MIST AVRO

Executive Summary

Undergraduate Design Team

Department of Aeronautical Engineering, Military Institute of Science & Technology, Mirpur Cantonment, Dhaka, Bangladesh

Vertical Flight Society 40th Annual Student Design Competition

Sponsored by

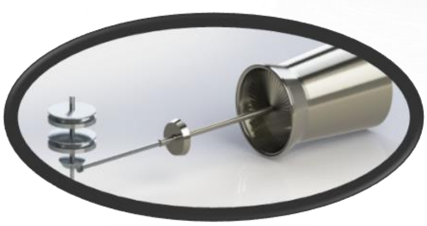
SIKORSKY
A LOCKHEED MARTIN COMPANY

<u>Main Features</u>

1. Combination of rotor and wing.

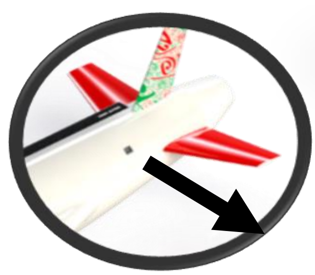
2.Folding Mechanism of Rotor

3. Turbofan to Turboshaft mode using Clutch

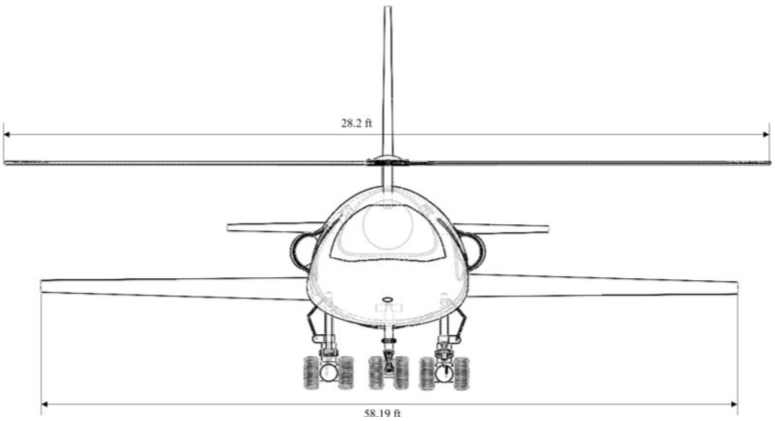


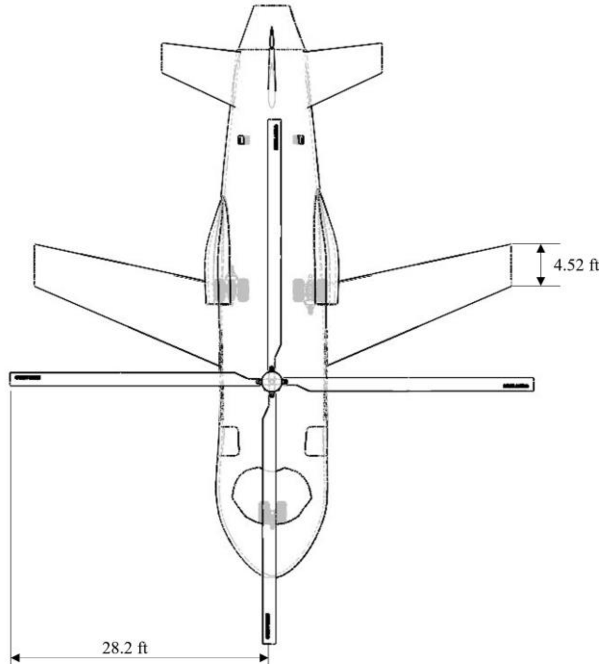
5. Fixed wing for High-Speed Cruise

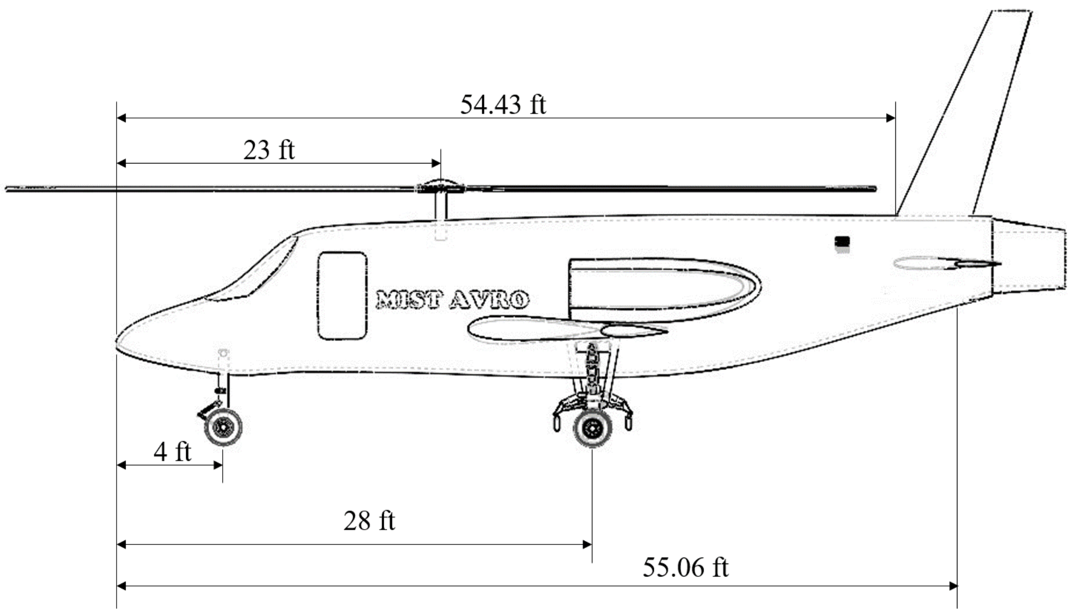
4. Anti-Torque System



Dimensions


28.2 ft
58.19 ft


4.52 ft
28.2 ft


54.43 ft
23 ft
MIST AVRO
4 ft
28 ft
55.06 ft

Introduction

The AVRO is an innovative aircraft designed for the 40th Annual Student Design Competition on High-Speed Vertical Takeoff and Landing (HSVTOL) Aircraft. It aims to surpass specified cruise speed and altitude thresholds, providing superior vertical flying capabilities. The AVRO combines cutting-edge technologies and unique design ideas to optimize payload capacity within an interior cargo bay. Motivated by the value of vertical flight in emergency response, transportation, and logistics, the AVRO aims to contribute to the evolution of vertical flying capabilities by excelling in performance and adaptability.

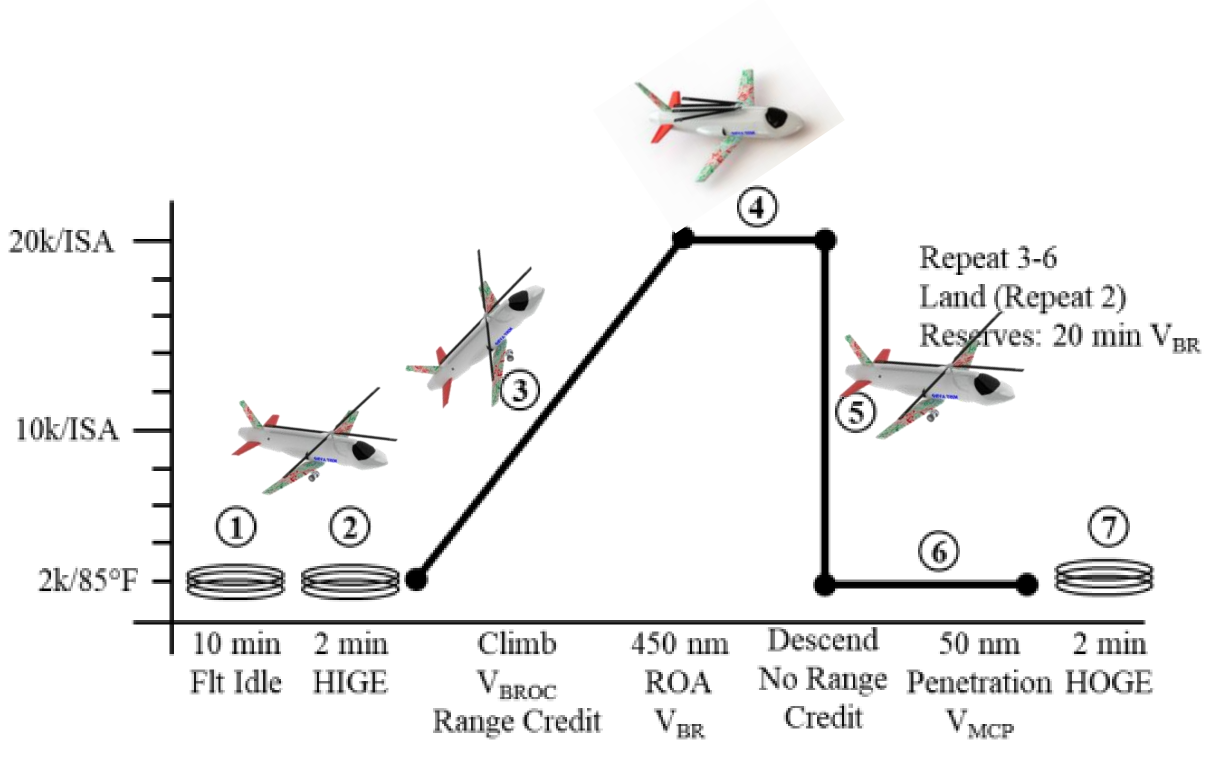
Design & Overview

The AVRO is a revolutionary hybrid aircraft that combines rotary- and fixed-wing flying, offering unmatched performance and agility. Its unique design and cutting-edge technology enable it to switch between rotor-driven and pure turbofan modes for improved agility. The rotor system, folded in midair, reduces drag and enables the aircraft to cruise through the atmosphere like a conventional turbofan-powered aircraft. The anti-torque system uses engine bleed air, directed to strategically deposited thrusters along the fuselage.

MTOW (lb.)	Payload (lb.)	Cruise Speed (kts)	Empty Weight (lb.)
28,701.85	5,000	450	16,101.85

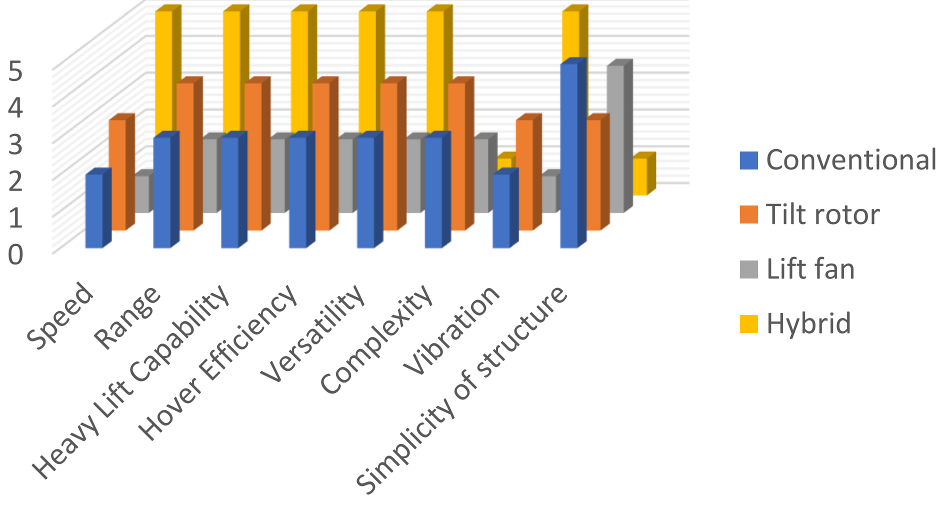
Mission Profile

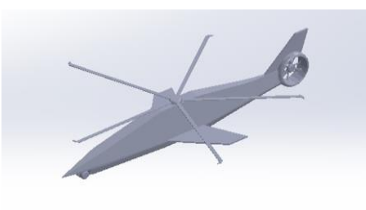
The operation requires a manned aircraft with a 5000-lb cargo capacity, including a 1000-lb MEP. HIGE takeoff and hover in a mid-mission landing zone should be possible. It should cruise up and maintain an optimum climb speed, then cruise range at 450 KTAS. The aircraft must land HOGE and conduct low-altitude, high-speed penetration for 50 nm. It should also hover and cruise at high speeds with a 500-nm radius of action (ROA).



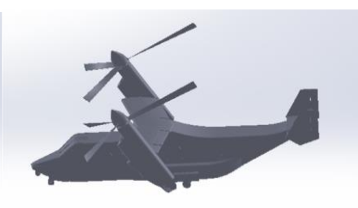
Configuration Trade Off Study

Criteria	Weights (%)	Hybrid	Conventional	Tilt rotor	Lift fan
Speed	20	5	2	3	1
Range	15	5	3	4	2
Heavy Lift Capability	20	5	3	4	2
Hover Efficiency	15	5	3	4	2
Versatility	10	5	3	4	2
Complexity	10	1	3	4	2
Vibration	5	5	2	3	1
Simplicity of structure	5	1	5	3	4
Total	100	4.35	2.75	3.75	1.9

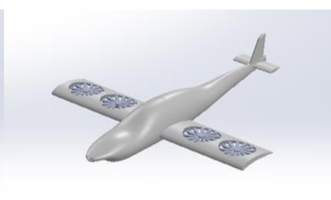




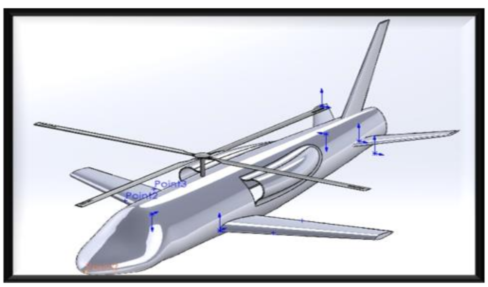
Conventional Helicopter



Tilt Rotor



Lift Fan

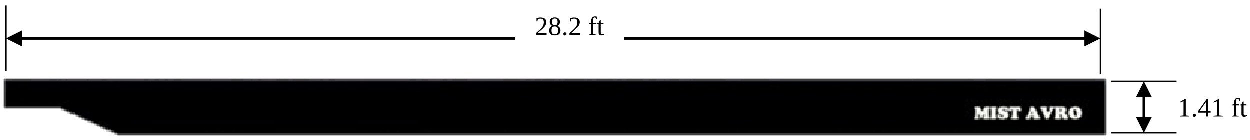


Hybrid Aircraft

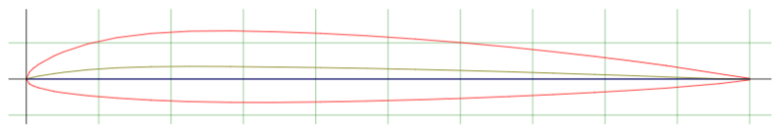
Selected Configuration

After analyzing four configurations, hybrid aircraft are the best option for achieving all RFP requirements. The other three variants fulfill some but not all dedicated mission criteria. The hybrid structure initially had a fixed wing for high-speed cruising and a folding rotor system for hovering. The fixed wing and low rotor disk loading will reduce downwash and outwash, allowing high-speed travel.

Rotor Design

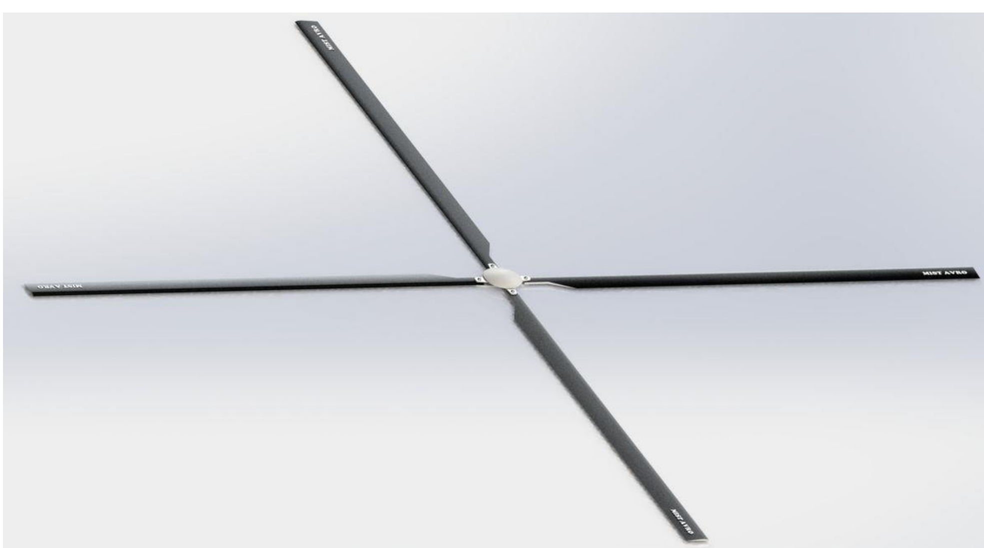


Airfoil

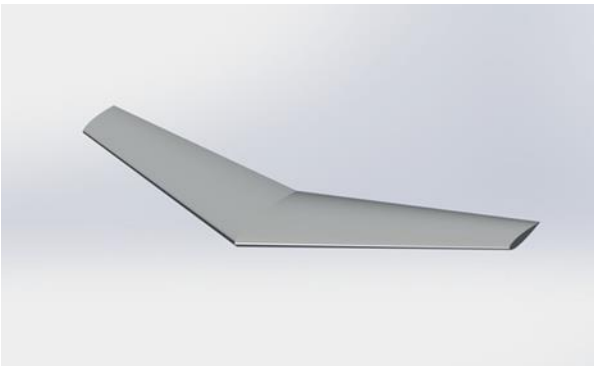


FX 69-H-098

Disk Loading	12 psf
Blade Diameter	56.419 ft
Blade Chord	1.41 ft
Number of Blade	4
Aspect Ratio	20
Coefficient of thrust, C_T	0.00968
Solidity, σ	0.06366
Figure of Merit	0.7885
Hover tip Mach Number	0.65
Rotor RPM	252



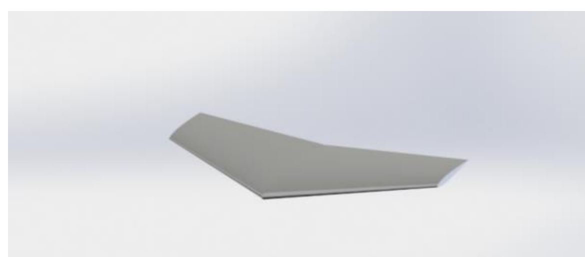
Wing Design



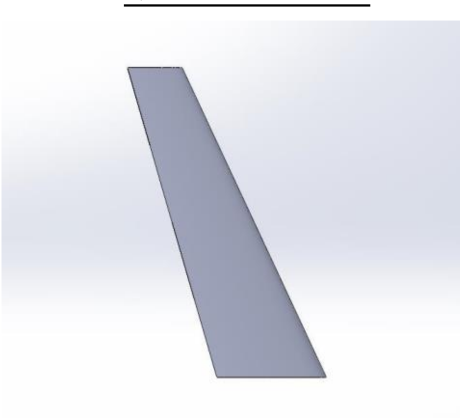
Number of Wings	Monoplane
Wing Vertical Location	Mid-Wing
Wing Configuration	Swept-back
High Lift Device	Fowler Flap
Airfoil	NACA 23018
Wing loading (lb/ft^2)	101.1214498
Wing Planform Area (ft^2)	296.6729617
Aspect Ratio, AR	6
Taper Ratio	0.5
Wing Span(ft)	42.19049383
Effective Span(ft)	41.81933612

Horizontal Tail

Horizontal Tail Location	Aft
Horizontal Volume Coefficient	1.4
Correction Factor	2
Optimum Tail Moment Arm (ft)	30.49012722
Horizontal Tail Planform Area (ft^2)	95.78778368
Airfoil	NACA 0012



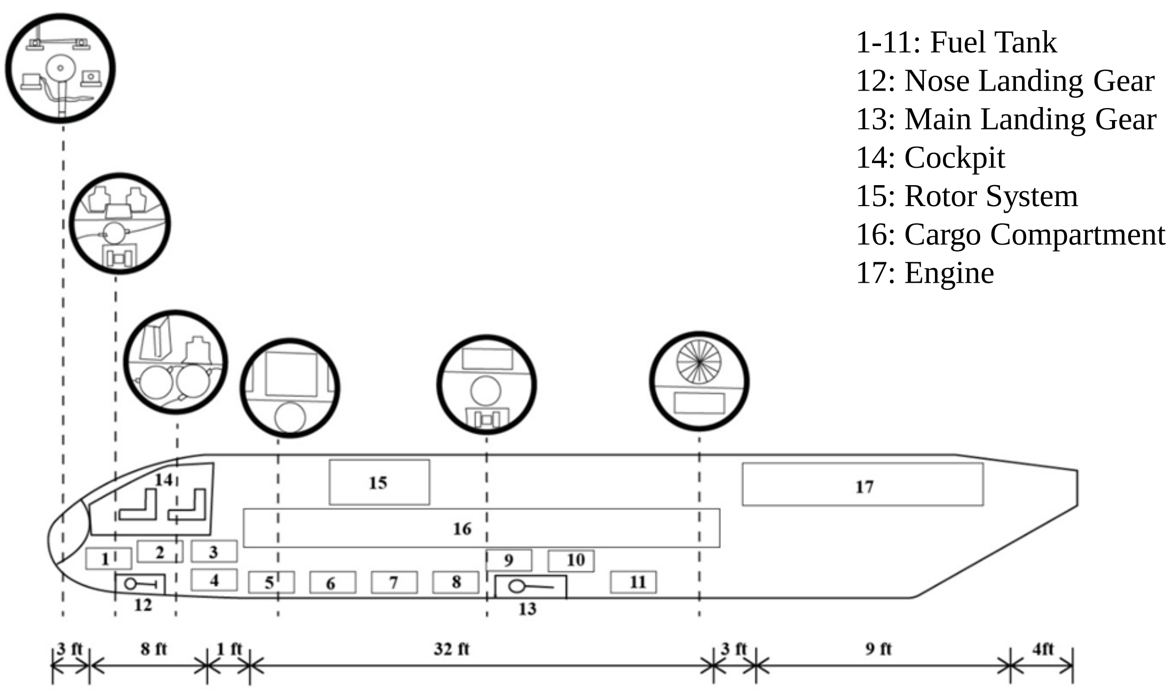
Vertical Tail



Vertical Tail Configuration	Conventional
Vertical Tail Volume Coefficient	0.15
Vertical Tail Moment Arm (ft)	30.49012722
Vertical Tail Planform Area (ft^2)	61.57786094
Vertical Tail Airfoil Section	NACA 0015
Vertical Tail Aspect Ratio	4
Vertical Tail Taper Ratio	0.5

Fuselage Design

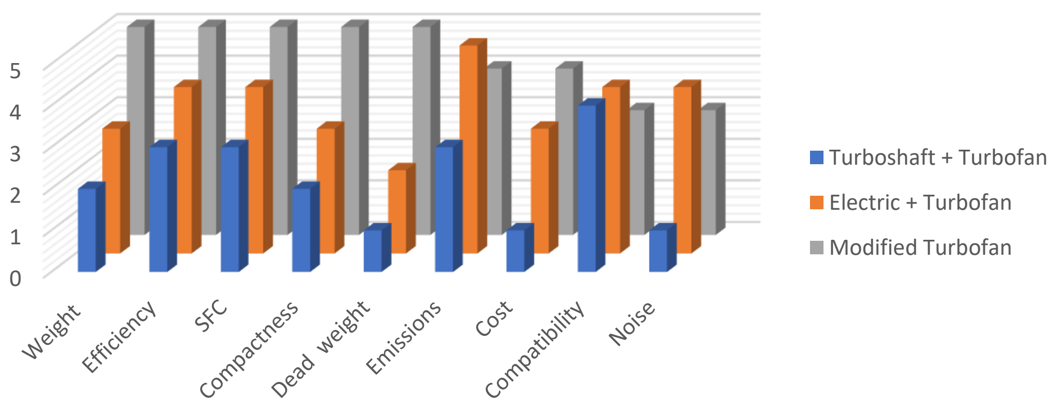
Fuselage length (ft)	60
Wall thickness, T_w (ft)	0.328084
External fuselage diameter, D_f(ft)	16
Number of crew	3
Nose length (ft)	3
Cockpit length L_c (ft)	8
Door length (ft)	5
Cockpit to cargo clearance (ft)	1



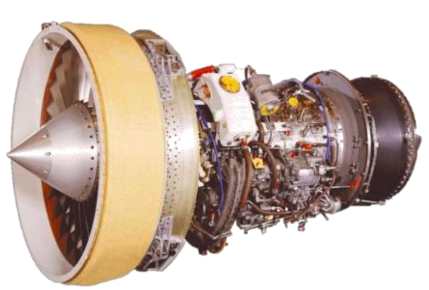
Component placement inside fuselage

Power Plant Selection

Criteria	Weights (%)	Dual propulsion 1: Turboshaft + Turbofan	Dual propulsion 2: electric + Turbofan	Modified Turbofan
Weight	10	2	3	5
Efficiency	15	3	4	5
SFC	15	3	4	5
Compactness	10	2	3	5
Dead weight	10	1	2	5
Emissions	10	3	5	4
Cost	10	1	3	4
Compatibility	15	4	4	3
Noise	5	1	4	3
Total	100	2.45	3.6	4.4



Modified Turbofan gets the highest score of 4.4, followed by Dual Propulsion 2 (3.6) and Dual Propulsion 1 (2.45). According to the weights, the Modified Turbofan system is the best alternative for efficiency, SFC, emissions, and noise.

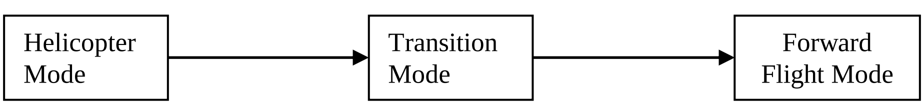


GE CF34-3B

CF34-3B	
Thrust (lb)	9220
Pressure Ratio	21:1
Bypass Ratio	6.2:1
Airflow (lb/sec)	321.9
SFC (lb/lbst-hr)	0.346
Fan Diameter (in)	44
Length (in)	103
Weight (lb)	1,669

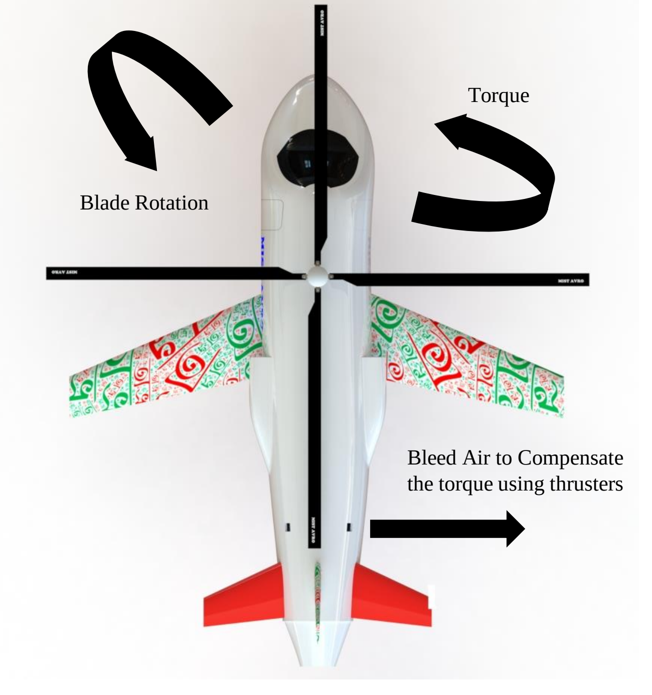
Transmission System

- **Power Delivery:** The transmission system effectively transfers power from the turbofan engine to the rotor system and aircraft propulsion. It optimizes engine power for vertical lift and forward propulsion, enabling smooth flight mode changes.
- **Pitch and Speed Control:** The transmission system transfers power from the engine to the rotor blades to regulate pitch and speed. Maneuverability, precision hovering, vertical takeoffs and landings, and other rotary-wing tasks require this control.
- **Reduction Stages:** The transmission's rotor gearbox is critical. Bevel Gear Reduction and Sun and Planetary Gear Reduction are its primary reduction stages. The sun and planetary gear reduction step decreases the speed to 252 RPM by 12:1 ratio, while the bevel gear reduction stage reduces it by 6:1.
- **Cone Clutch for Mode Transitions:** The transmission system's cone clutch allows seamless mode transitions between rotor-driven flying and pure turbofan mode. Cone-shaped surfaces and friction engage and disengage the rotor assembly. The clutch transfers engine power to the rotor during rotor-driven flight mode and disengages to fold the rotor blades for pure turbofan mode, lowering drag and improving forward flight.
- **Seamless Changeover:** The transmission technology makes rotor-driven flying and pure turbofan mode seamless. It ensures seamless rotor system engagement and disengagement during mode changes, maximizing power consumption and flying mode capabilities.

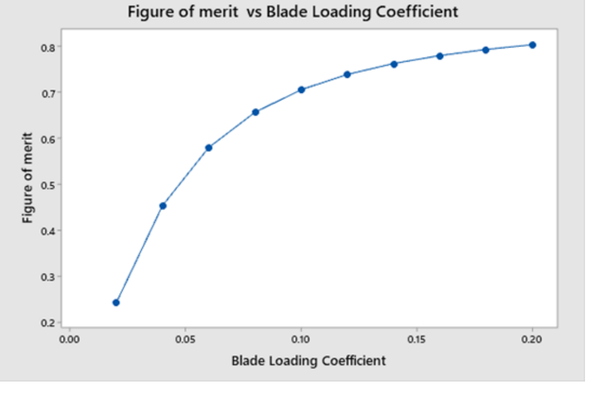


Anti-Torque System:

Avro's anti-torque technology balances rotational forces without a tail rotor. The Avro maximizes anti-torque control and flying reliability by strategically using bleed air. The bleed air system seamlessly counters main rotor torque, improving stability and agility. The Avro uses bleed air to reduce energy losses and increase flying performance, improving safety and control. The Avro's innovative anti-torque technology is a better tail rotor replacement.

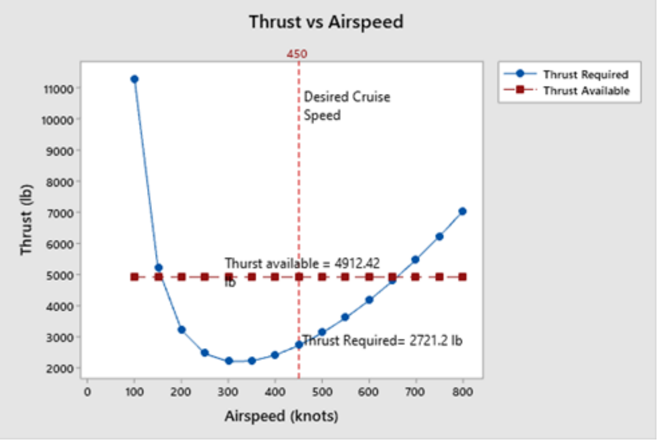


Vehicle Performance

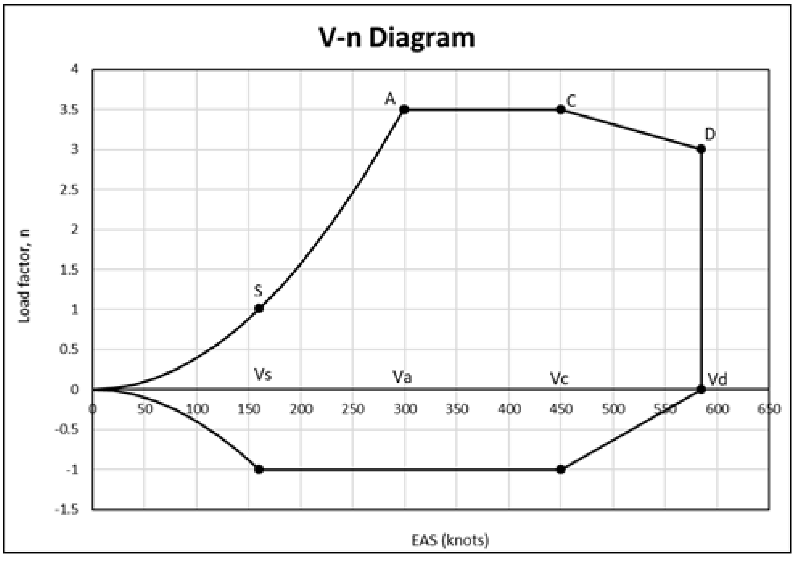


The ratio of ideal Hover Out-of-Ground-Effect (HOGE) power to actual HOGE power required for the aircraft AVRO is 0.8.

At 20,000 feet, the aircraft has 4912.42 pounds of available thrust and 2721.2 pounds of required thrust, exceeding the required thrust to maintain a cruising speed of 450 knots.



Structural Loads



The aircraft's stall speed is 160 knots, determined by a load factor of 1. The maximum load factor is 3.5, restricting maneuver speed to 300 knots. Increased load above the parabolic line causes stalling. After 300 knots, the aircraft can cross the 3.5 limit, but may experience deformation or failure. The maximum load is restricted to -1 for safety.

Avionics System

Cockpit HUD Layout

Primary Flight Display (PFD): EFI-890R Advanced Flight Display
Navigation Display (ND): SN3500 Primary Navigation Display
Engine Indicating and Crew Alerting System (EICAS): Astronautics 6×8 EICAS Display
Radio Altimeter: RA-4000 Radar Altimeter System
VOR: AV-12 VOR
Auxiliary Power Unit (APU): Safir 5K/G Z8 APU.
Multi-Function Display (MFD): SkyView HDX MFD from Dynon
Weather Radar: PicoSAR
Surveillance Radar: Gabbiano

SN3500 Primary Navigation Display

EFI-890R Advanced Flight Display

Astronautics 6×8 EICAS Display

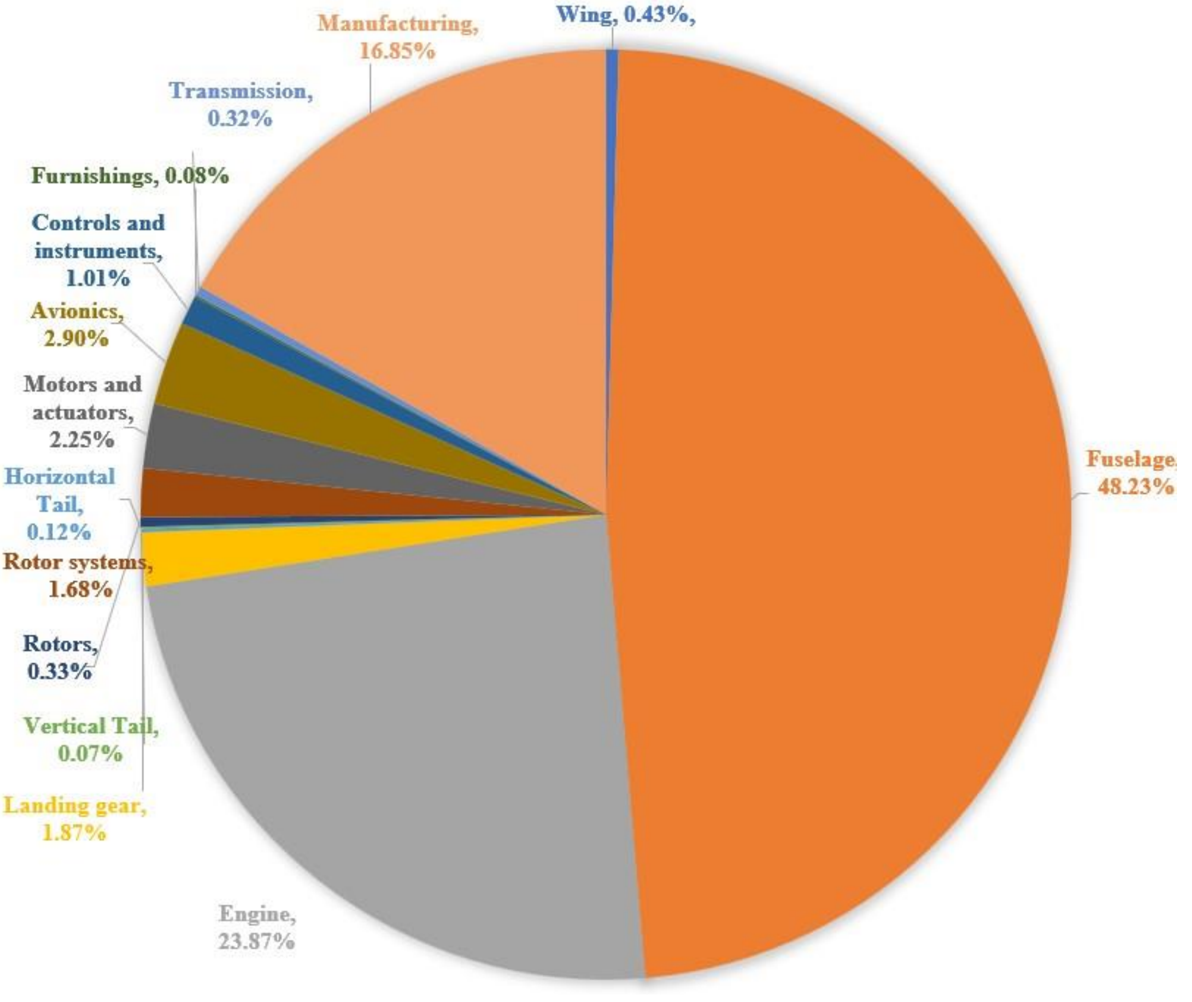
Weight Analysis

Component	Weight (lb)	X cg (in ft from nose)	Moment Arm (lb-ft) w.r.t. x axis	Y cg (in ft from FCL)	Z cg
Wing	1377.44	29.6	40772.22	0.1012	Along fuselage
Rotor System	1521.84	23	35002.32	0	0
Horizontal tail	378.52	55.06	20841.31	0.354	Along fuselage
Vertical tail	241.36	54.43	13137.22	5.72	Along fuselage
Fuselage	6870.56	28	192375.68	0.8	Along fuselage
Landing gear	1144.84	28	32055.52	1.15	Along fuselage
Engine	2066.26	51.29	105978.48	0	Along fuselage
Crew	600	6	3600	3	Along fuselage
MEP	1000	13	13000	0	0
Payload	5000	29	145000	0	0
Tank 1	600	5	3000	0	0
Tank 2	600	6	3600	0	0
Tank 3	600	10	6000	0	0
Tank 4	600	12	7200	0	0
Tank 5	600	18	10800	0	0
Tank 6	600	24	14400	0	0
Tank 7	600	28	16800	0	0
Tank 8	600	32	19200	0	0
Tank 9	600	36	21600	0	0
Tank 10	600	40	24000	0	0
Tank 11	600	44	26400	0	0
Total		28.47		0.95	0

Maximum Forward	Average	Maximum Aft
27.05 ft	28.47 ft	32.65 ft

The whole aircraft cg has been determined to be at 35.1% of MAC, which is usually maintained for better aircraft performance. Longitudinal cg flexibility allows for increased aircraft stability and versatility. The lateral CG analysis was simplified because all components of our aircraft are oriented in such a way so that the lateral mass center lays in the exact center of the vehicle.

Cost Analysis



The total cost of manufacturing this aircraft has been estimated to be about $3,561,225.

Summary

The AVRO's capacious internal cargo compartment and payload capacity enable mission-specific supply transfer. The AVRO runs smoothly and meets cargo capacity while optimizing space.

Long missions need the AVRO's large Radius of Action and rapid cruising speed. Its aerodynamic shape and powerful propulsion system enable speedy reaction and transportation during critical military operations.

In stressful settings, AVRO components lessen dangers. The AVRO minimizes ground crew outwash/downwash during vertical takeoff and landing (VTOL) operations by operating at lower altitudes.

The AVRO avoids FOD with smart design. Airflow management, structural design, and the engine's rear fuselage placement reduce FOD issues. Performance is reliable even in tough operational conditions.

The groundbreaking AVRO notion combines cutting-edge technology and an all-encompassing design philosophy. Due to its increased danger avoidance, operational range, and reliability, it is the finest choice for military operations in disputed areas.

In conclusion, the AVRO concept shows our commitment to the RFP by delivering a versatile and cutting-edge air vehicle. Due to its performance, adaptability, and payload capacity, the AVRO is important for military operations in severely disputed areas. The AVRO will assist military missions succeed in these tough scenarios.