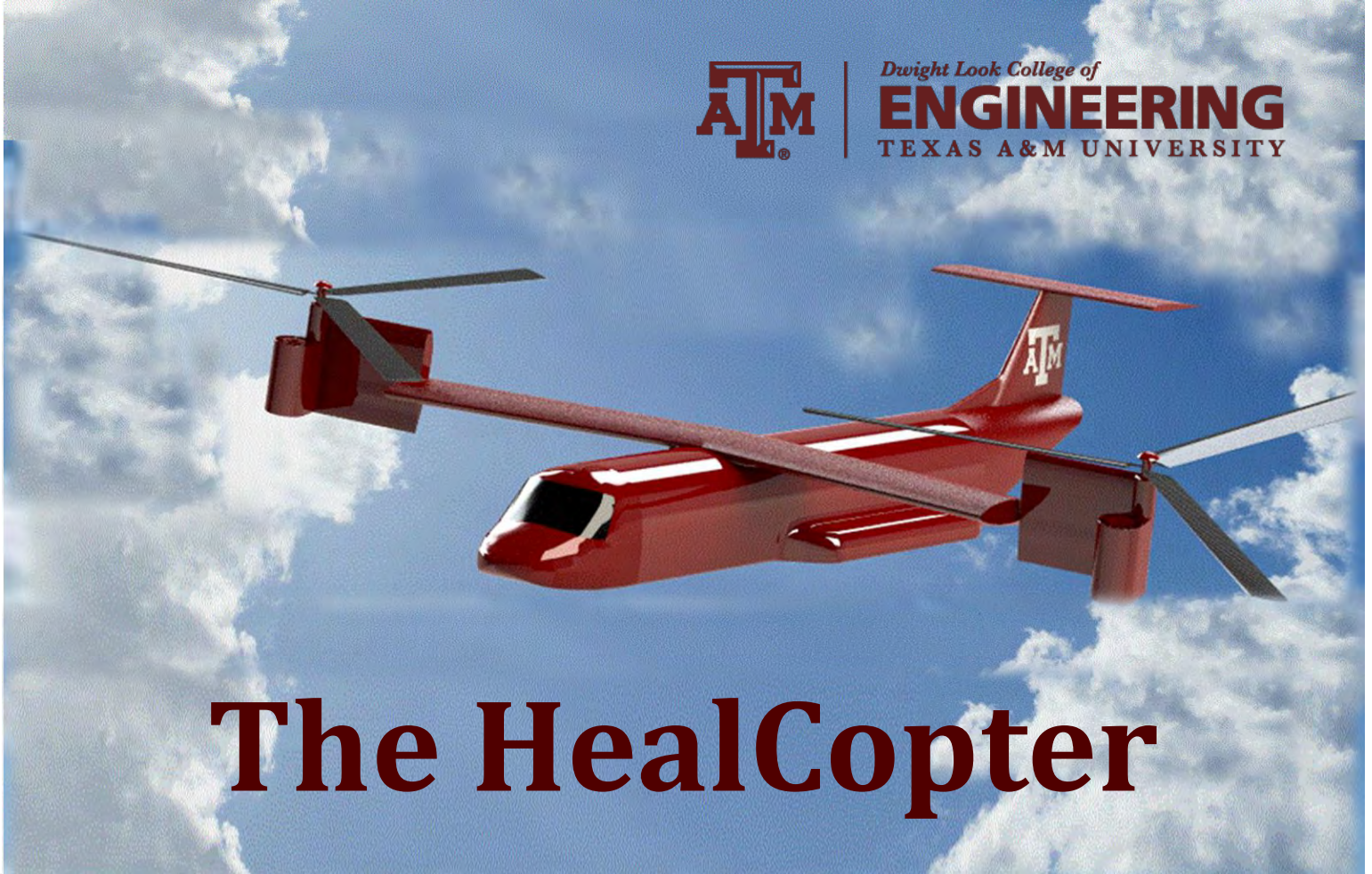




Dwight Look College of
ENGINEERING
TEXAS A&M UNIVERSITY



The HealCopter

Team Members

Sarah Atkinson

Katie Lane

Josh Mickle

Tyler Noesser

Lisa Warren

Advisor

Dr. Jonathan Rogers

Executive Summary

30th Annual AHS International
Student Design Competition
Undergraduate Category



LONESTAR HELICOPTERS
TEXAS A&M UNIVERSITY

Design Summary

Performance Summary

| | Requirement | Lonestar Design |
|------------------------------|-------------------------------------|--------------------------------------|
| Min./Max. Speed | N/A, 240 kts | 100 kts, 300 kts |
| Range | | |
| Mission 1 | 1,800 km | 1,943 km |
| Mission 2 | 1,400 km | 1,506 km |
| Mission 3 | 1,210 km | 1,662 km |
| Max. Density Altitude | 6,000m (19,685 ft) ISA + 15°C | 7,200 m (23,500 ft) ISA + 15°C |
| Max. Take Off Weight | 15,000 kg (33,100 lb) | 15,875 kg (35,000 lb) |
| Min. Useful Load | 6,000 kg (13,225 lb) | 6,250 kg (13,775 lb) |
| Min. Climb Rate | 2,000 ft./min. | 2,200 ft./min. |
| Number of Passengers | 3 crew, 6 PAX | 3 crew, 9 PAX |
| Load/Unload Max. Time | 60 minutes | 60 minutes |
| Endurance | 6.5 hours | 6.75 hours |
| Direct Operating Cost | N/A | \$4,500/ flight hour |

Power Plant

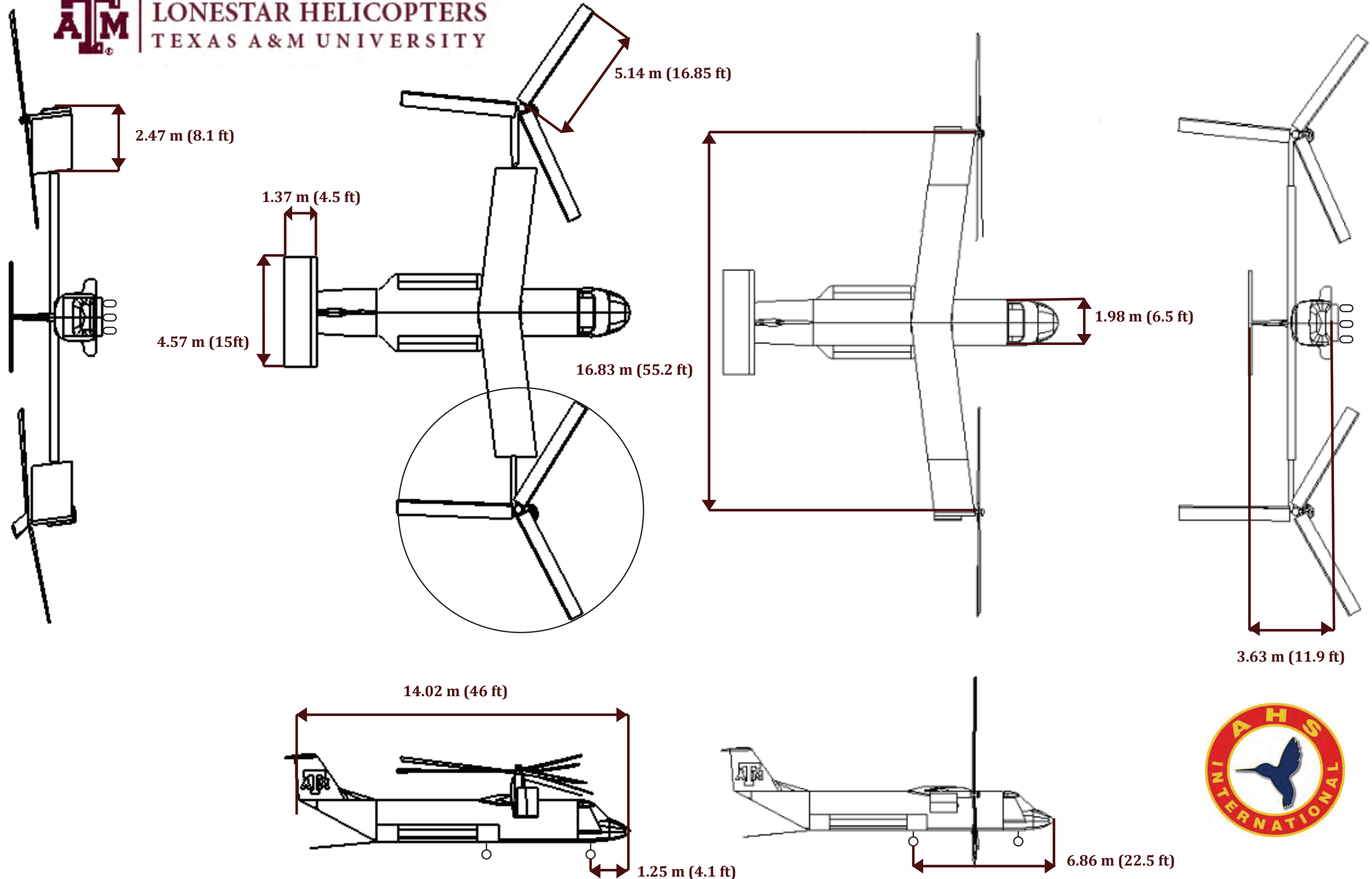
Honeywell T55 Turboshaft Engine

| | |
|--------------------------|---------------------|
| Number of Engines | 2 |
| Max. Power | 3800 hp |
| Continuous Power | 3000 |
| SFC | 0.53 |
| Weight | 354 kg (780 lbs) |

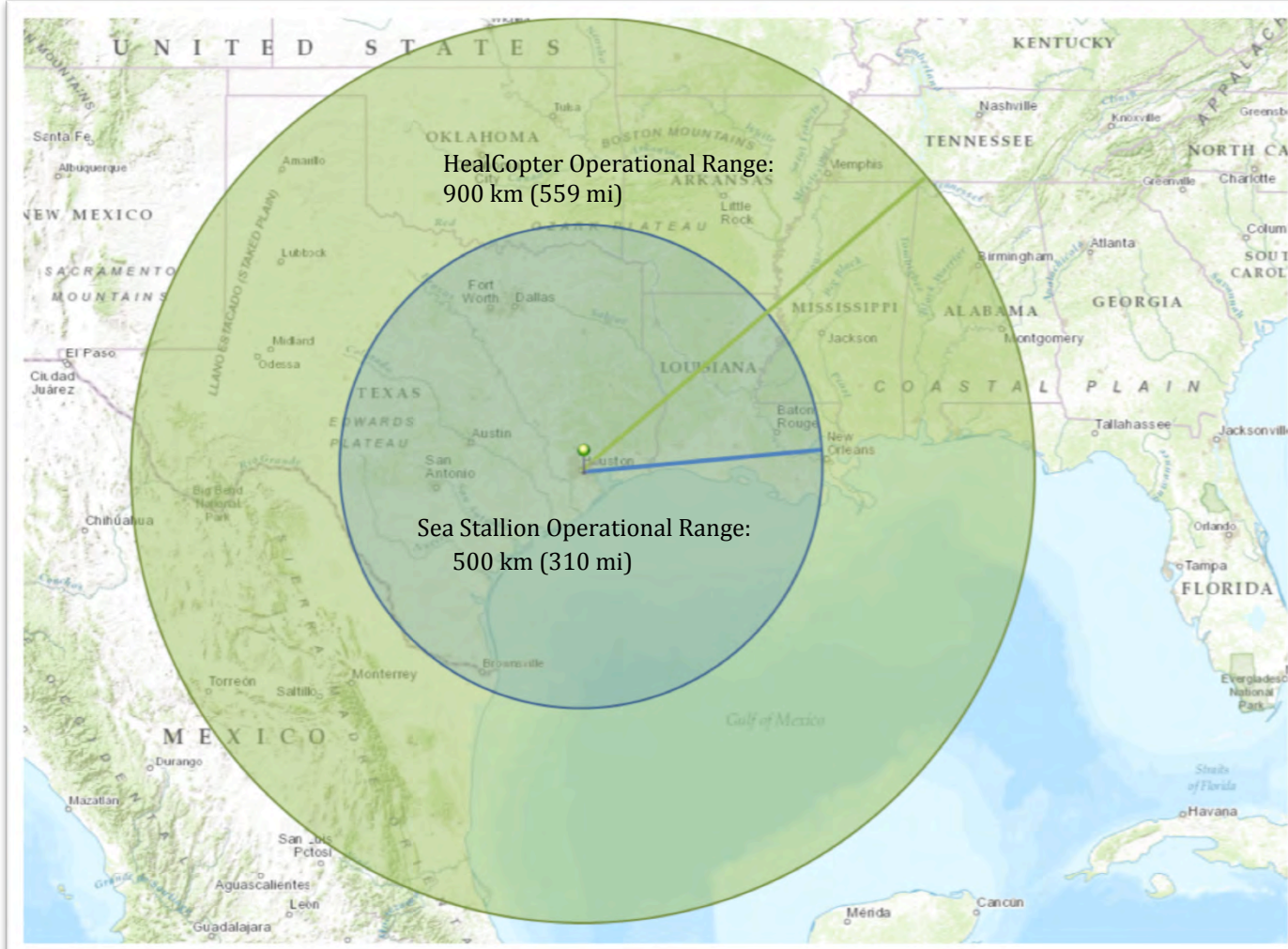




LONESTAR HELICOPTERS
TEXAS A&M UNIVERSITY



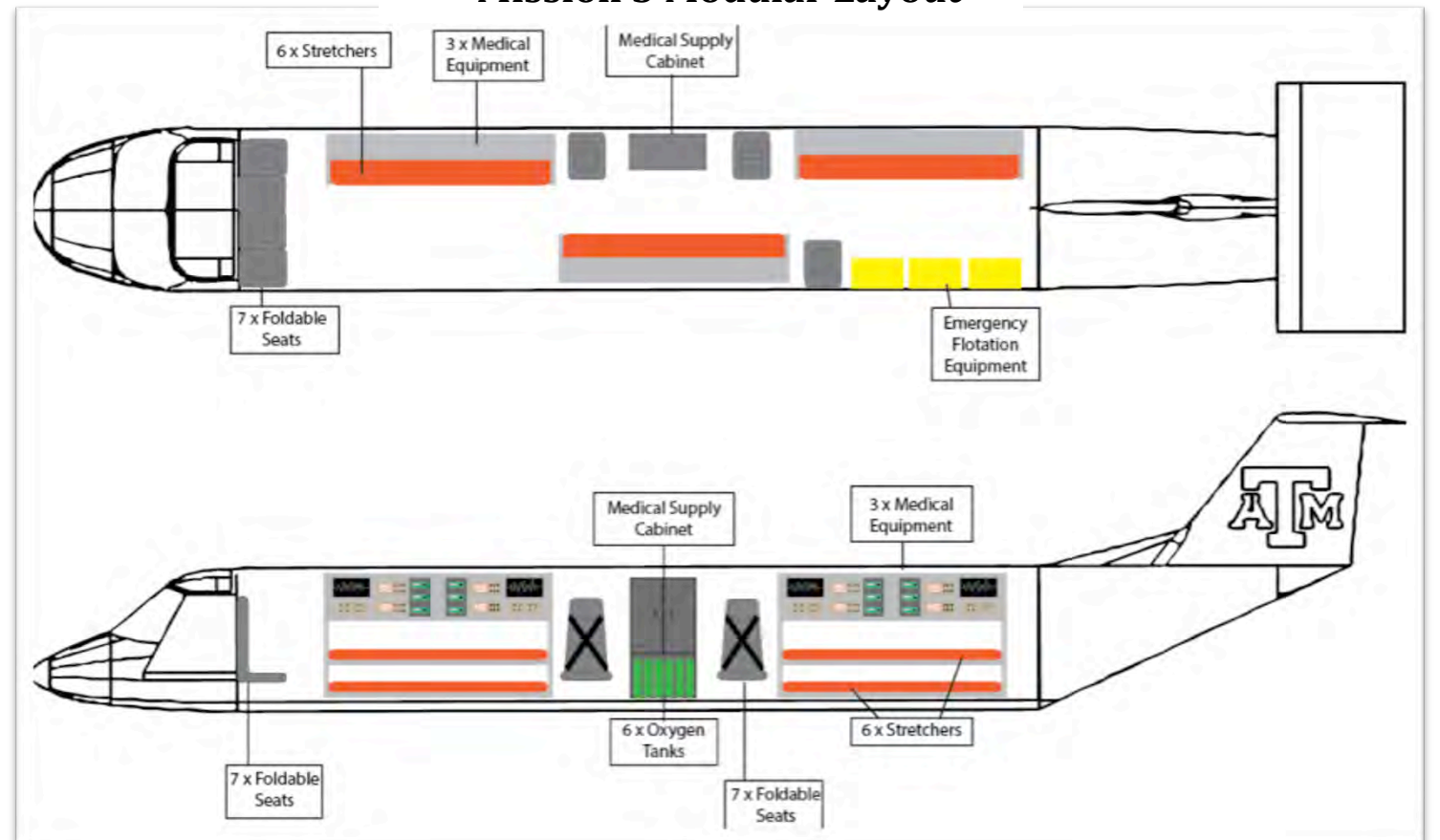
Operational Range



Missions 1 & 2 Modular Layout

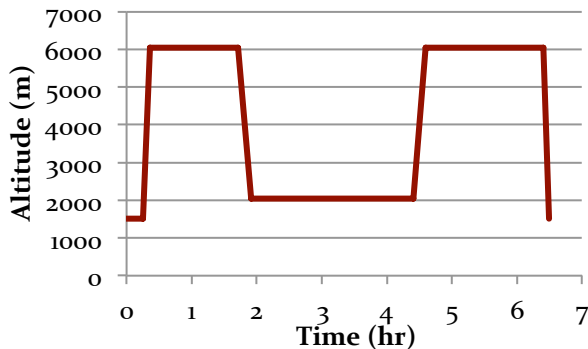


Mission 3 Modular Layout



Acknowledgement of Requirements

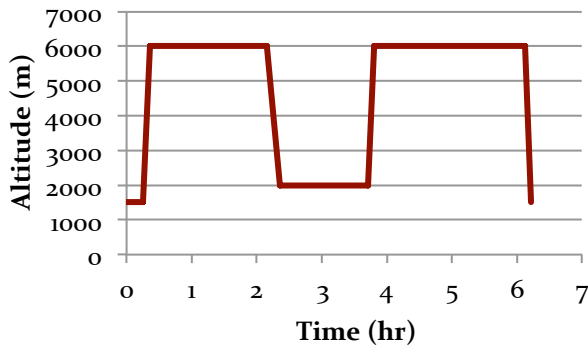
Mission 1



Rescue Coordination:

- Approach, 600 km @ 240 kts.
- Flyover, 600 km @ 120 kts.
- Return, 600 km @ 180 kts.

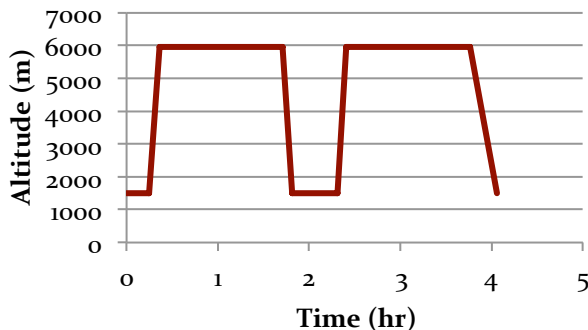
Mission 2



Aid Distribution:

- Approach, 600 km @ 180 kts.
- Flyover, 600 km @ 80 kts.
- Return, 600 km @ 140 kts.

Mission 3



Search and Rescue:

- Approach, 600 km @ 240 kts.
- Descent, Land, Takeoff, 10 km
- Return, 600 km @ 240 kts.

Hard Requirements (all missions):

- Cruise speed of 240 kts.
- Exceed range of all three missions
- Include search and rescue equip.

All missions have a max density altitude of 6000 m ISA +15° C.



Design Process

- ✓ Identify Requirements
- ✓ Configuration Selection and Vehicle Sizing Dec 2012
- ✓ Create Preliminary Design Tools
- ✓ Conduct Preliminary Design
- ✓ Design Optimization
- ✓ Submit Design Review to AHS May 2013, AHS
- Continue with Detailed Design

Configuration Selection

Overview of Methods Used

Quality Function
Deployment (QFD)

Weighted Decision
(Pugh) Matrix

Technique for Order
Preference by
Similarity to Ideal
Solution (TOPSIS)

Overall Evaluation
Criteria (OEC)

R_f Method for Sizing



Configuration Selection

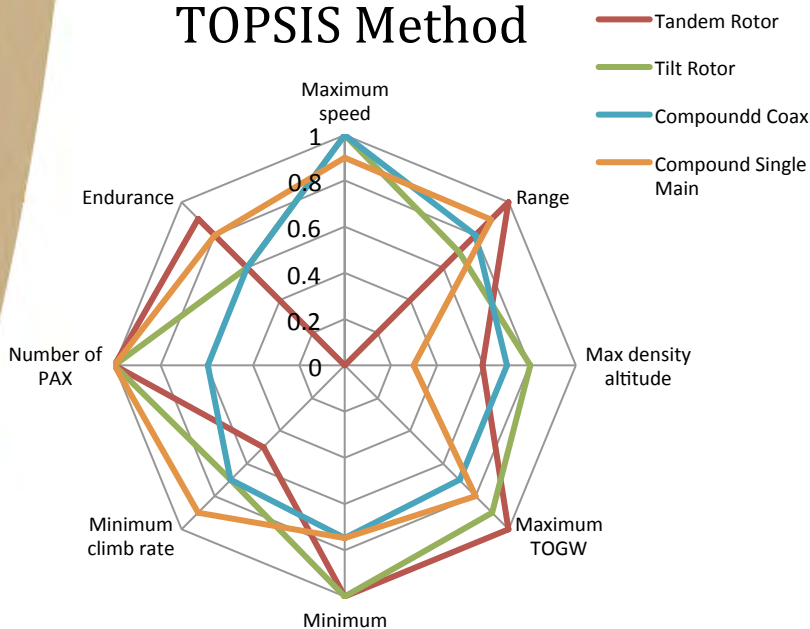
Relative Importance & TOPSIS

- Identified customer and engineering requirements
- Found correlations between each and mapped in a QFD matrix using the scoring guide listed
- Added scores for each engineering requirement to find “relative importance”
- Range and Useful Load found to be the most important requirements. (highlighted)

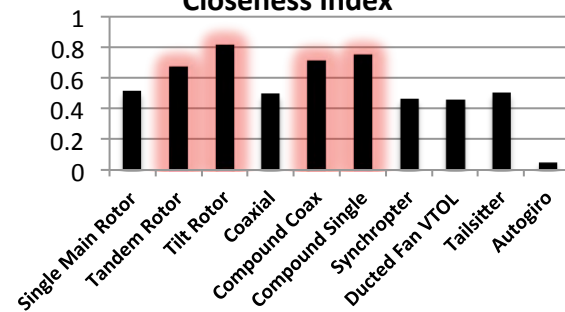
Relative/Weighted Importance of Engineering Requirements

| | Weighted Importance | Relative Importance |
|------------------------------|---------------------|---------------------|
| Maximum Speed | 0.14 | 85 |
| Range | 0.14 | 88 |
| Max Density Altitude | 0.12 | 74 |
| Maximum Takeoff Gross Weight | 0.08 | 49 |
| Minimum Useful Load | 0.15 | 91 |
| Minimum Climb Rate | 0.09 | 55 |
| Number of Passengers | 0.06 | 39 |
| Load/Unload Max Time | 0.11 | 66 |
| Endurance | 0.11 | 66 |

TOPSIS Method



Closeness Index



4 design configurations were taken forward to OEC analysis: Tandem, Compound Coaxial, Compound Single Main, and Tiltrotor

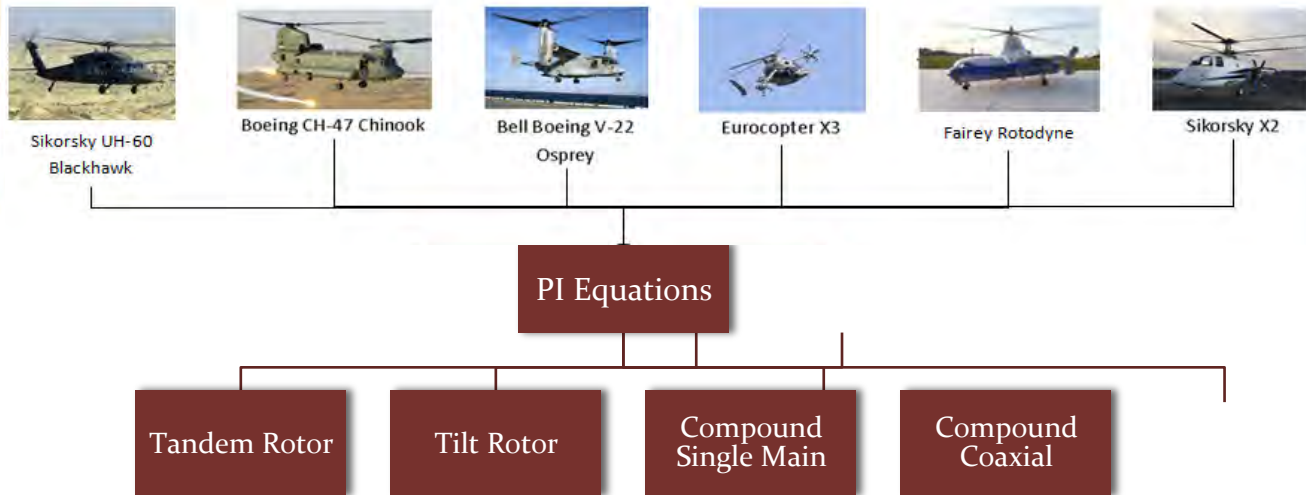


Configuration Selection

Pugh Matrix & OEC

Decision Matrix Generated Using the Pugh Method

| | Single Main Rotor | Tandem Rotor | Tilt Rotor | Coaxial | Compound Coax | Compound Single Main | Synchropter | Ducted Fan VTOL | Tailsitter | Autogiro |
|-----------------------|-------------------|--------------|------------|---------|---------------|----------------------|-------------|-----------------|------------|----------|
| Maximum speed: | 0 | 0 | 1.39 | 0 | 1.39 | 1.25 | 0.28 | 0.97 | 1.39 | 0 |
| Range: | 1.29 | 1.44 | 1 | 1.29 | 1.15 | 1.29 | 0.72 | 0.43 | 0.43 | 0.14 |
| Max density altitude: | 0.72 | 0.72 | 0.97 | 0.48 | 0.85 | 0.36 | 0.6 | 1.09 | 1.21 | 0.36 |
| Maximum TOGW: | 0.56 | 0.8 | 0.72 | 0.56 | 0.56 | 0.64 | 0.32 | 0.48 | 0.48 | 0.16 |
| Minimum useful load: | 0.89 | 1.19 | 1.19 | 1.04 | 0.89 | 0.89 | 0.74 | 0.59 | 0.3 | 0.15 |
| Minimum climb rate: | 0.54 | 0.45 | 0.63 | 0.36 | 0.63 | 0.81 | 0.72 | 0.27 | 0.9 | 0.18 |
| Number of PAX: | 0.45 | 0.64 | 0.64 | 0.13 | 0.38 | 0.64 | 0.13 | 0.13 | 0.06 | 0.13 |
| Load/unload max time: | 1.08 | 1.08 | 1.08 | 1.08 | 1.08 | 1.08 | 1.08 | 1.08 | 1.08 | 1.08 |
| Endurance: | 0.54 | 0.97 | 0.54 | 0.97 | 0.65 | 0.86 | 1.08 | 0.54 | 0.11 | 0.43 |



- The 4 configurations identified through the TOPSIS method were compared using OEC
- Performance Indices were calculated from historical data and the RFP mission profiles
- Results to the right; tiltrotor (V-22) scored the highest
- HealCopter has performance index of 9.67

Performance Indices

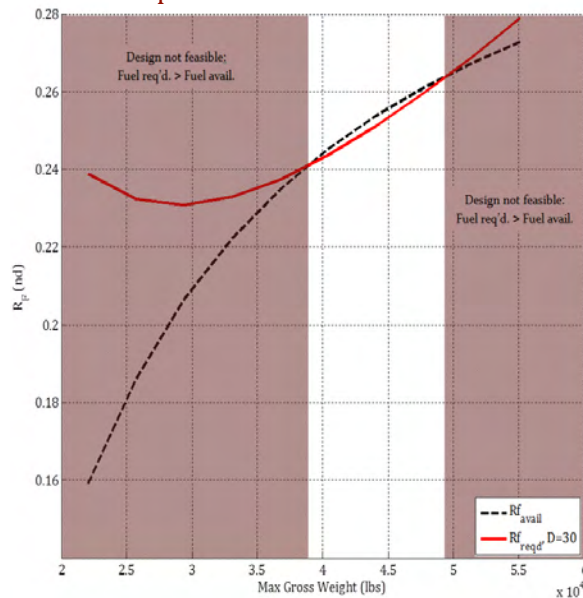
| | Previous Design | Total PI |
|-----------------------------|------------------------------------|----------------------|
| Tandem Rotor | Chinook | 7.45 |
| Tilt Rotor | V-22 Osprey AW-609 | 13.42 7.00 |
| Compound single main | Eurocopter X3 Fairey Rotodyne Y | 8.91 6.58 |
| Compound coaxial | Sikorsky X2 | 8.89 |



Vehicle Sizing

R_f & BEMT

R_f Method, Mission 1



- R_f method used for finding minimum gross weight of each mission
- Compares different GTOW configurations for a given mission
- Compares fuel required with fuel available

R_f Method, Varying Mission Payload to Calculate Mission 1 Fuel Required

| | Mission 1 | Mission 2 | Mission 3 |
|----------------------------|-----------|-----------|-----------|
| Disk Diameter, m | 9.14 | 9.14 | 9.14 |
| (ft.) | (30) | (30) | (30) |
| TOGW, m.tons | 19.3 | 19.3 | 19.3 |
| (lbs) | (39,007) | (39,015) | (39,015) |
| Min. Rf | 0.241 | 0.19 | 0.13 |
| Min. Fuel, kg | 4,268 | 3,440 | 2,305 |
| (lbs) | (9,411) | (7,584) | (5,082) |
| Payload, kg | 2,066 | 2,967 | 4,201 |
| (lbs) | (4,555) | (6,542) | (9,263) |
| Useful Load, m.tons | 6.9 | 7.0 | 7.1 |
| (lbs) | (13,966) | (14,126) | (14,345) |

- Min. GTOW to complete “critical” mission, Mission 1 found to be 17,700 kg (39,000 lbs.)

- R_f Method calculated fuel required for Mission 1 to be 4,268 kg

- BEMT agreed, finding that 4,142 kg of fuel was required for Mission 1

- Similar calculations for Missions 2 and 3 confirmed that BEMT and R_f sizing estimates agreed

BEMT Power & Fuel Req'd, Mission 1

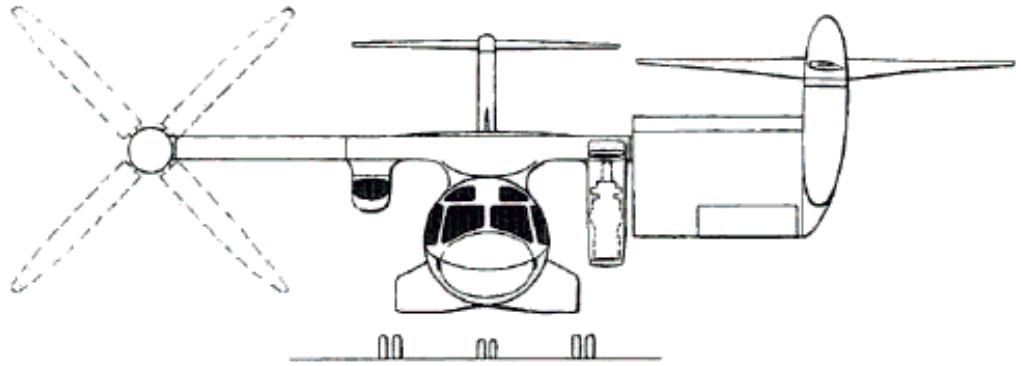
| Mission 1 | | |
|-----------|----------------|-------------------|
| Time, m | Power, kW | Fuel Weight, kg |
| 15 | 1950 (2611 hp) | 124.4 (274.2 lb) |
| 7 | 2286 (3066 hp) | 63.9 (140.9 lb) |
| 81 | 1373 (1841 hp) | 473.3 (1043.5 lb) |
| 162 | 1132 (1518 hp) | 780.8 (1721.5 lb) |
| 108 | 1254 (1682 hp) | 576.6 (1271.3 lb) |
| 7 | 1849 (2480 hp) | 51.6 (113.9 lb) |

Fuel Weight, 1 Rotor: 2070.8 kg (4565.3 lb)

Fuel Weight, 2 Rotors: 4141.6 kg (9130.6 lb)



Justification for Tilt-Wing



Inspiration from the Eurotilt/ERICA program (1999)

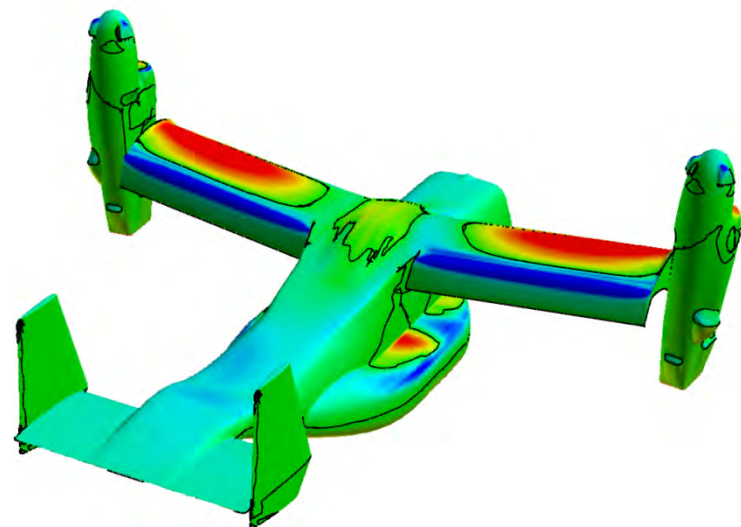
- 4% download reduction by tilting portion of the wing
- Improves vehicles hover performance
- Allows for a smaller rotor radius

- Conventional helicopter configurations have a download penalty of around 4% caused primarily by the fuselage

- Potsdam and Strawn found that the V-22 has a 10% download penalty

- 69% of that is derived from wake interaction with the wing

- Estimation of the HealCopter's download penalty* found that the tilting wing section reduced the overall download penalty by 4% (wing-wake interaction penalty reduced by 60%)



V-22 Time-Averaged Airframe Download Pressure Component (Potsdam & Strawn, 2002)

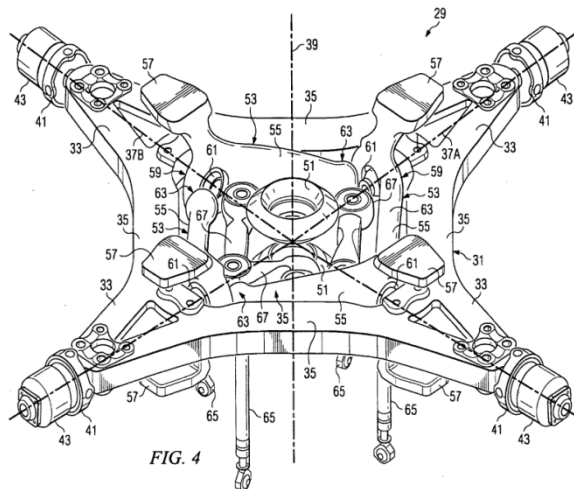


Top-Down view of HealCopter, highlighting 7 foot tilting portion of each wing

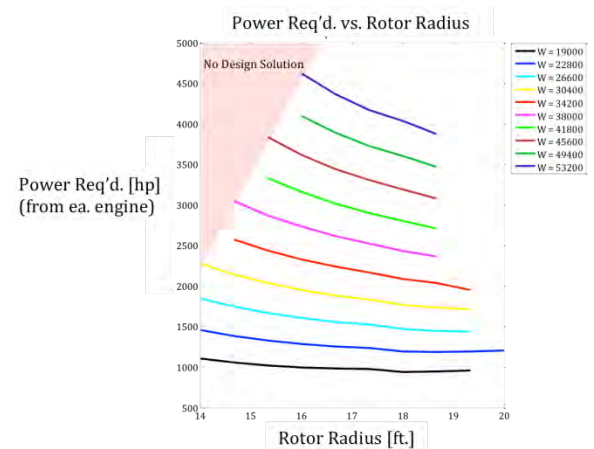


Hub Design & Rotor Optimization

- Stiff in-plane gimbaled hub with homo-kinetic joint
 - To be modified for three blades instead of four, as pictured
- Large flapping angles provide adequate control power for hover
- Reduces Coriolis effect typically encountered with blade flapping
- Permits greater pitch-flap coupling to aid with rotor stability
- Homo-kinetic joint eliminates 2-per-rev torsional loading from lead-lag of the blades, and reduces resonance issues

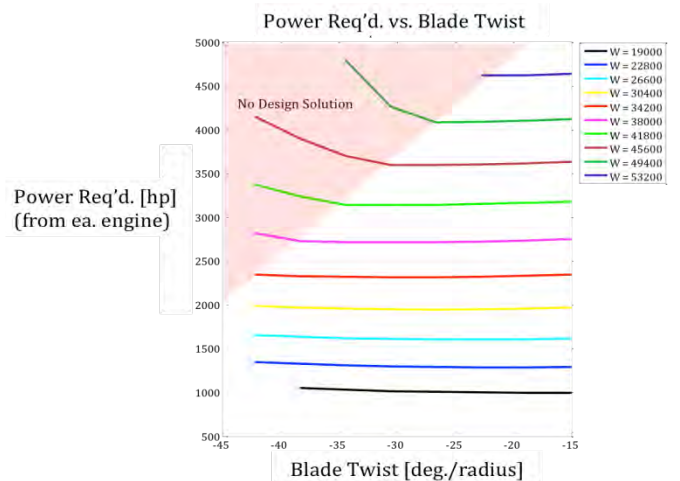


**Stiff, In-plane Gimbaled Hub,
US Patent #20080292468 A1**



Optimization studies conducted to find most efficient rotor configuration for both forward flight and hovering operations.

Final rotor parameters discussed on next page.



Main Rotor Design

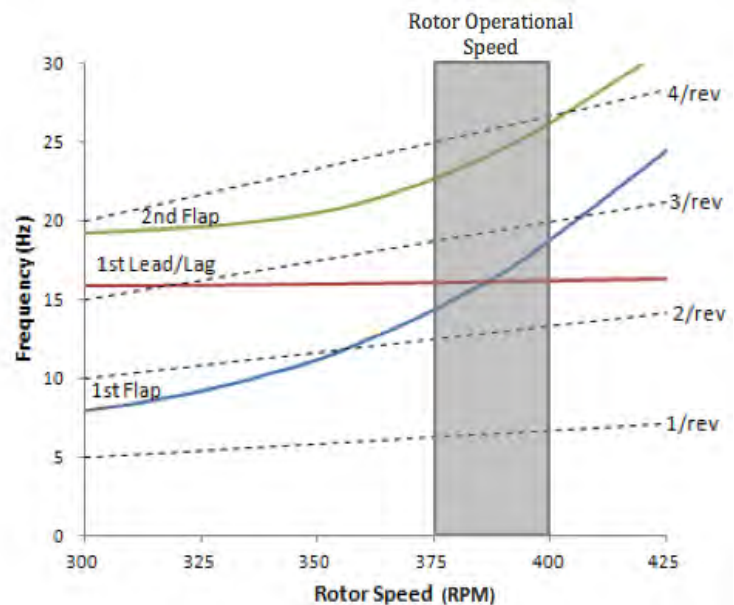
| Parameter | AW609 | Lonestar | V-22 |
|----------------------------------|-------------------|----------------------|----------------------------------|
| GTOW, kg (lbs) | 7,620 (16,800) | 15,875 (35,000) | 21,545-25,400 (47,500-56,000) |
| Rotor Rad., m (ft) | 3.86 (12.67) | 4.88 (16) | 5.79 (19) |
| Twist [deg.] | --- | - 30 | - 48 |
| Chord, m (ft) | --- | 0.68 (2.25) | 0.76 (~ 2.5) |
| Rotor RPM (hover/fwd.) | --- | 400/385 | 397/303 |
| Tip Speed, m/s (fps) | --- | 204/197 (670/645) | 241/184 (790/603) |
| Disk Loading | 16.8 | 21.75 | 20.9/24.5 |

*Note: "---" denotes that information for that parameter could not be found or was not available

Design based on parametric studies for critical mission (Mission 1)

Disk loading, rotor radius, tip speed, solidity, blade twist were primary design variables

VABS/DYMORE used to verify that rotor blade natural frequencies don't cross N/rev vibrational frequencies of the aircraft within operational speed envelope

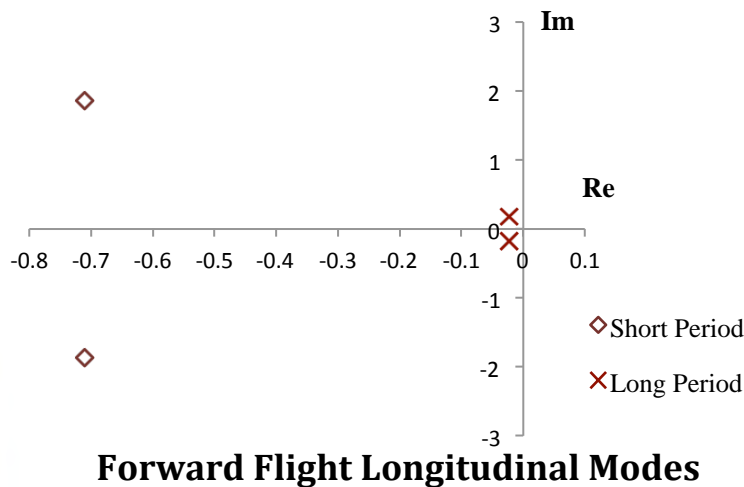


| Airfoil | Radial Location | Camber | Thickness |
|---------|-----------------|--------|-----------|
| VR-7 | 0 – 0.40R | 3.1% | 12.0% |
| VR-12 | 0.40R – 0.75R | 2.3% | 10.6% |
| VR-8 | 0.75R – 0.825R | 1.3% | 8.2% |
| VR-15 | 0.825R – R | 1.3% | 8.0% |

Blended rotor blade allows for higher lift at root and lower profile at blade tip to improve performance



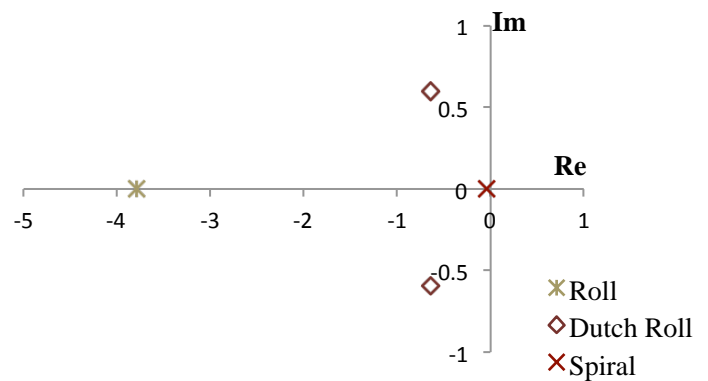
Controls and Handling



Analysis performed at several speeds necessary for RFP, including 120 and 240 kts

Forward flight stability derivatives calculated in AAA

Eigenvalues plotted to show stability modes

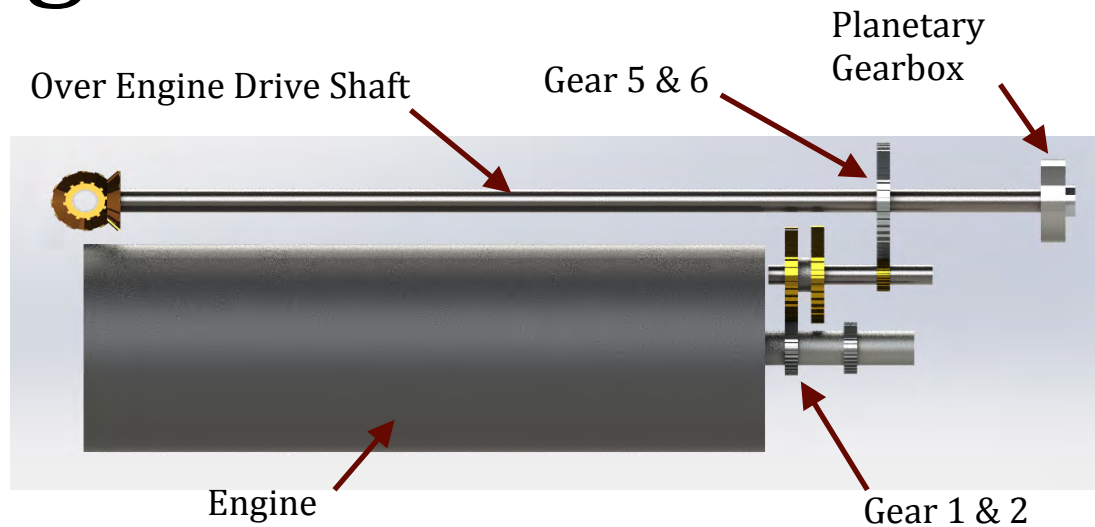


| Flight Mode | Level 1 Requirement | Actual Value |
|--------------|--|---------------------------------------|
| Long Period | $\zeta_d > 0.04$ | $\zeta_d = 0.126$ |
| Short Period | $0.3 < \zeta_d < 2$ | $\zeta_d = 0.358$ |
| Dutch Roll | $\zeta_d > 0.08$ and $\omega_n > 0.4$ | $\zeta_d = 0.7288$ $\omega_n = 0.871$ |
| Roll | $\tau < 1.4$ | $\tau = 0.2639$ |
| Spiral | $\lambda < 0$ or Time to double > 12 seconds | $\lambda = -0.0453$ |

The HealCopter design exhibits Level 1 handling qualities in all forward flight stability modes

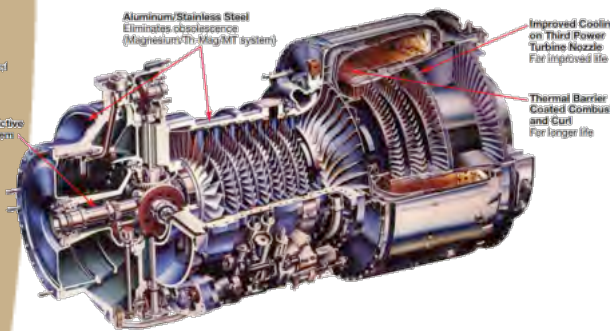


Engine & Transmission



Gear Sizing

| | Radius | Torque N-m (ft-lbs) | RPM |
|---------------|----------------------|------------------------|------|
| Gear 1 | 10.8 cm (4.25 in) | 1986 (1465) | 7500 |
| Gear 2 | 19.7 cm (7.75 in) | | |
| Gear 3 | 10.2 cm (4 in) | 2183 (1610) | 8000 |
| Gear 4 | 20.4 cm (8 in) | | |
| Gear 5 | 6.1 cm (2.4 in) | 7945 (5860) | 1875 |
| Gear 6 | 24.4 cm (9.6 in) | 8731 (6440) | 2000 |



In comparing existing engine platforms, perfect solution was not found; however, it was deemed too financially risky to develop a new platform

Lycoming T55 was chosen



Engine Comparisons

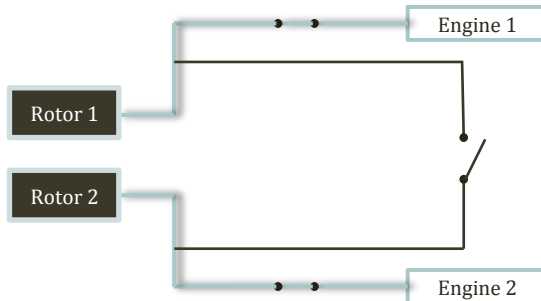
| Engine | Max Power [kW] | Continuous Power [kW] | SFC | Weight [kg] |
|-------------------|----------------------|-----------------------|------|--------------------|
| AL5512 | 3038.72 (4075 hp) | 2218.48 (2975 hp) | .543 | 353.8 (780 lb) |
| T55-L-712A | 2833.66 (3800 hp) | 2237.09 (3000 hp) | .530 | 353.8 (780 lb) |
| AE 1107C | 4548.77 (6100 hp) | 3251.25 (4360 hp) | .426 | 440.44 (971 lb) |



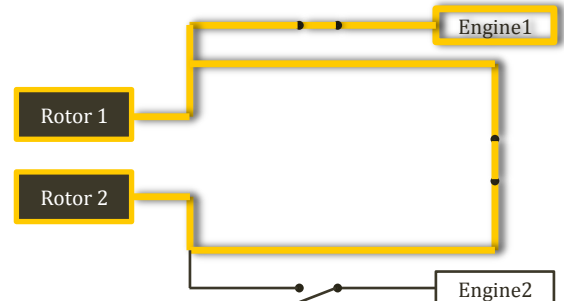
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One Engine Inoperable

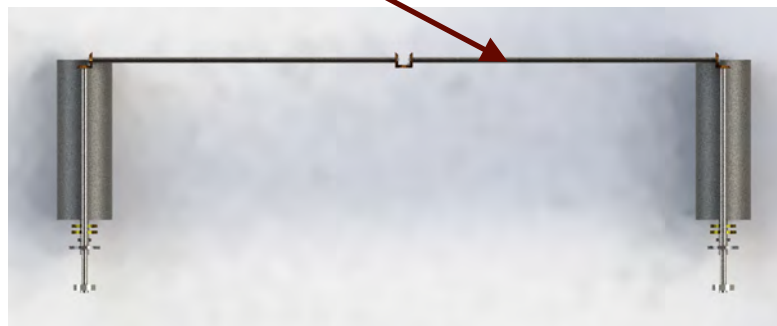
Normal Operating Condition



One Engine Inoperable



Thru-Wing OEI
Drive Shaft



In the event of an engine failure, power will be transfer from the remaining (operable) engine to the inoperable one via a drive shaft over the span of the wing

Shaft Sizing

| | Outer Radius | Inner Radius |
|---------------------------------|----------------------|----------------------|
| Intermediate Drive Shaft | 4.45 cm (1.75 in) | 3.81 cm (1.5 in) |
| Over Engine Drive Shaft | 5.08 cm (2.0 in) | 4.45 cm (1.75 in) |
| Wing OEI Drive Shaft | 5.08 cm (2.0 in) | 4.19 cm (1.65 in) |
| Rotor Drive Shaft | 5.72 cm (2.25 in) | 4.45 cm (1.75 in) |

The transfer of power from the operable to inoperable engine will be coordinated automatically via the flight control system

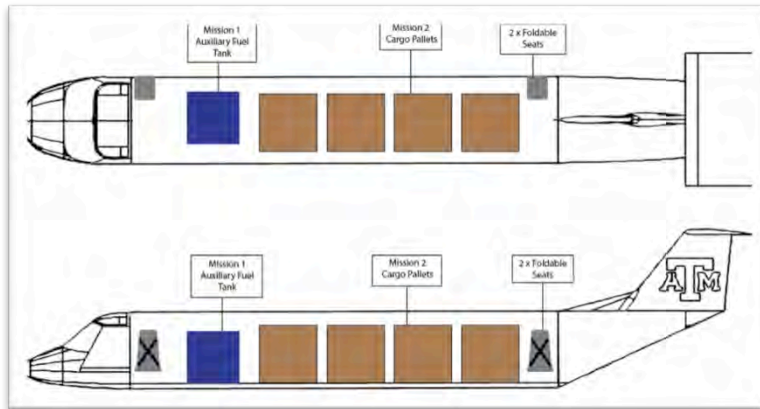
Autorotation of a tilt-rotor has never been successfully tested, and the the HealCopter rotor is not sized to accommodate an auto-rotative index large enough to safely land the aircraft via autorotation. In emergency situations, the aircraft relies solely on its capability to safely land using only one engine.



Modular Mission Capability

The HealCopter was designed with modular capabilities in order to accomplish a wide range of missions: Rescue Coordination, Aid Distribution, and Search & Rescue

Missions 1 & 2 Layout

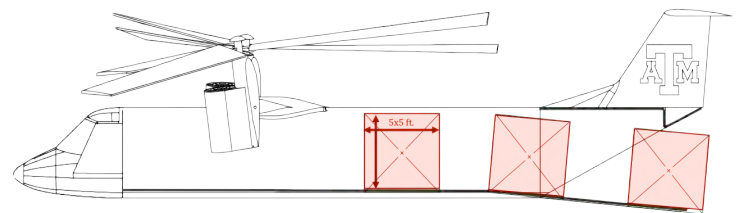


- Since Mission 1 required the most fuel, it was identified as the “critical” mission

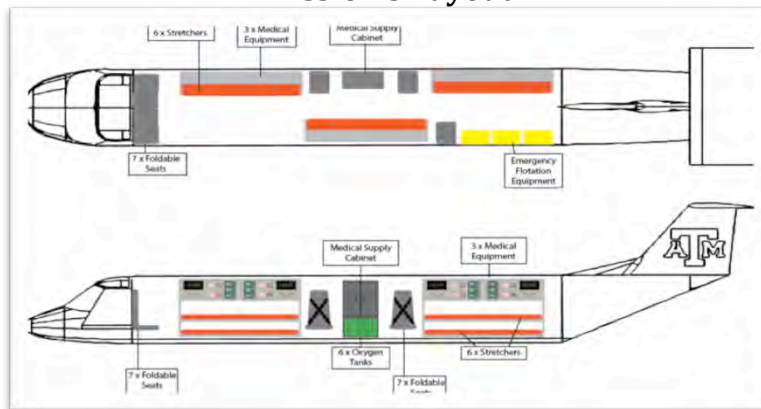
- Robbie Tanks’ 4’ x 4’ fuel tanks will be added for Mission 1 in order to achieve the desired range

- Mission 2 does not require internal fuel tanks. The Robbie Tanks can be uninstalled in ~15 minutes.

- Instead, up to four 4’ x 4’ cargo pallets can be loaded to accomplish the aid distribution mission



Mission 3 Layout



- In order to accomplish Mission 3, the Search and Rescue mission, modular gurney/medical equipment stations to tend for 6+ wounded will be loaded

- The removable medical stations are pictured on the next page

Cockpit & Mission Equip.

The HealCopter cockpit is modeled after the EC-365 Dauphin instrument panel and avionics suite with modified controls for the tilting wing.



BAE Systems BLAST (Brownout Landing Aid System Technology) provides synthetic vision in degraded visual environments

BAE Systems Striker Helmet is a helmet mounted display compatible with many interfaces and night vision capable



Removable medical stations will have two stacked stretchers and above head medical equipment. Additionally the HealCopter will be outfitted with an electric hoist, a searchlight, and emergency flotation equipment.



Cost Analysis & Timeline

| Direct Maintenance Cost | |
|-------------------------------------|---------------------|
| Labor | |
| Maintenance man hours/Flight hou | 20 |
| Maintenance cost/hour | \$ 73.00 |
| Labor cost/year | \$ 730,000.00 |
| Materials | |
| Material cost/flight hour | \$ 365.00 |
| Material cost/year | \$ 182,500.00 |
| Subtotal | \$ 912,500.00 |
| Direct Operating Cost | |
| Direct Maintenance Cost | \$ 912,500.00 |
| Fuel | |
| Fuel Price/gallon | \$7.21 |
| Fuel Burned/hr | 282.7695496 |
| Cost Fuel Burned/year | \$1,019,384.23 |
| Insurance | \$ 15,000.00 |
| Crew | |
| Cost of 1 crew/hour | \$ 185.00 |
| Number of crew | 3 |
| Cost of crew/year | \$ 277,500.00 |
| Subtotal | \$ 2,224,384.23 |
| Research & Development | |
| Wrap Rates | |
| Engineering | \$ 86.00 |
| Tooling | \$ 88.00 |
| Quality Control | \$ 81.00 |
| Manufacturing | \$ 73.00 |
| Hours | |
| Engineering | 4800000 |
| Tooling | 3500000 |
| Quality Control | 1150000 |
| Manufacturing | 8670000 |
| Development Support Cost | \$ 965,000,000.00 |
| Flight Test Cost | \$ 57,500,000.00 |
| Manufacturing Materials Cost | \$ 225,000,000.00 |
| Subtotal | \$ 2,694,360,000.00 |
| Per rotorcraft | \$ 5,987,466.67 |

| Production Cost | |
|---------------------------|------------------|
| Main Rotor System | \$ 2,515,047.88 |
| Airframe | \$ 6,646,149.62 |
| Landing Gear | \$ 67,956.73 |
| Powerplant Structure | \$ 61,049.22 |
| Air Induction | \$ 155,759.79 |
| Propulsion | \$ 2,834,374.56 |
| Flight Controls | \$ 18,868.69 |
| Intruments | \$ 1,001,404.22 |
| Hydraulics | \$ 144,591.28 |
| Electrical | \$ 173,699.31 |
| Avionics | \$ 188,680.87 |
| Furnishings and Equipment | \$ 293,547.86 |
| Air Conditioning | \$ 140,900.06 |
| Load and Handling | \$ 28,067.43 |
| Final Assembly | \$ 21,105,990.61 |
| Subtotal | \$ 35,376,088.14 |

Totals Per HealCopter

| | |
|----------------------------------|--------------|
| Production Cost | \$35,379,088 |
| R&D Program Cost | \$5,987,467 |
| Selling Price | \$62,045,332 |
| Direct Maintenance Cost (yearly) | \$912,500 |
| Direct Operating Cost (hourly) | \$4,449 |

