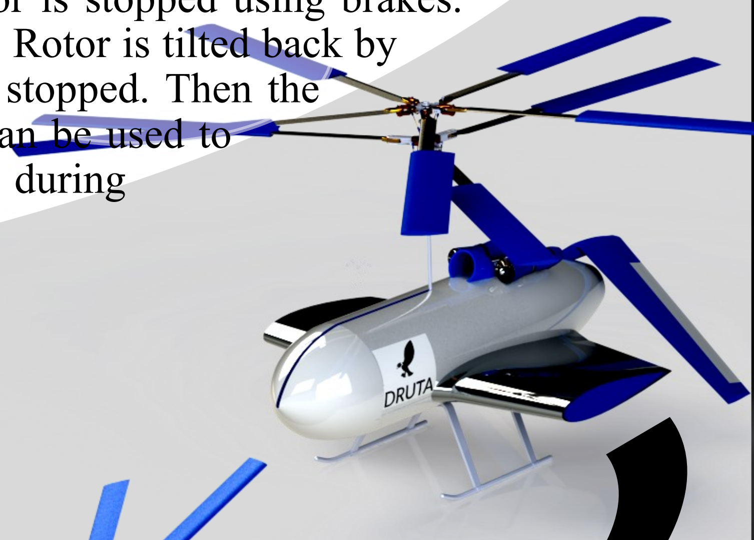


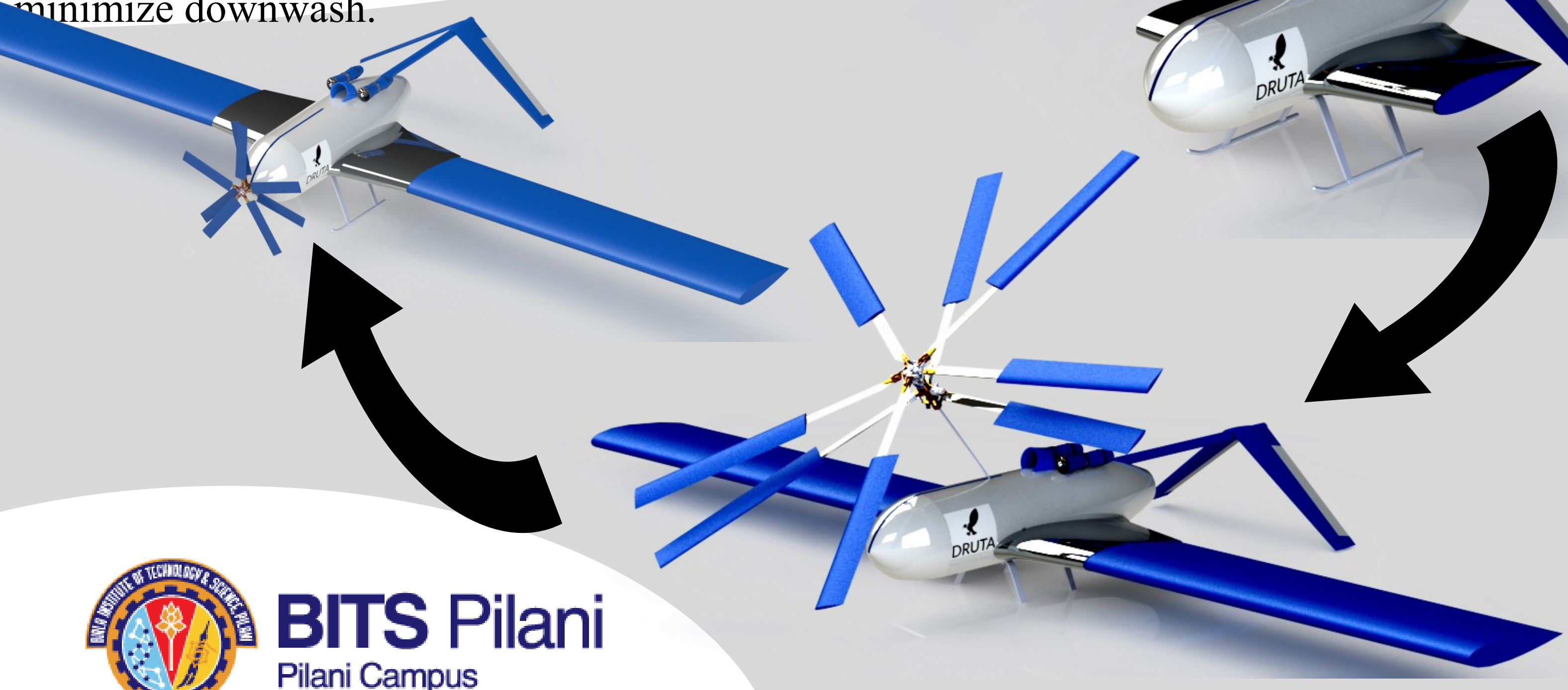
Reconfiguration details

With a reconfiguration time of 105 seconds, Druta is able to reconfigure on its own by components which remain onboard the aircraft at all times. The reconfiguration is reversible and can be executed multiple times without external support.

To change the hover configuration to forward flight configuration, wings are extended and two turbojet engines placed over the fuselage are started. When Druta gains a forward velocity sufficient to balance the downward force, rotor is stopped using brakes and then tilted. Rotor blades are retracted from 1.5 m radii to 1 m radii. When rotor gets tilted by 90 degree, it is again started and turbojets are stopped. This reconfigures vehicle to forward flight. The rotor is stopped while tilting to prevent the gyroscopic forces and problems encountered due to oblique airflow. This also increase the reliability of vehicle. Use of turbojets makes transition smooth and fast.

When it is required to change the vehicle from forward flight configuration to hover configuration, jets are started and then rotor is stopped using brakes. Blades are extended from 1m radii to 1.5 m radii. Rotor is tilted back by 90 degree to top and started again. Turbojets are stopped. Then the air brakes are used and swash plate mechanism can be used to counteract inertia and set an appropriate speed during hover. Wings are retracted to have a maximum span of less than 3m in hover configuration and minimize downwash.





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Flight Control

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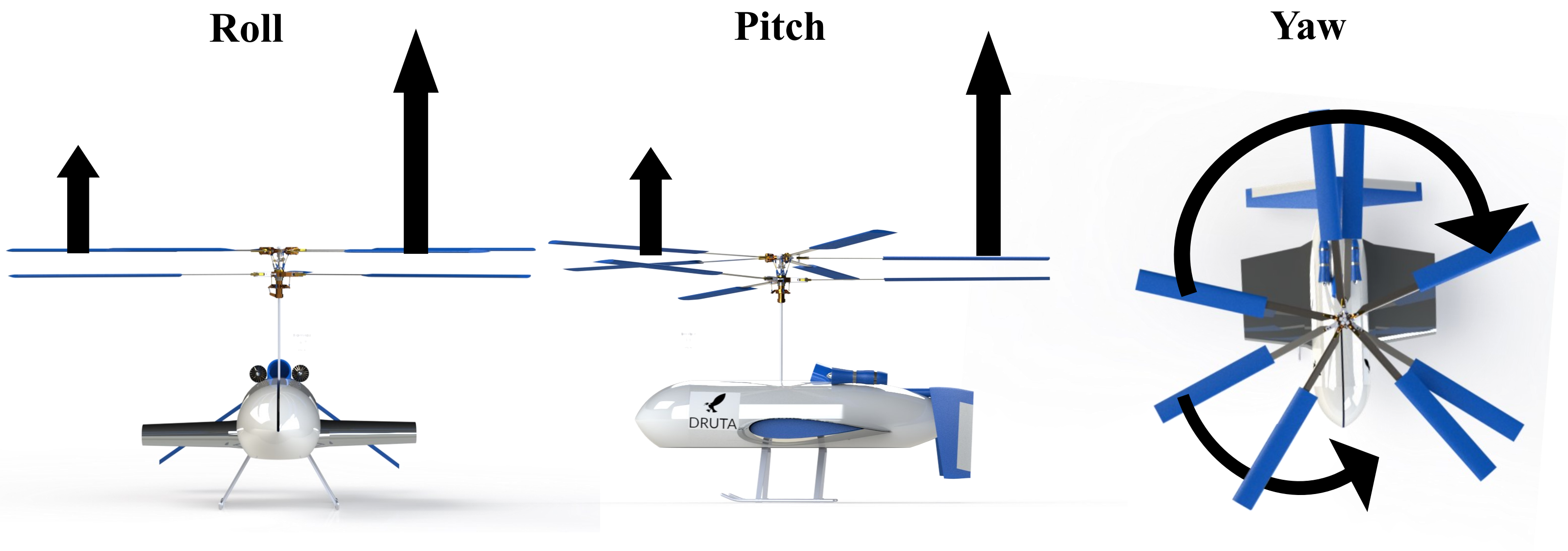
- In hover configuration, a swash plate is used for the collective and cyclic control to change the altitude of the vehicle and for roll and pitch movement.

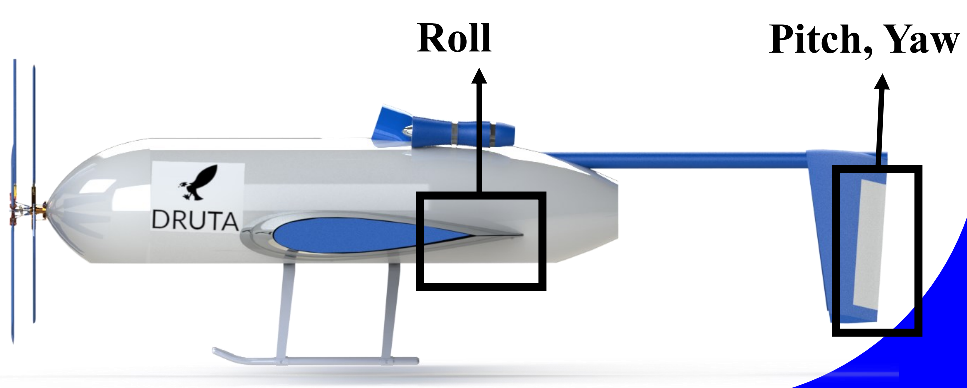
- Coaxial rotor differential RPM is used for the yaw control of the vehicle



- The 3-axis control of the system is achieved by the usage of a total of only 4 control surfaces. A pair of ailerons are employed to provide roll control. The yaw and pitch control function are fused into one pair of control surfaces called the ruddervator. This control surface is mounted on the inverted V-tail of the system.

- During hover to forward flight transition, since the wings are extended from the start, total control of the system is observed by the use of these 4 control surfaces.

- Partial use of the swash plate in forward flight gives the system resistance to gusts by cancelling out minor pitch or yaw moments generated due the angled attack of the winds. This in conjunction with the control exercised by the ruddervator ensures stable flight.



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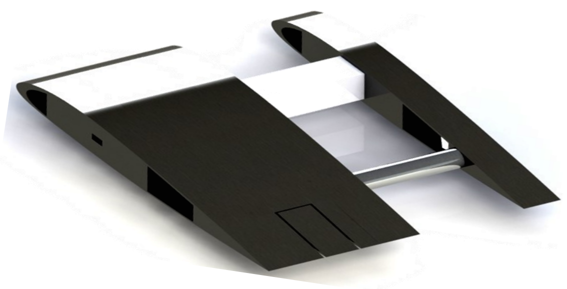
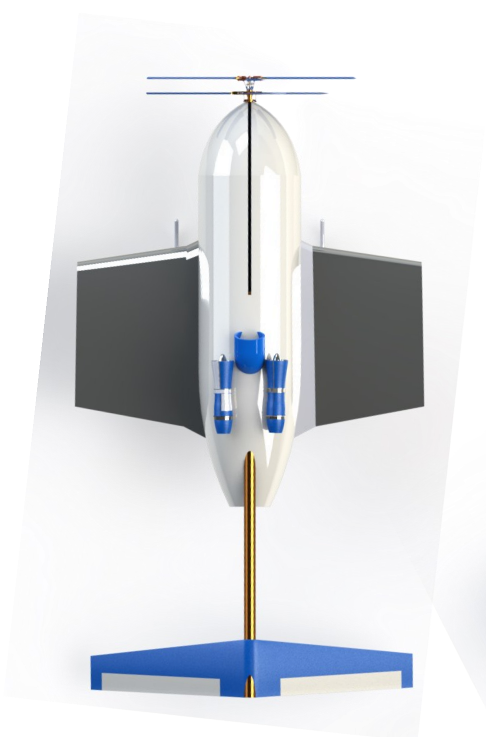
Span-wise adaptive wings

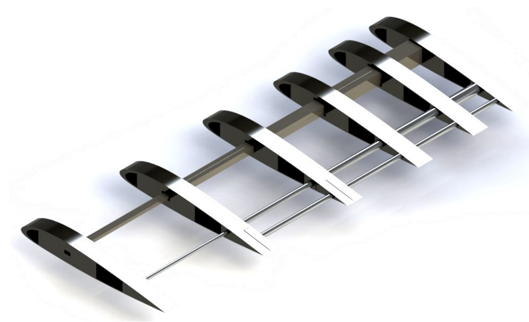
Hover





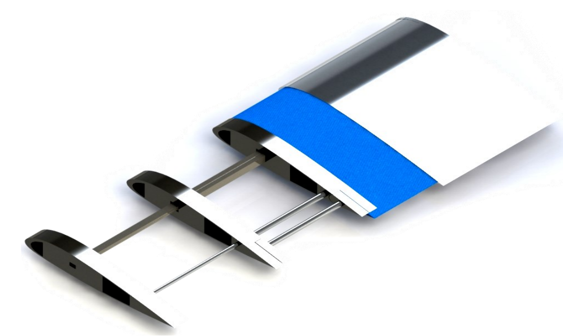
The fully retracted wings produces a minimum download in hover configuration due to the air wash of rotors. This decreases the power requirement during hover and increases the hover time.

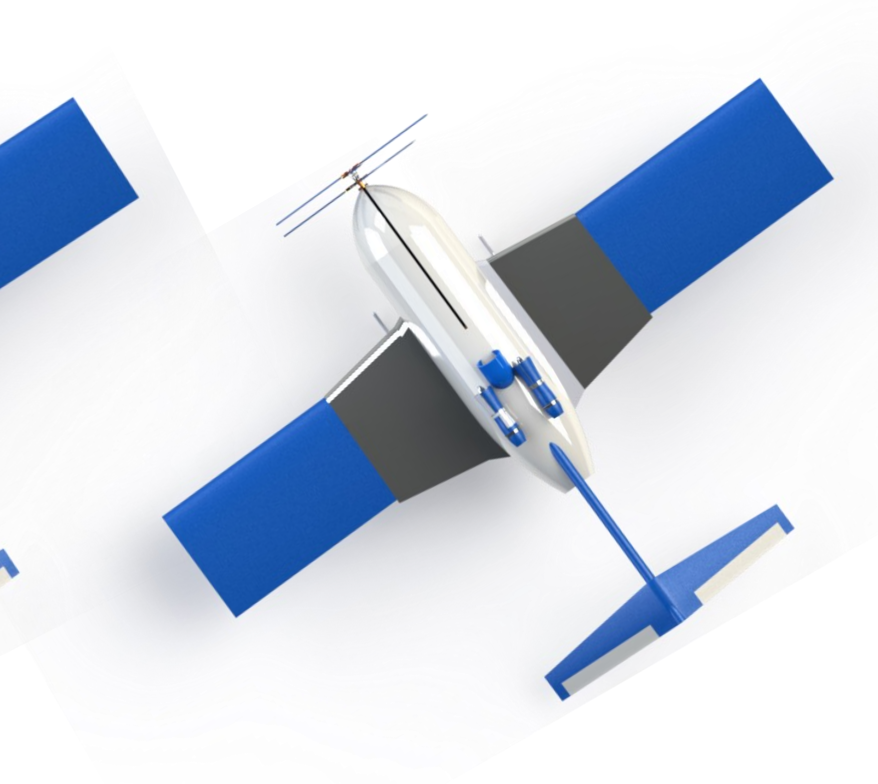
Transition



During transition, wing span opens up to the tip to tip length of 7.5 m, thus gives larger lift and stall limit at lower speeds. Such a span also provides the gliding ability for the long range operations.

Cruise



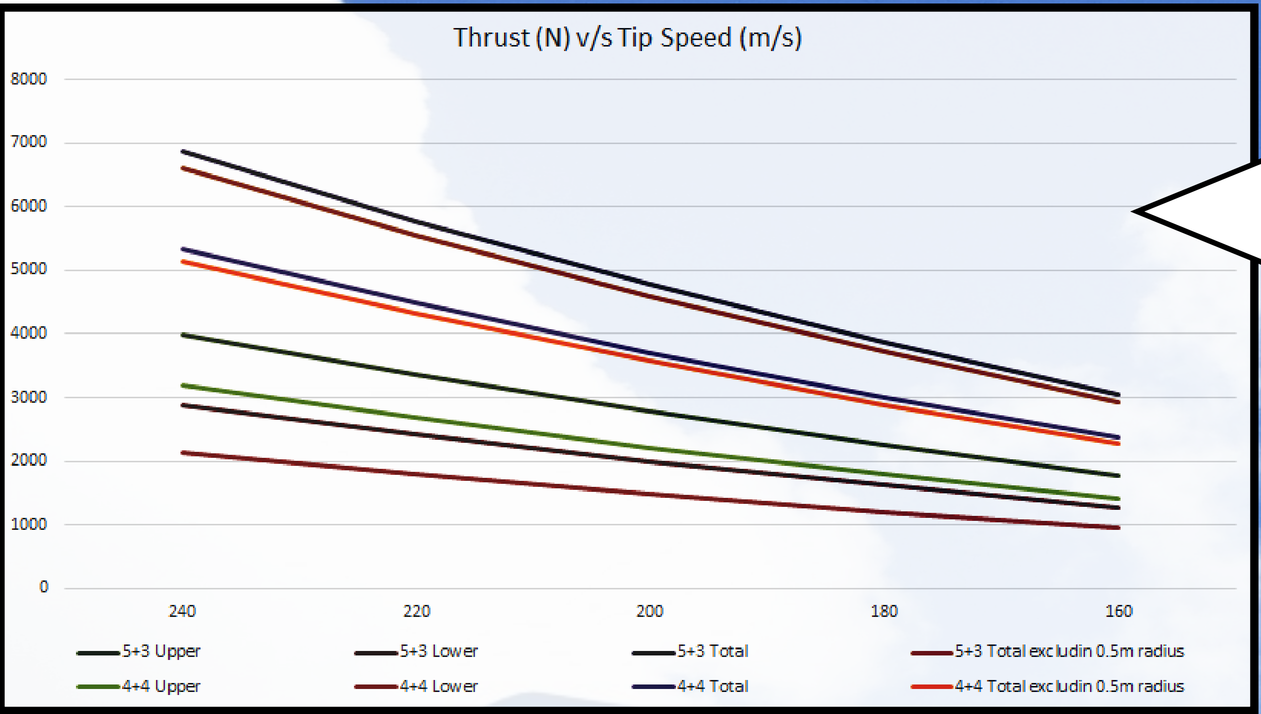


The cruise flight takes place at the wing span of 6.5 m. The wing can be retracted back from fully extended configuration to support fast forward speed, and is helpful in achieving maximum dash speed.

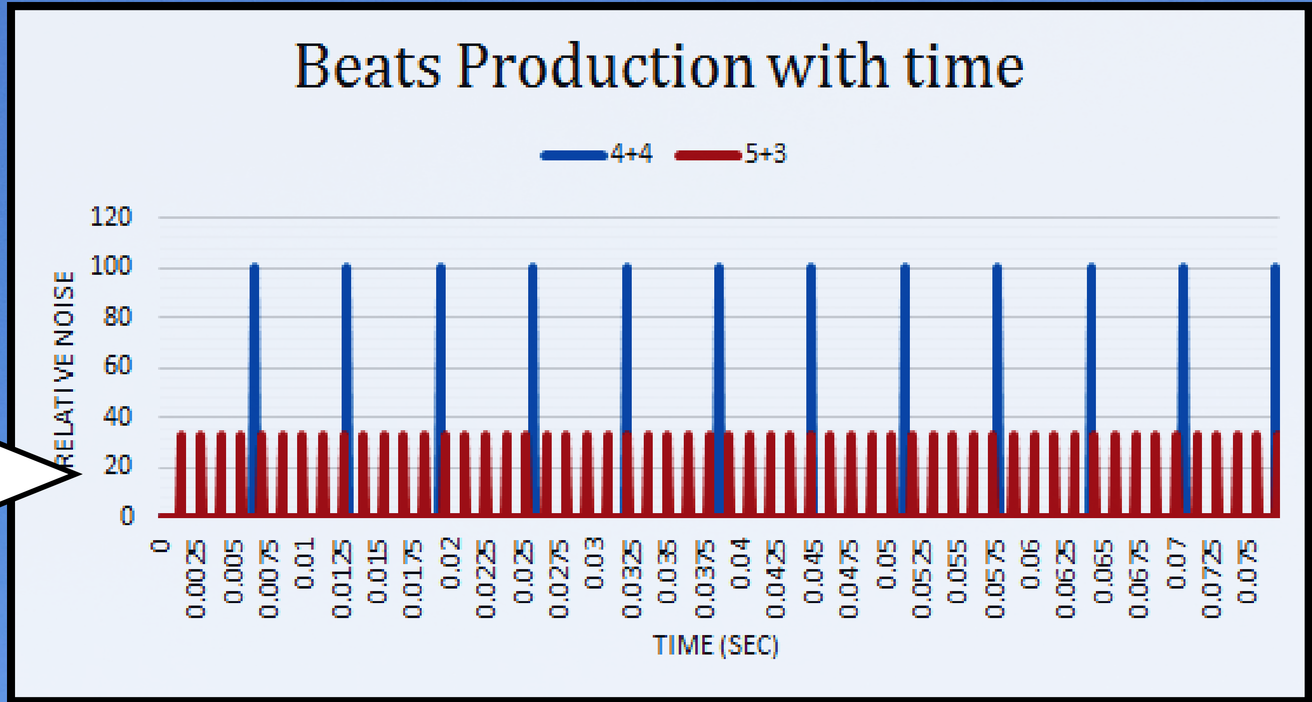
Wingspan of Druta is varied using a retracting torque box and skin covering of Vectran. Wings are retracted in hover configuration while extended to a span of 6.5m in forward flight configuration.

The wing is mainly comprised of a single torque box, which is manufactured to run the length of the wing-span. The torque box provides the necessary stiffness to prevent the whirl flutter instabilities, as well as to support all of the anticipated aerodynamic and structural loads during normal flight operations.A graphite-epoxy composite material is used for the construction of the torque box and ribs as it meets the high material stiffness requirements of the design while reducing the weight at the same time. Skin covering of wing structure is made up of Vectran. Vectran is a high-performance multifilament yarn spun from liquid crystal polymer (LCP). It is the only commercially available melt-spun LCP fiber. Vectran fiber exhibits exceptional strength and rigidity. Pound for pound, Vectran™ fiber is five times stronger than Steel and ten times stronger than Aluminum. Wings are made up of fabric kind material so to prevent sagging of fabric between the ribs a pressure of 185-200 kPa is maintained inside the wing. To maintain this pressure the engine bleed air is used. The bleed takes less than 50 seconds to completely fill the wings.

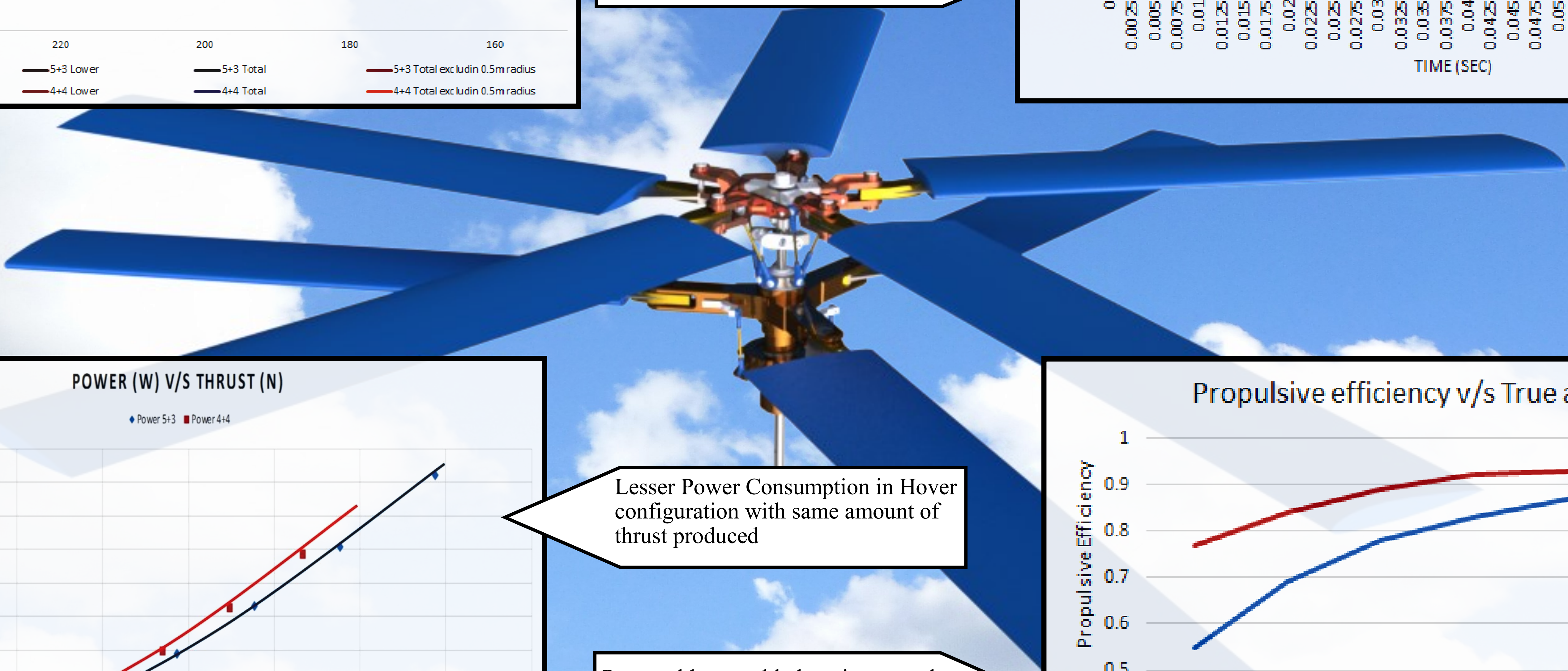
Novel 5+3 Retractable Rotor System

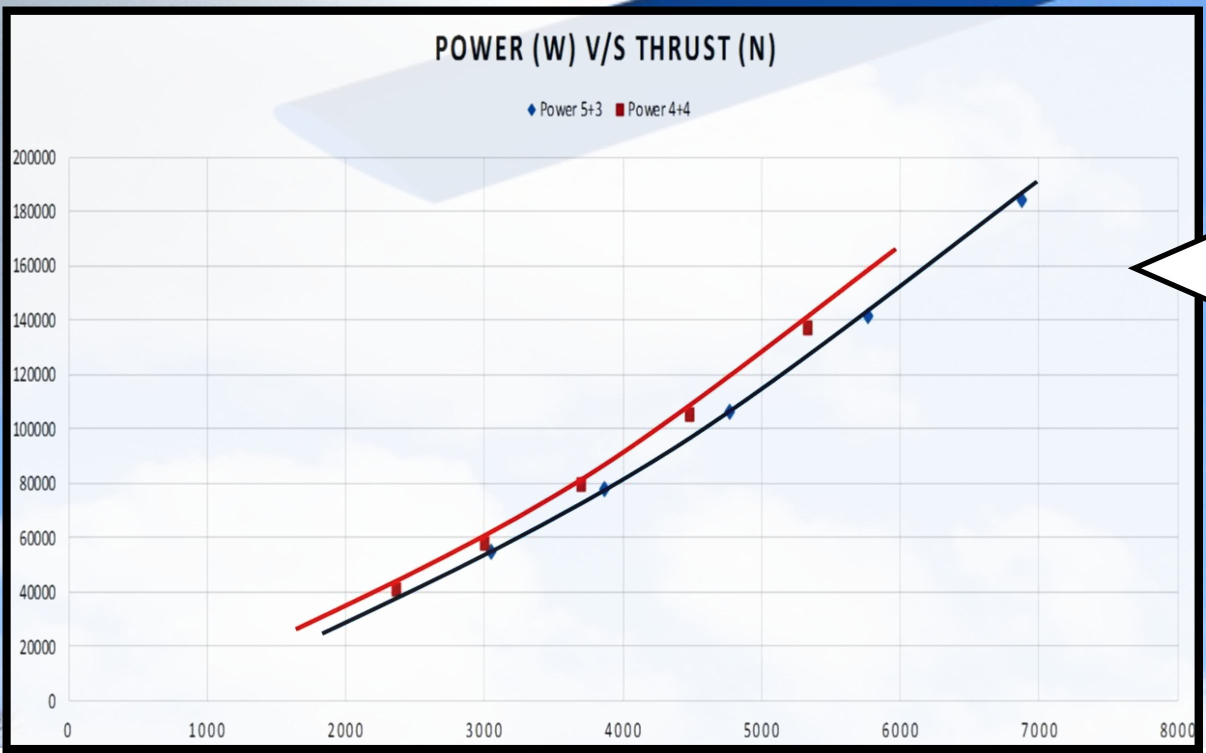


20% more thrust is produced compared to conventional coax-system at constant tip speed of 232m/s



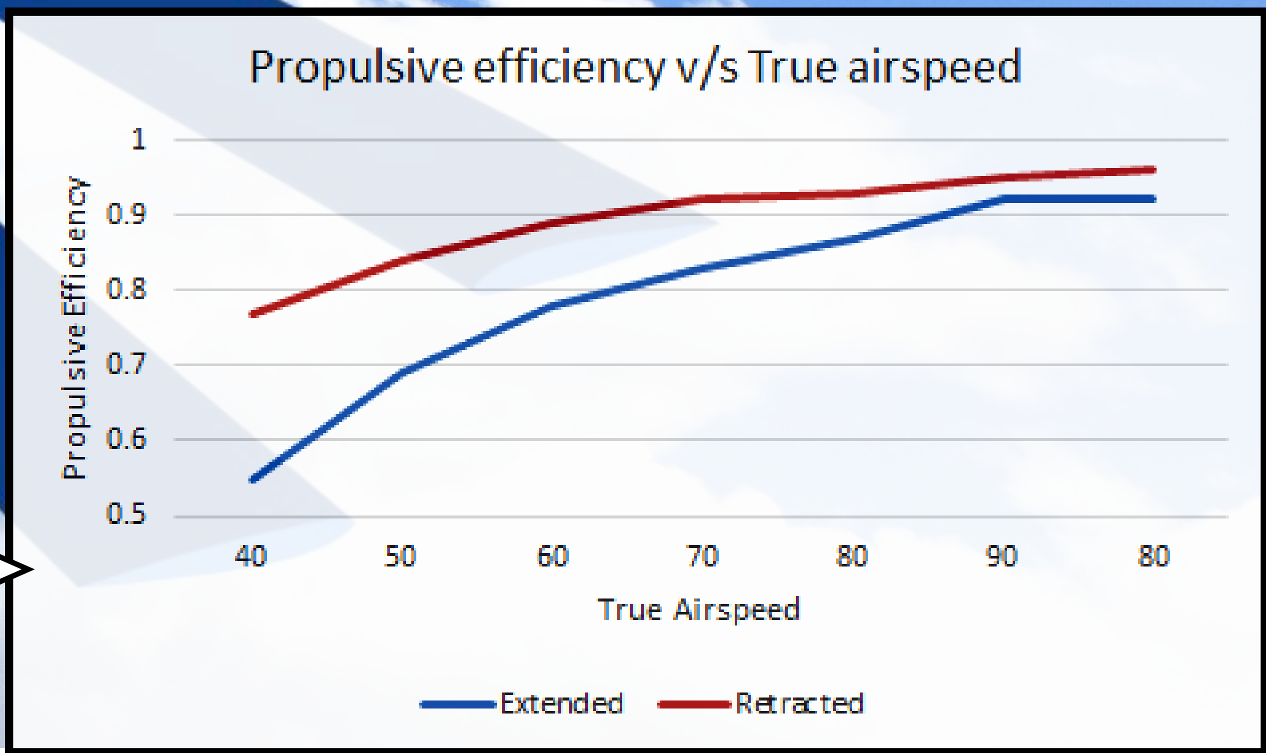
75% noise reduction as compared to conventional coaxial rotor system





Lesser Power Consumption in Hover configuration with same amount of thrust produced

Retractable rotor blade to increase the propulsion efficiency by 14% at 62 m/s in forward flight configuration.



Rotor System

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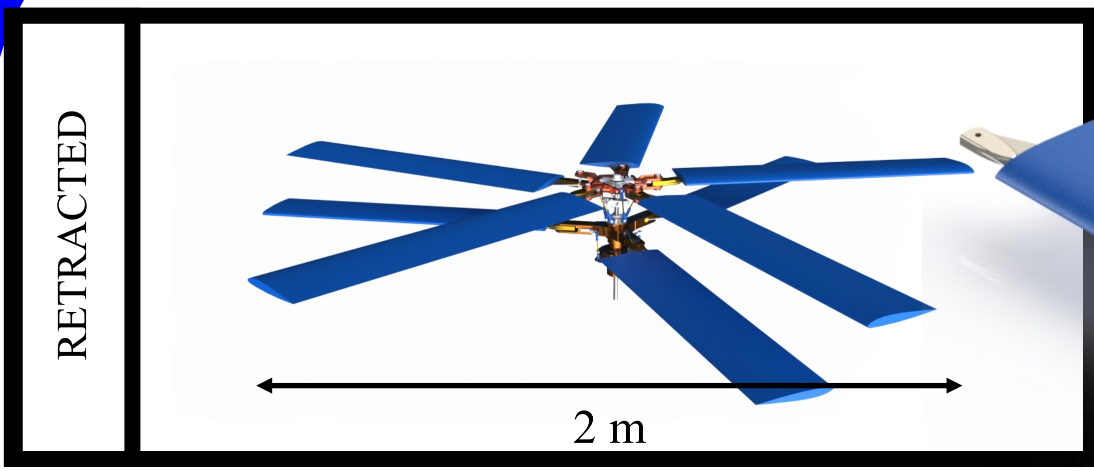
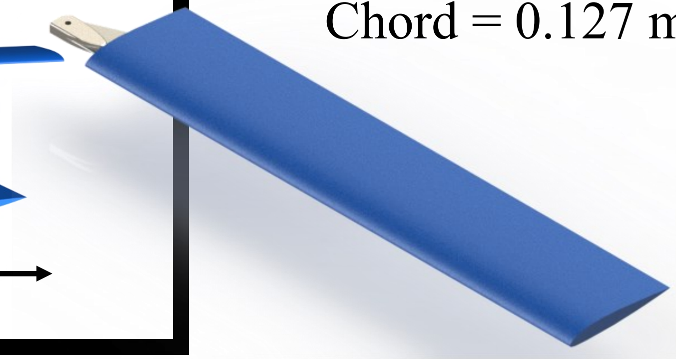
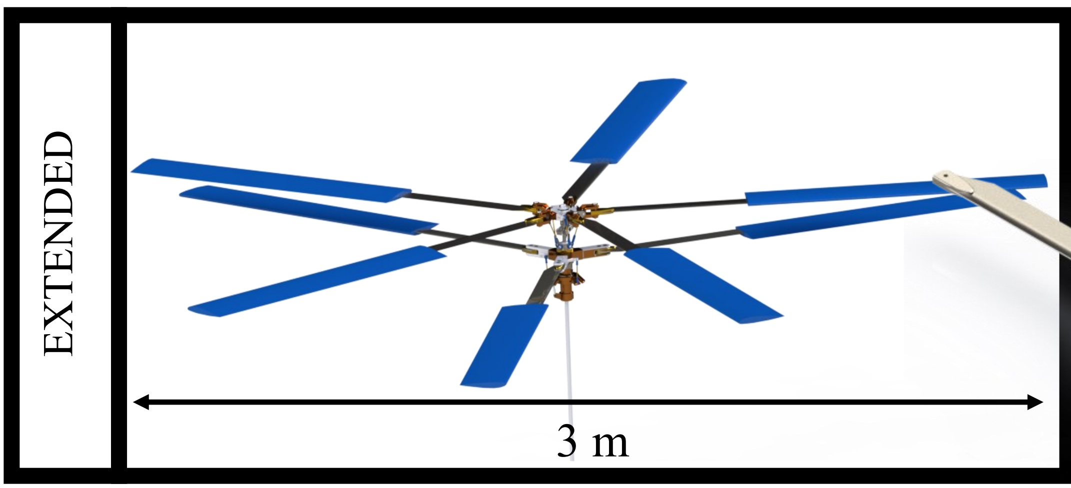
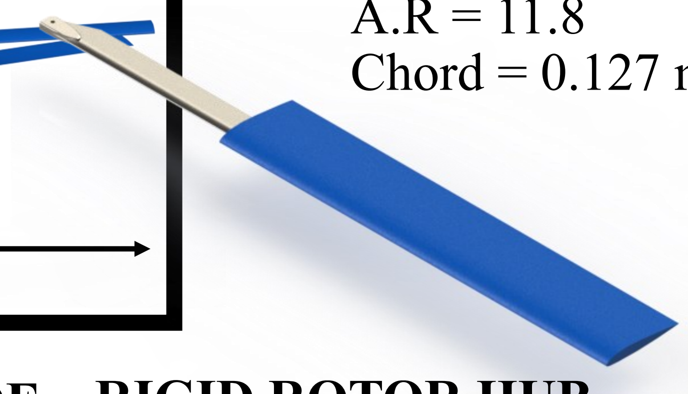




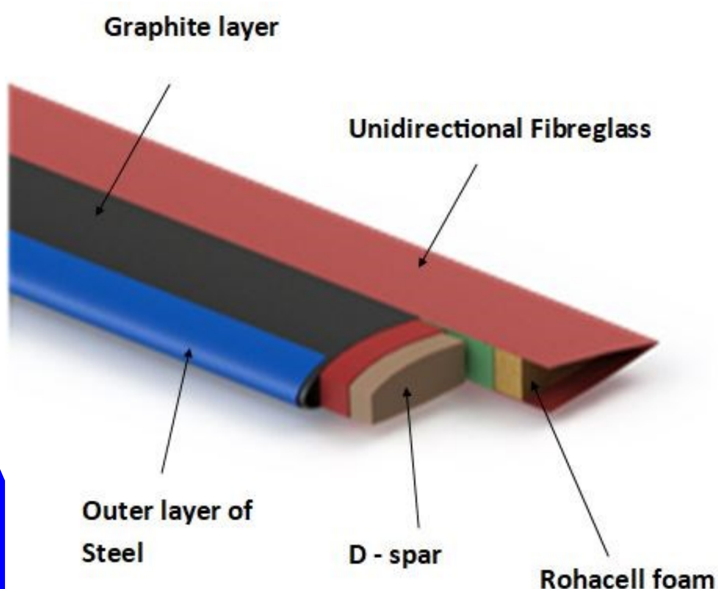
Retracted blade
Twist = -4 degree
A.R = 11.8
Chord = 0.127 m



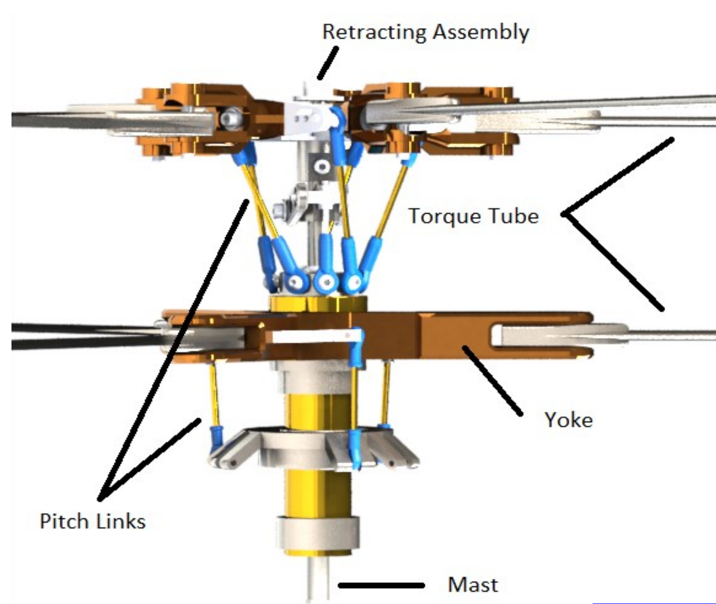


Extended blade
Twist = -6 degree
A.R = 11.8
Chord = 0.127 m

CROSS SECTION OF ROTOR BLADE



RIGID ROTOR HUB



Retraction mechanism for wing and rotor blades

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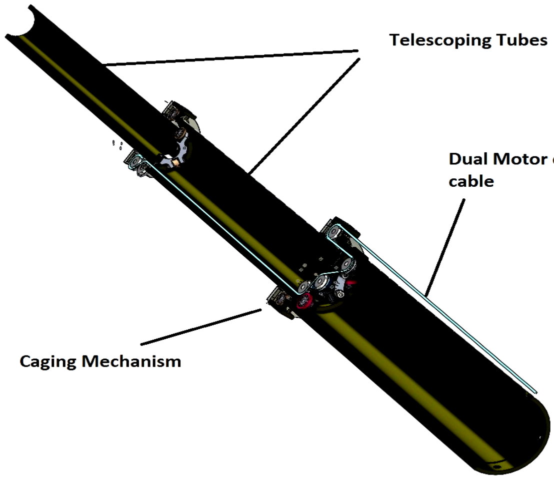
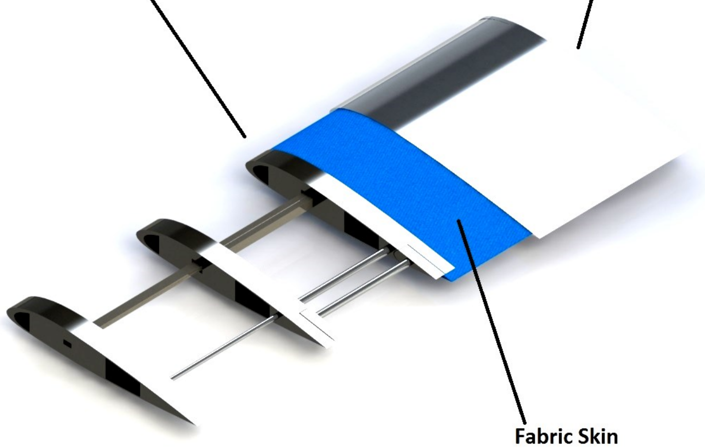
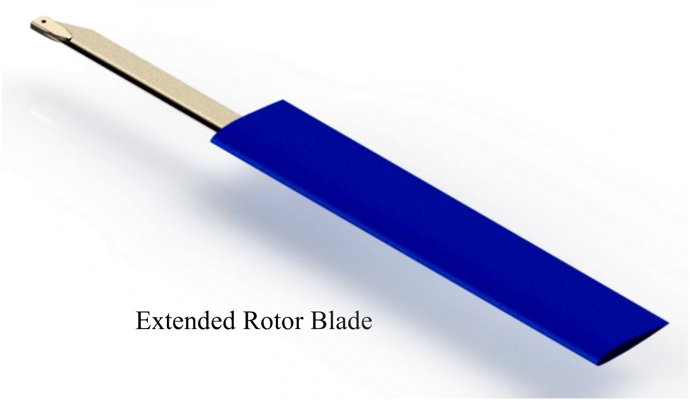


Torque box is an antenna like structure. A mechanical system is used to deploy the torque box.
A series of telescoping tubes are nested one within the other when the antenna is in a retracted stowed position. The outermost tube is rigidly attached to the support and the inner tubes are latched in the stowed position by a caging mechanism. The antenna is driven toward a deployed position by a dual motor driven cable which is terminated in a driving tube at the lower end of the innermost tube, from whence the cable is trained about pulleys at the tops and bottoms of successively large tubes of the antenna. The cable is wound on a drum at the lower end of the antenna and coaxial therewith.

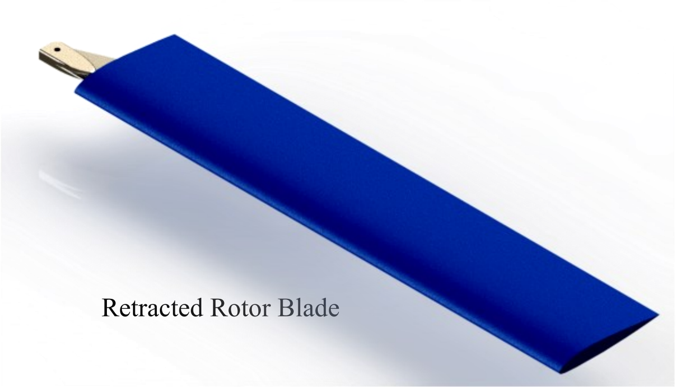
During deployment of the antenna, the drum rotates, thereby reeling in the deployment cable. The initial movement of the cable causes cam releasing of the latches in the caging device. Thereafter, the antenna tubes are extended until the final deployed position of the antenna is reached. A ratchet attached to the drum prevents reverse rotation of the drum and locks the antenna in the deployed position until the ratchet is released.

Similar kind of mechanism is used in rotor blade and tail rod extension/retraction.





Extended Rotor Blade



Retracted Rotor Blade

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Performance

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- The system boasts of a long range with decent burst capabilities. This is possible by the use of a twin propulsion system.

- When best range is required, the efficient rotor system is used. This achieves a half energy range of nearly 500 km at a steady speed of nearly 60 m/s.

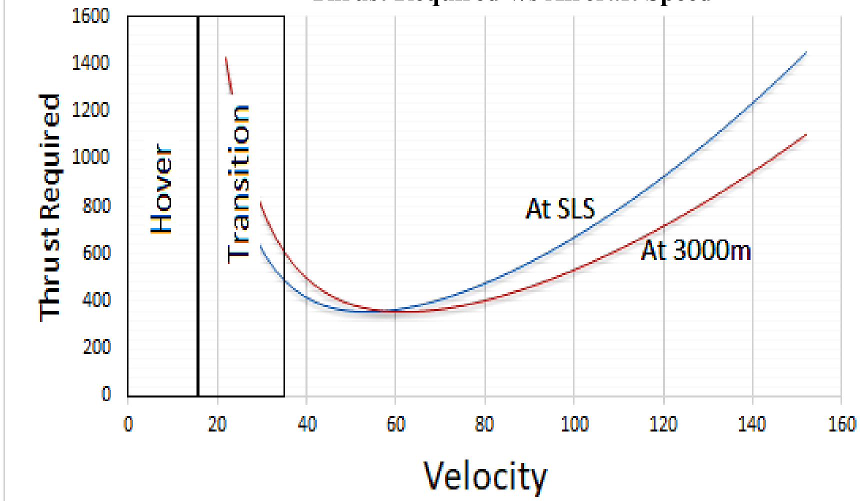
- When burst speed is required, along with maximum thrust from the rotor, the turbojets are switched on the give a dash speed up to 145 m/s. This level of thrust can only be sustained for a maximum of 20 minutes before the fuel reserves run too low for transition back to hover for safe landing.

- The unique non symmetric rotor configuration makes the system highly efficient and achieves a hovering capability for 138 minutes with 100% fuel usage and 72 minutes with 50% fuel at an altitude of 3000 m and also 149 minutes and 78 minutes for 100% and 50% fuel usage respectively at SLS.

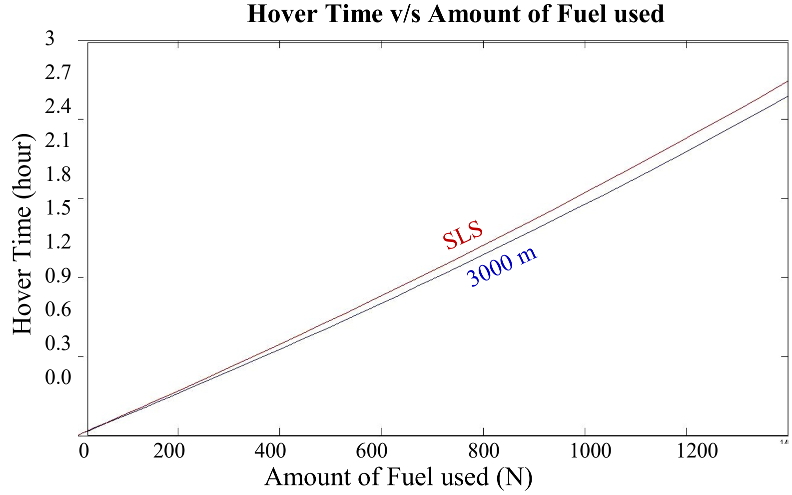
- Because of the high tip speed and minimum disc loading, the Druta has the Autorotation capability useful in the cases of engine failure.

The system is not designed to take-off or land in forward flight mode, but it is capable of performing an emergency water landing in forward flight mode. The inflatable wings act as a flotation device which will keep the payload above water in such cases. The performance of an emergency water landing would render the system unusable since the rotor and tail sections would likely break off during such a landing.

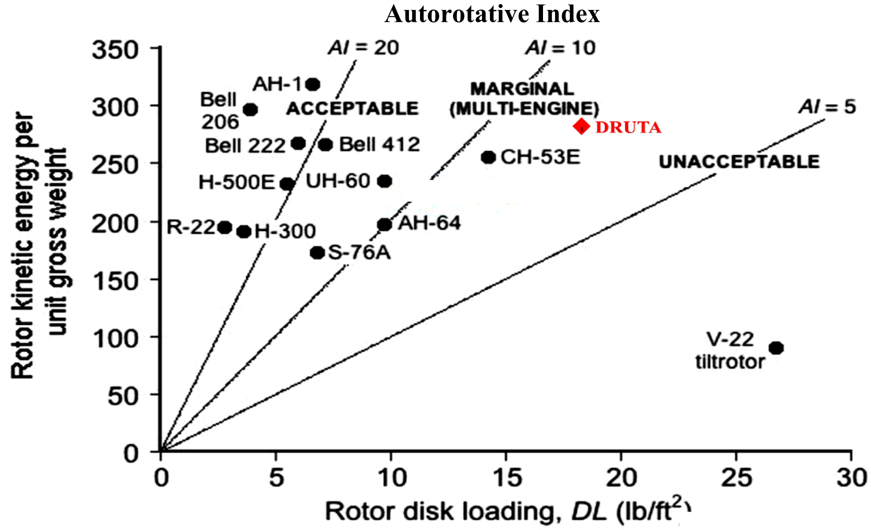
Thrust Required v/s Aircraft Speed



Hover Time v/s Amount of Fuel used



Autorotative Index



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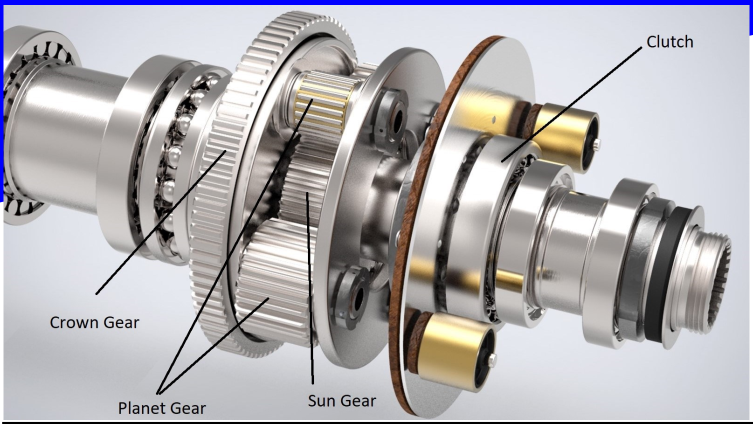
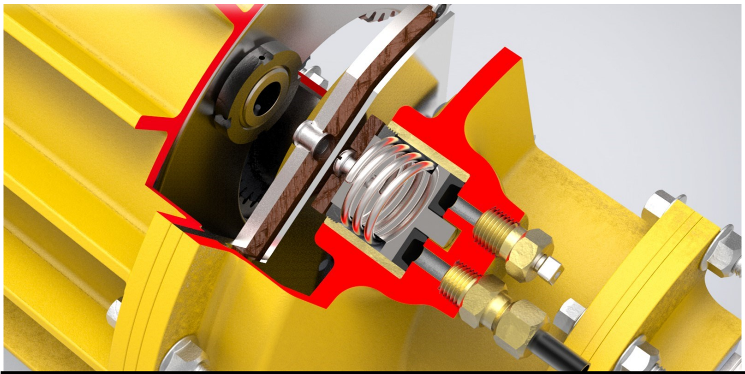
Drive Train



Planetary Gearbox with Hydraulic Brake



Hydraulic Brake

The transmission systems are elegantly designed to minimize gearbox weight while maximizing efficiency, compactness and strength. The other parameters considered are overall simplicity, ease of assembly / disassembly, vibration minimization and ease of manufacturability.

Hydraulic actuators are used to tilt the gearbox when transitioning from helicopter mode to forward flight mode. The gearbox steps the engine output RPM to the required rotor RPM using single stage planetary gears allowing for the design of an efficient, relatively light weight gear box. Additionally, the planetary ring was incorporated into the gearbox casing to reduce its weight and size.

Nickel chromium steel alloy provides high hardness and good wear resistance to the transmission system.

Hydraulic brakes are used for better control accuracy and easy maintenance.

Stage	Sun/ Satellite	Satellite/ Crown
No. of teeth (pinion/ gear)	26/41	26/65
Reduction ratio	1.58	2.5
RPM (pinion/gear)	6016/3815	3815/1526
Module	3	3

Light Weight Gearbox Body

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PROPULSION

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The propulsion system of *Druta* boasts of an innovative solution to the problem of tiltrotors experiencing forces during transition. The propulsion system of Druta consists of a turboshaft Rolls Royce M-250 C10 B 63 Kg and two minijets TJ23U of 2 Kg each

Turbojet Engine

- Very high thrust to weight ratio (>100)
- Compact and light (2Kg)
- Easy and rapid startup

Turboshaft engine

- High power to weight ratio
- Tried and tested multiple times
- High max continuous power(201 KW)

Engine Property	Value
Weight	2 Kg
Thrust(Max)	230 N
Specific Fuel Consumption	0.65 liters/ min
Dimensions (Diameter*Length)(mm*mm)	121*316

Engine Property	Value
Max Take-off Power	236 KW
Max Continuous Power	201 KW
Output Shaft RPM	6000
Engine Weight	63 Kg
Specific Fuel Consumption (Approximately)	0.47-0.51 kg/KW-h
Dimensions (Length*Width*Height) (mm*mm*mm)	1035*480* 585

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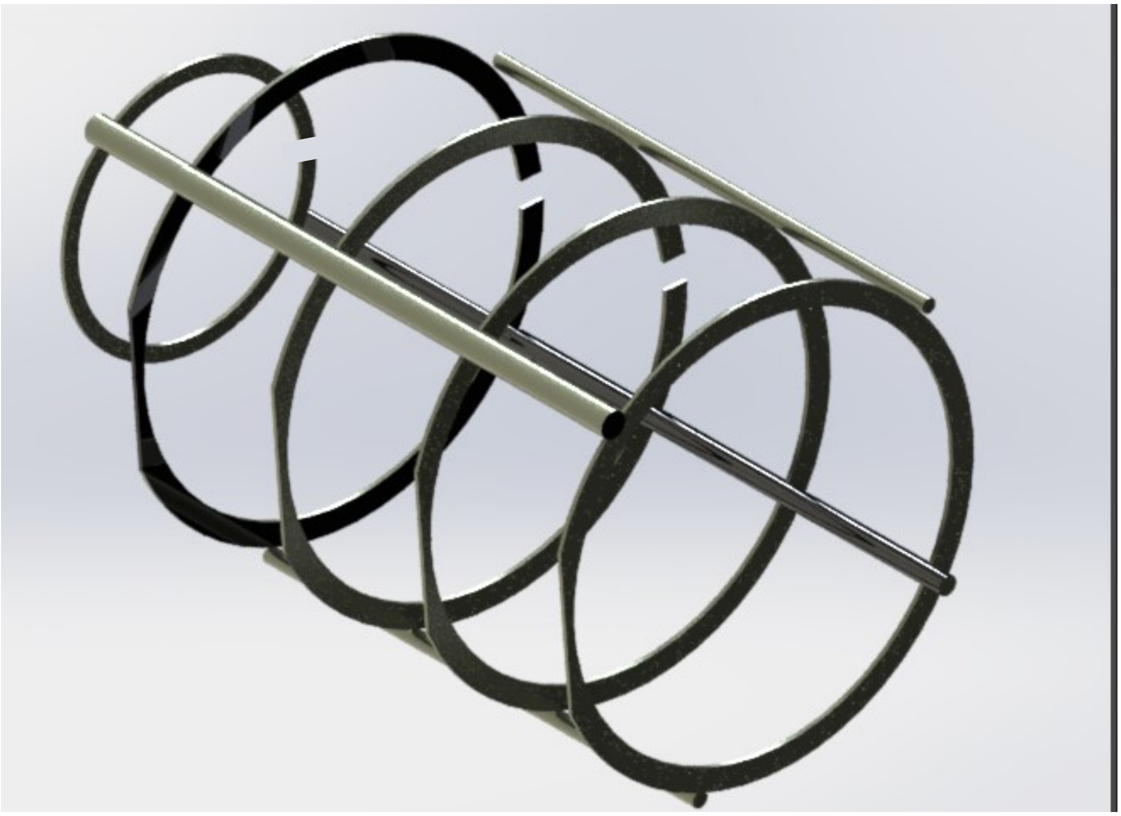
Airframe structure

The fuselage of Druta consists of four primary bulkheads and one secondary bulkhead. The secondary bulkhead is to support the rotor in forward flight configuration. The first primary bulkhead supports the payload. The second and third primary bulkhead is for supporting the transmission, wing and rotor in hover configuration. The fourth primary bulkhead supports the main engine and V-tail. Two jet engines placed over the fuselage are supported by the third and fourth primary bulkheads together. There are also many thin stringers that were included in the airframe in order to reduce the load on bulkheads and maintain the shape of the skin. The cross-section of the fuselage is circular in shape.



Aluminum-Lithium (Al-Li) was chosen for the construction of the main fuselage because it is lighter than standard aluminum and can be manufactured using traditional techniques. The tail is a composite construction to reduce weight. In addition to reducing weight, the composite structure is resistant to many of the harsh environments in which the aircraft will likely be operating.

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Avionics

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LIDAR-VLP-1
- 3D mapping with 300,000 points per second
- 100m range and 30° horizontal field of view

8x IR Camera
- 1080p/30fps video
- Motion detection
- 90° field of view

GNSS(GPS-701-GG) Antenna and Receiver
- 2 cm Location Accuracy

Laser Rangefinder
- Obstacle detection at up to 8.63 nmi (16 km)

2x Autopilot-VECTOR
- Fully autonomous operation
- Redundant CPU
- Inertial navigation system integrated

Rugged Mini PC
- Intel i7 processor for 3D mapping

Traffic Collision Avoidance System
- Detects aircrafts and obtains location and flight path trajectory

RADAR Altimeter
- Altitude above ground level up to 2550 ft.

Control System

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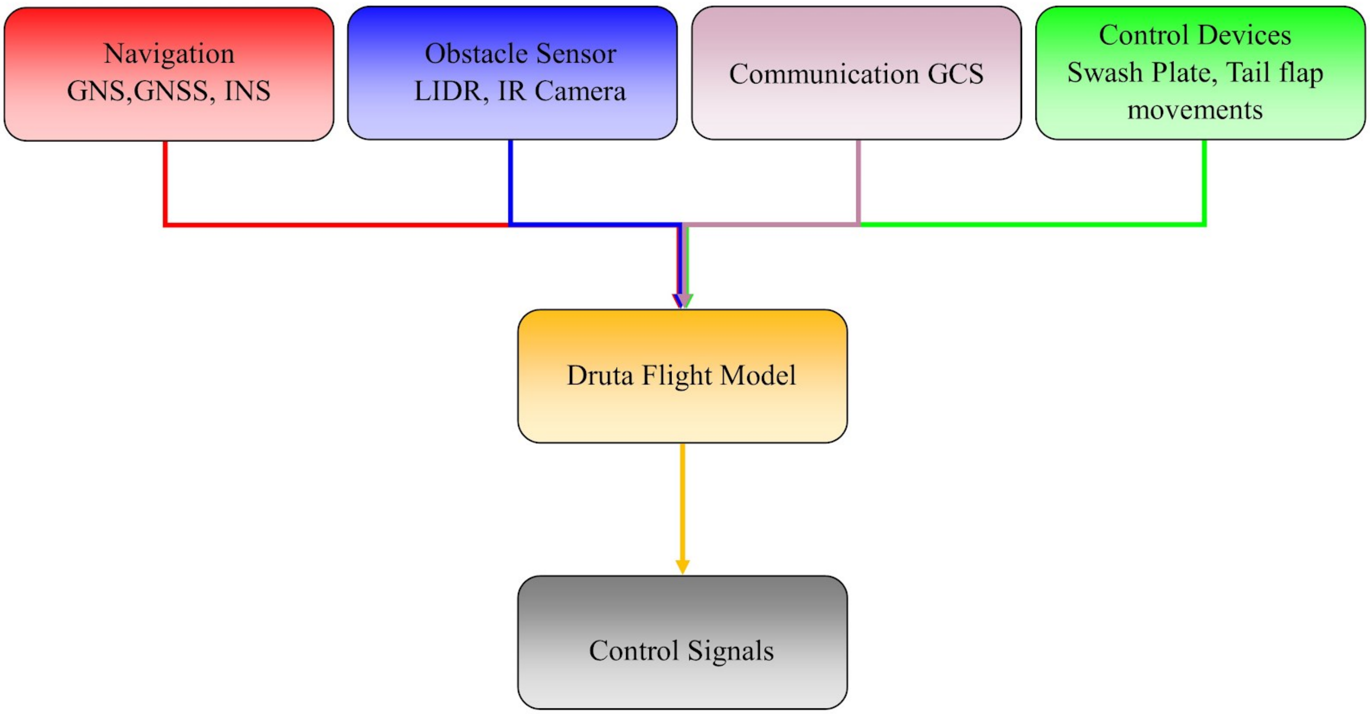
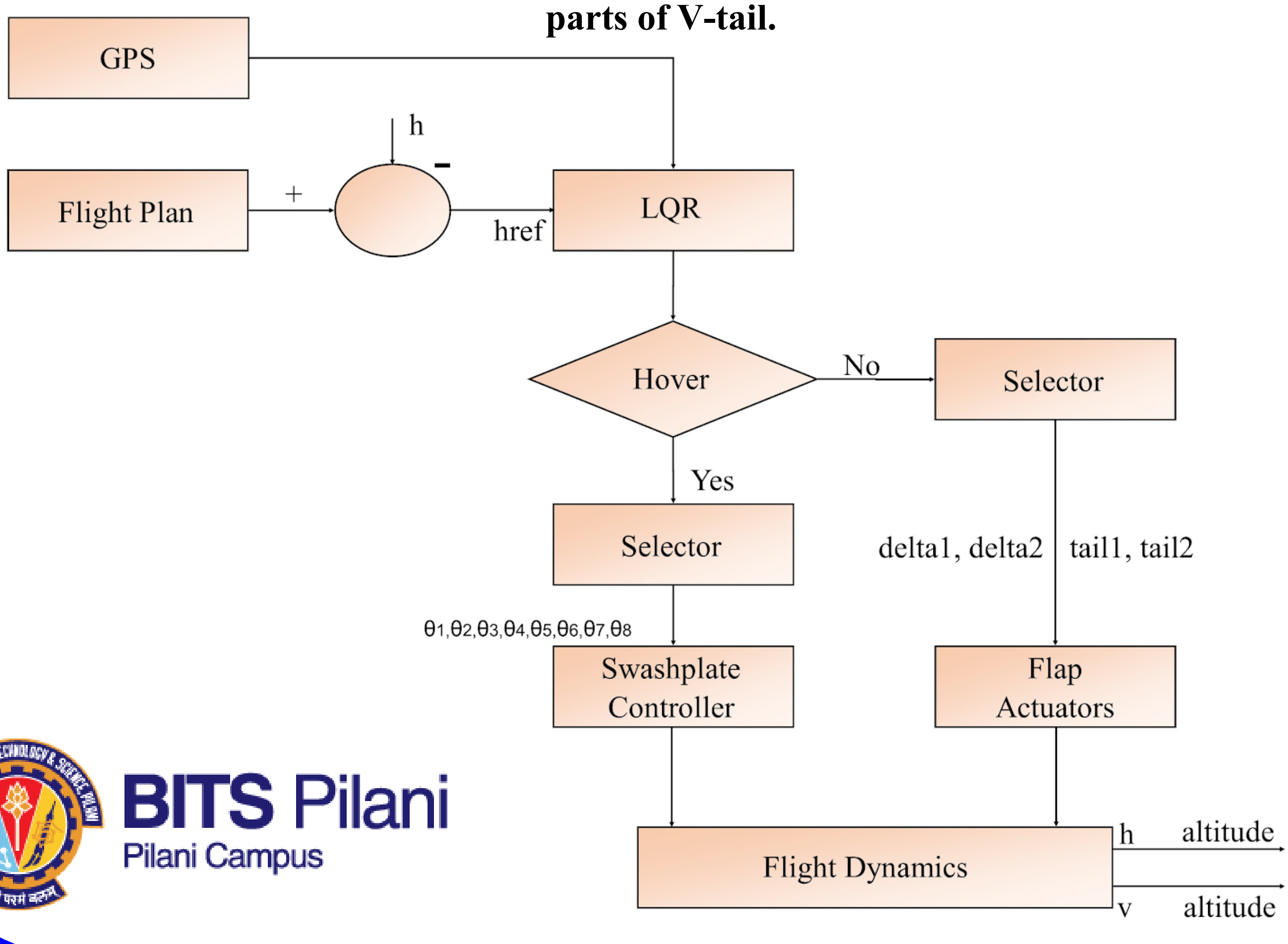
General signal flow diagram



Design of Control systems for Druta. θ1,θ2,θ3,θ4,θ5,θ6,θ7,θ8 these refer to pitch angel of individual rotor blade. delta1,delta 2 represents deflection in ailerons while tail1,tail2 represents angles of two parts of V-tail.



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Landing Gears

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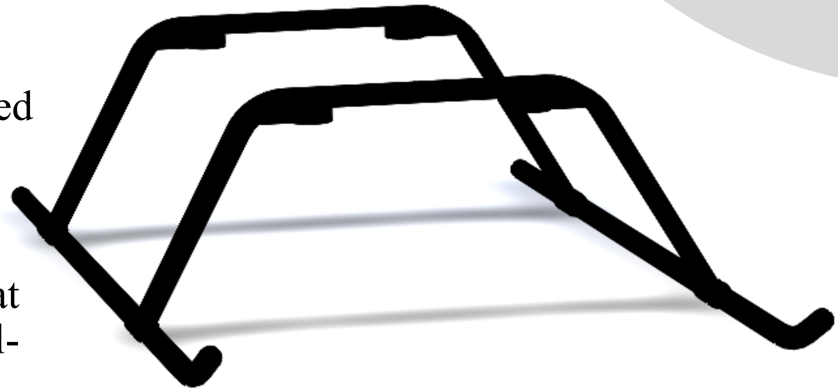
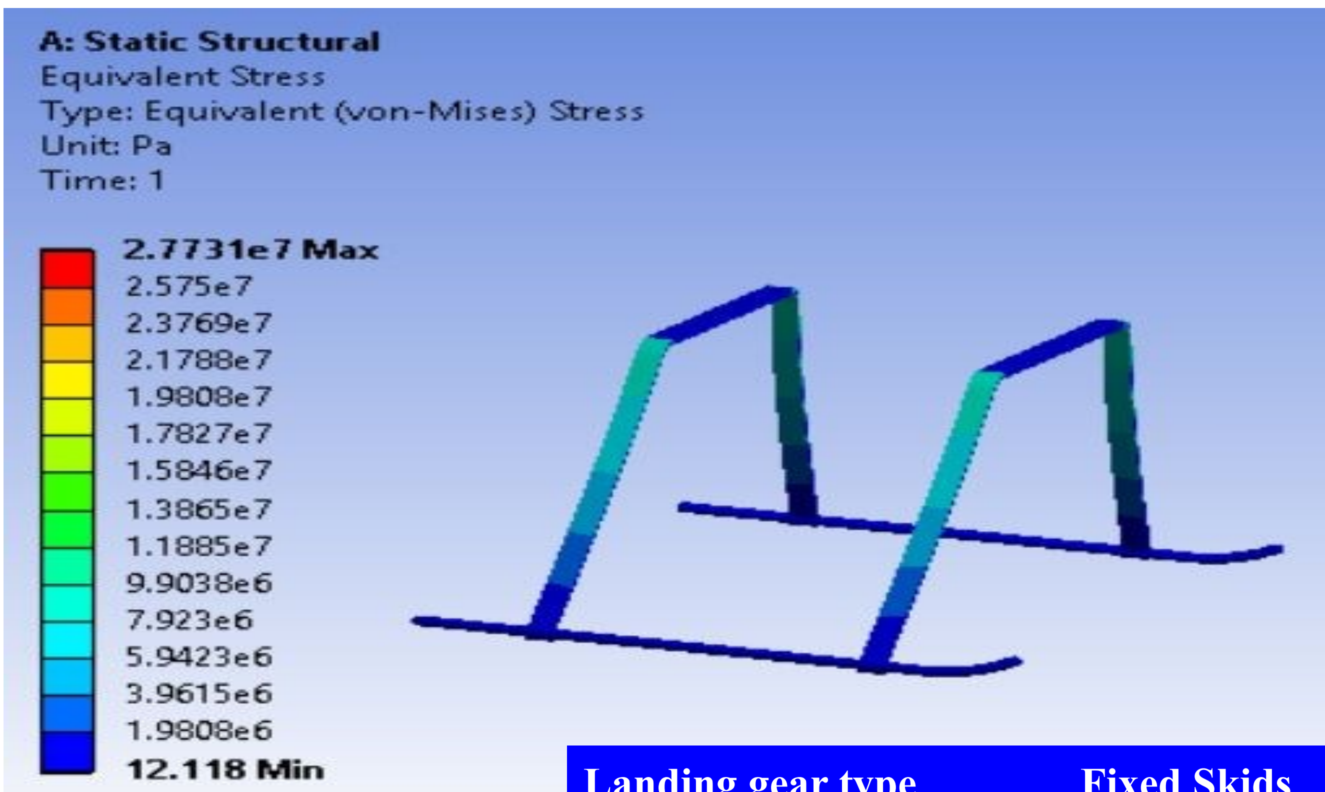
- Druta uses fixed skid landing gear which is light in weight and simple.
- Landing gear is statistically placed about the C.G. which balances the aircraft.
- Aluminum 1060 H 18 is used that gives it enough strength and reliability.





The landing gear has the following parameters:

Landing gear type	Fixed Skids
Length of landing gear	0.45 m
Lower separation	1.5 m
Weight	13 kg

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Summary

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At the Aero India Show– 2019, BITS Pilani Undergraduate team presents *Druta, a variable diameter coaxial tiltrotor with span wise adaptive wings, to meet all of the vehicle and operational requirements . It is a unique innovative design and has an edge over other existing VTOL aircrafts.*

With many novel design variations like span wise adaptive wings, variable diameter coaxial tiltrotor, combination of turbojets and turboshaft engine, Druta meets and exceeds the requested capabilities. These design variations can be used independently in other aircrafts also or Druta can be developed further to scale to other versions.

Team GARUDA is proud to present this unique vehicle design solution in a platform like Aero India to support the Make in India campaign

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