DRUTA: The Rapid Eagle
A Modern-Day Reconfigurable VTOL Aircraft with Multi-Mission Capabilities

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ABSTRACT

The helicopter's high degrees of hover capabilities and maneuverability are certainly important performance features in today's domestic and international security environment. While able to hover for hours depending on fuel levels, conventional helicopters are limited to limited top speed by the rotors aerodynamics. On the other hand, fixed-wing planes can reach much faster speeds but are not able to hover with a great degree of efficiency. The challenge is to merge the aerodynamics required for hover capabilities and the propulsion necessary to achieve greater speeds 'without unacceptable compromises in range, efficiency, useful payload or simplicity of design'.

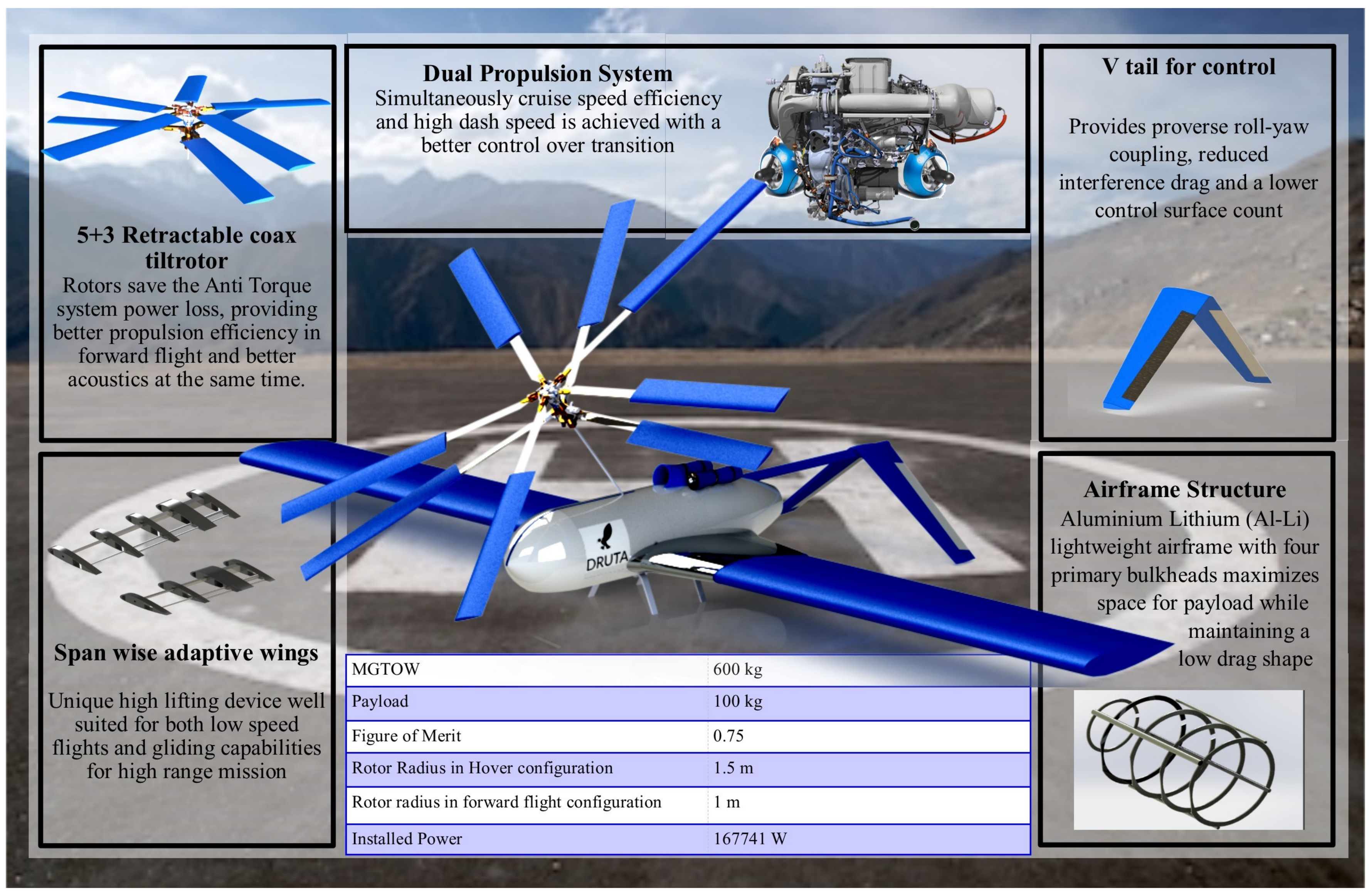
MISSION/PROBLEM STATEMENT

The aim of the team was to design a Group-3 sized unmanned VTOL aircraft that achieves high speed forward flight (relative to current VTOL aircraft) and efficient hover through the use of novel reconfigurable propulsive and lifting devices and has superior performance over a comparably sized aircraft that does not have reconfigurable systems. Druta was designed keeping the above problem statement in mind, with Maximum Gross Takeoff Weight (MGTOW) 600 kg having payload 100 kg or greater, to operate in a megacity-type environment and fit down narrow streets and in confined spaces, hence, limiting its maximum horizontal dimension to no more than 3 m in hover configuration and increasing its utility.

INNOVATION IN DESIGN

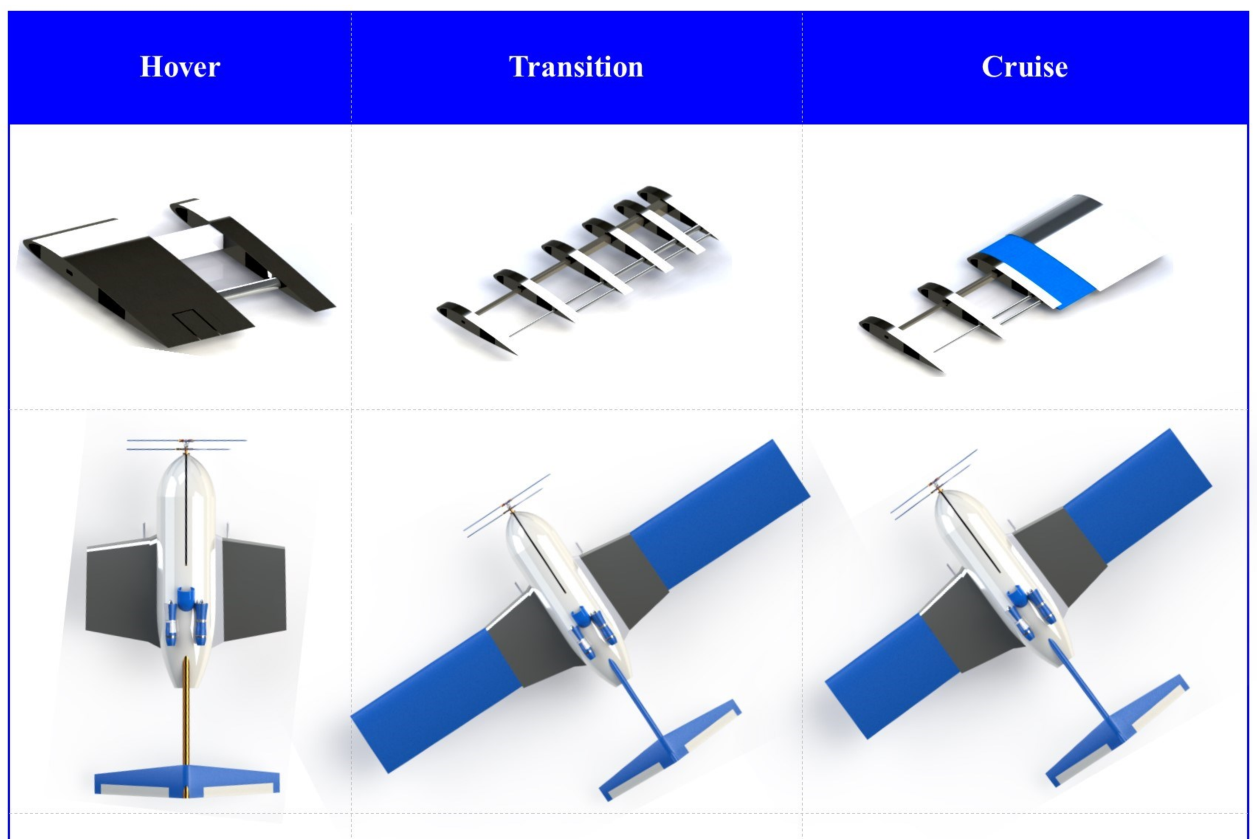
Druta is a reconfigurable VTOL with variable diameter coaxial tiltrotor and spanwise adaptive wings able to fit in between narrow streets and confined spaces for use in megacity type environments. The adaptive length of wings makes them suitable for both low-speed flights and gliding capabilities for long-range missions. The variable diameter coaxial tiltrotor provides the required thrust in hover configuration with lower disk loading and increases the efficiency in forward flight configuration. A unique combination of 5+3 coaxial rotor blades saves the Anti-Torque System power loss, providing better propulsion efficiency in forward flight and reduces noise at the same time. 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 whereas V-tail provides roll-yaw coupling in forward flight. With a combination of turboshaft and two turbojet engines, higher cruise speed efficiency and dash speed are achieved with better control over the transition. Druta can reach a maximum speed of 535 km/ hr. With cruise range of 498 km at 3000 m altitude and hover time of 75 minutes with 50% fuel capacity, it efficient in both forward flight and hover.

DESIGN FEATURES



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

SPANWISE ADAPTIVE WINGS

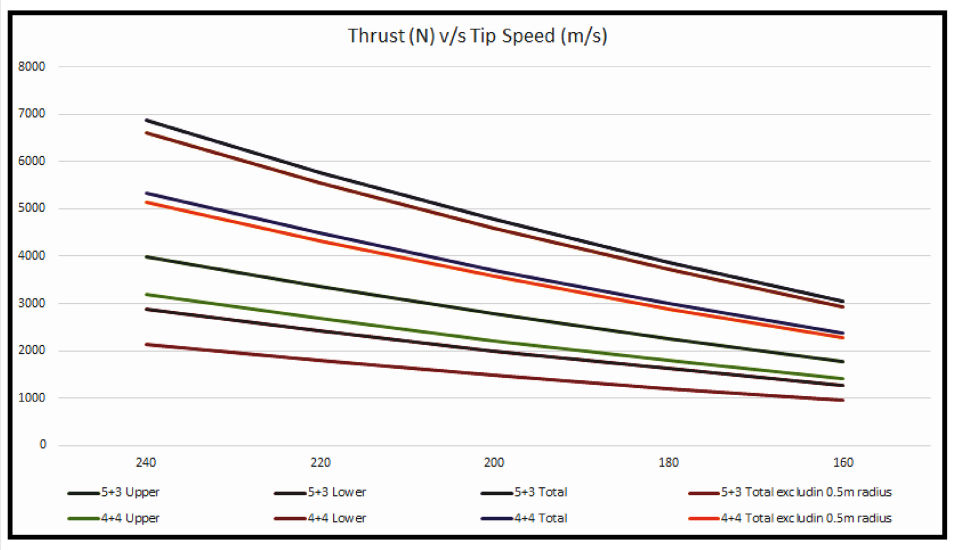


Hover	Transition	Cruise
The fully retracted wings produces a minimum download in hover configuration due to the air wash of rotors. This decreases the power requirement during hover and increases the hover time.	During transition, wing span opens up to the tip to tip length of 7.5 m, thus reaching the required thrust value at minimum. Such a span also provides the gliding ability for the long range operations.	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 very fast forward speed, and is helpful in achieving maximum dash speed.

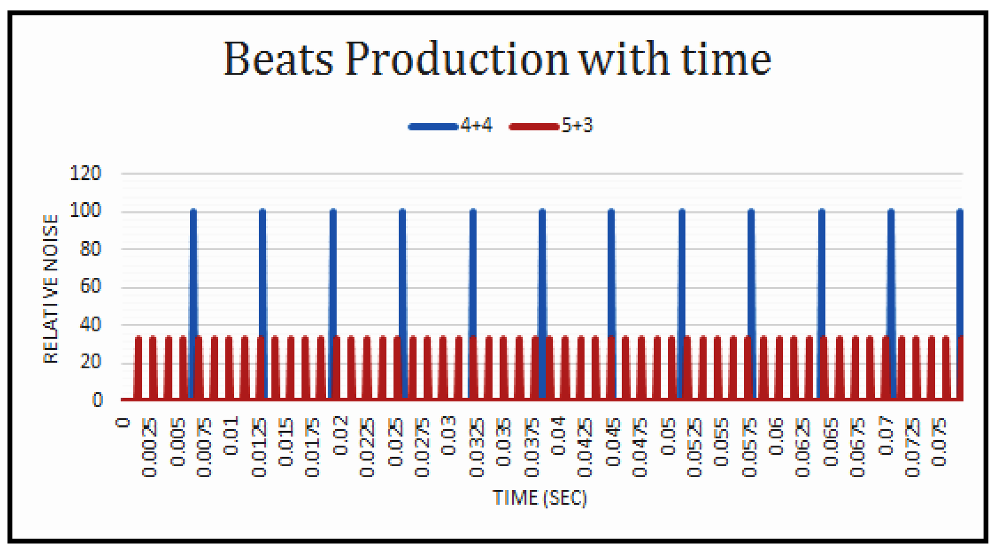
Wingspan of Druta is varied using a retracting torque box and skin covering of Vectran. Wings are retracted in hover configuration while completely extended to a span of 6.5m in forward flight configuration.

The wing is mainly comprised of a single torque box, which is manufactured to run the length of the wingspan. 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.

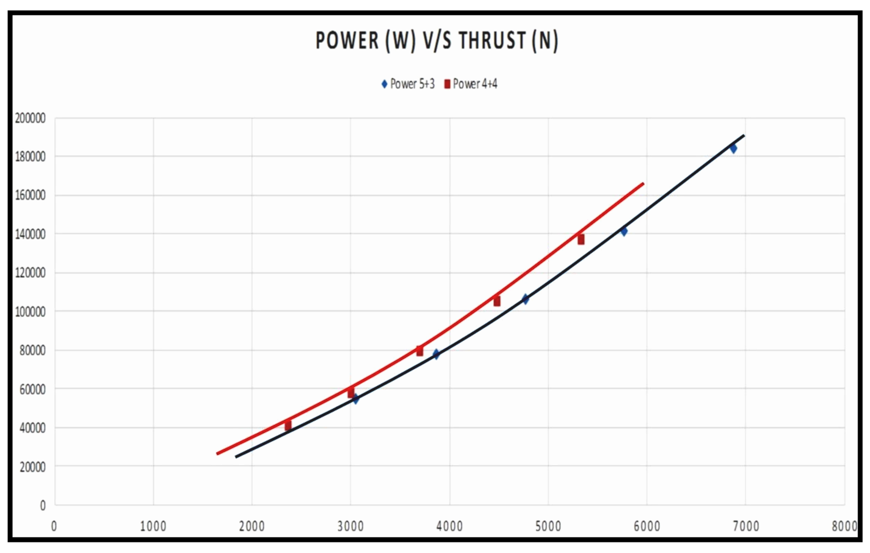
5+3 RETRACTABLE ROTOR SYSTEM



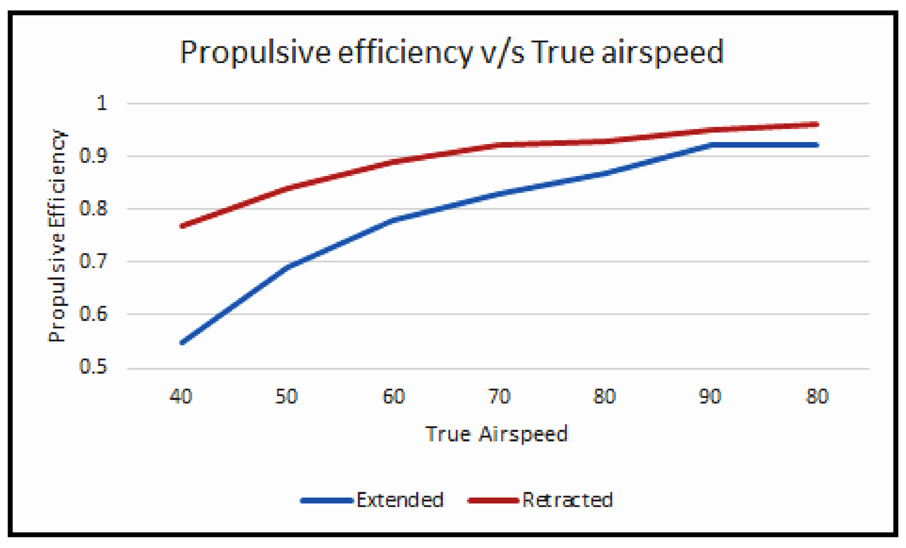
20% more thrust is produced compared to conventional coax-system at constant tip speed of 232m/s



75% noise reduction as compared to conventional coaxial rotor system

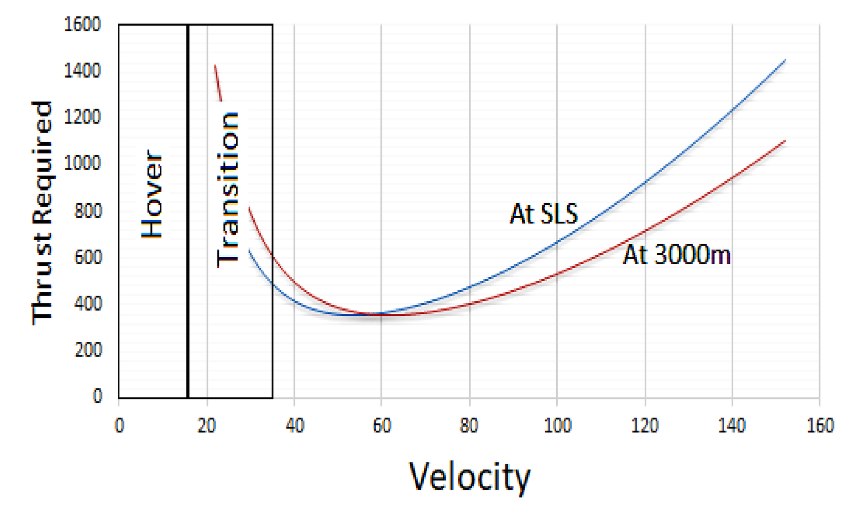


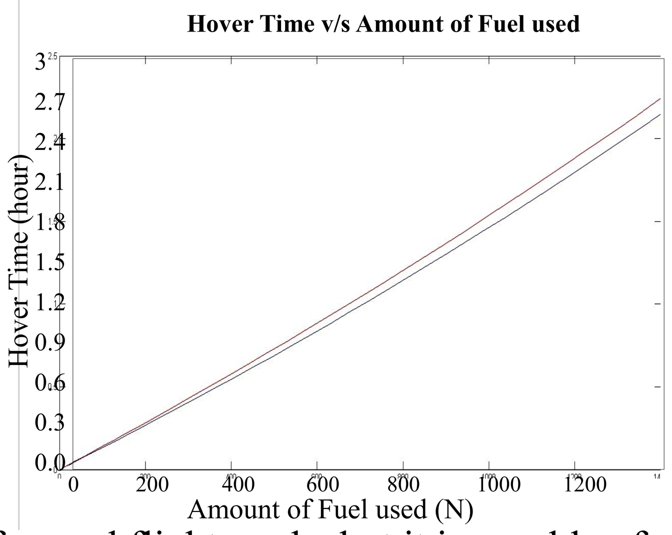
Lesser Power Consumption in Hover configuration with same amount of thrust produced

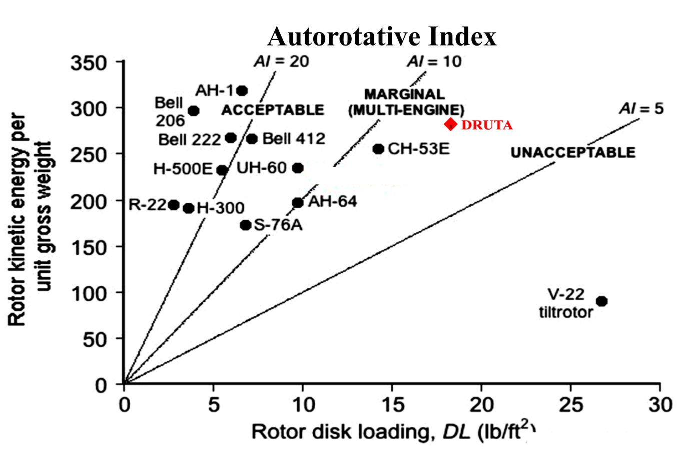


Retractable rotor blade to increase the propulsion efficiency by 14% at 62 m/s in forward flight configuration.

PERFORMANCE ANALYSIS







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.

- 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.

CONCLUSION

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 to Aero-India 2019.

ACKNOWLEDGEMENT

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