HammerHead

Advanced VTOL Concept for 31st AHS Student Design Competition

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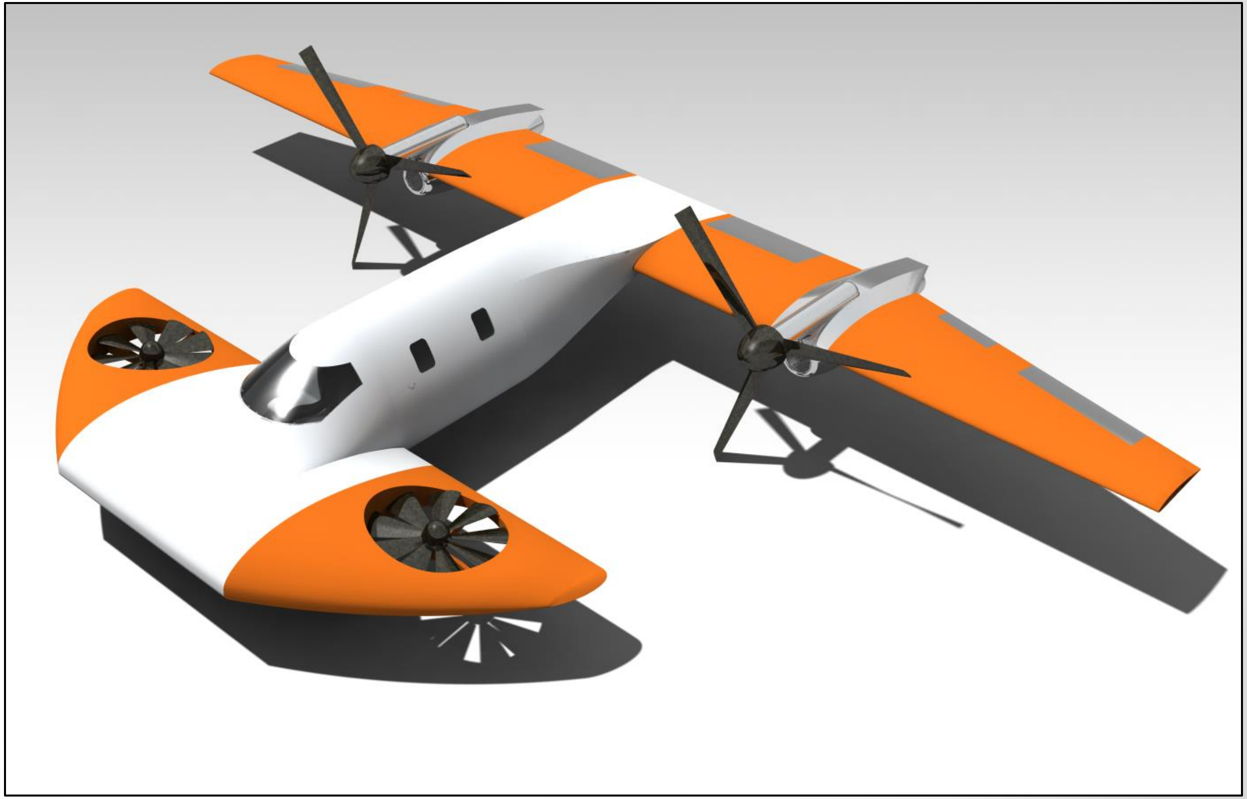
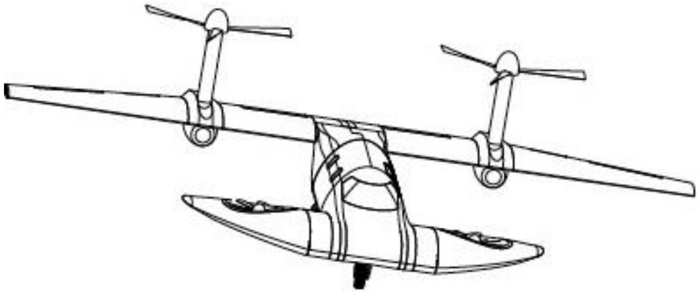


Concept Breakdown

The HammerHead Concept Meets All Requirements Set Forth in the RFP



Requirement	AHS Requirement	HammerHead
Gross Weight	10000-12000 lbs	10925 lbs
Maximum Speed	300-400 kts	320 kts
L/D	>= 10	10.3
Figure of Merit	>= 0.75	0.8
Useful Load Fraction	>= 40%	39.99%
Payload Fraction	>= 12.5%	18%
Ultimate load	>= 2.0	2.0

Flight Configurations

Forward Flight Configuration

Only the two Tiltrotors are used for thrust. They allow for the Hammerhead to operate fully as a fixed wing aircraft. In this configuration the canard Fan-In-Wings are covered and powered off.

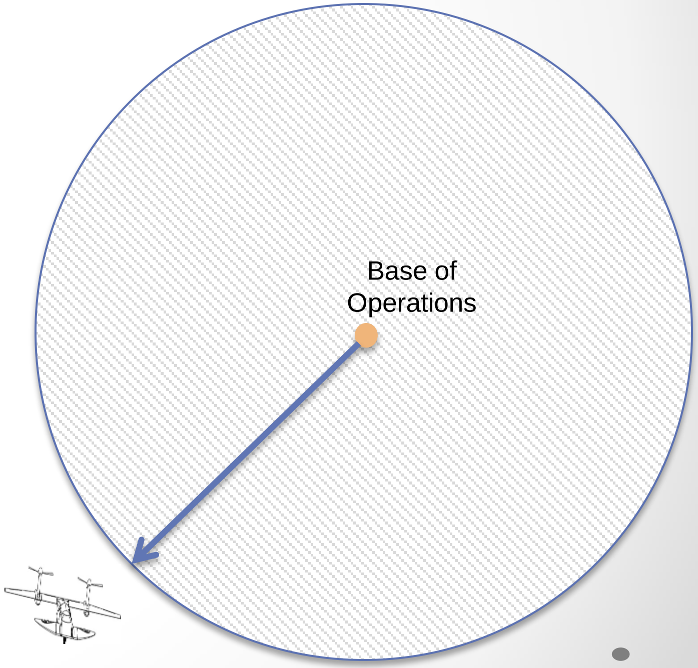
Transition-Hover Configuration

Both the two Tiltrotors and the two Canard Fan-In-Wings are used for thrust. The Tiltrotors are tilted to vary thrust along the x-body axis of the aircraft.

HammerHead RFP Mission Performance

Mission Segment	Time (min)	Condition	Segment Range (nmi)
Start-up/Warm-up/Taxi	10	Engine Idle, SLS	0
HOGE Take Off	1	95% Max Power, SLS	0
Climb	10	To Best Alt. (20,000 ft), ROC = 200 fpm, V_{broc}= 200 kts	32.8
Cruise Out 1	11	V_{br}= 220 kts, Best Alt. (20,000 ft), ISA	40.3
Cruise Out 2	15	Max Sustained Speed, 95% Max Power, Best Alt. (20,000 ft), ISA, Vmax = 315 kts	78.8
Descend	10	To SLS, ROC=-2000 fpm, V_{broc}= 155 kts	25.7
Mid Mission Hover	15	HOGE with Full Payload, 95% Max Power, SLS	0
Climb	10	To Best Alt, ROC = 200 fpm, V_{broc}= 200 kts	32.8
Cruise In 1	15	Max Sustained Speed, 95% Max Power, Best Alt., ISA	78.8
Cruise In 2	11	V_{br}= 220 kts, Best Alt. (20,000 ft), ISA	40.3
Descend	10	To SLS, ROC=-2000 fpm, V_{broc}= 155 kts	25.7
HOGE Land	1	95% Max Power, SLS	0
Shutdown/ Taxi	5	Engine Idle, SLS	0
Total	125	Mission Time and Range Totals	353.7

HammerHead Radius of Action
176.86 Nautical Miles



Design Methodology

1) Concept Comparison & Selection
   - ❑ Analyzing the requirements set forth by the RFP an overall evaluation criteria was created to compare different conceptual ideas
   - ❑ Low Fidelity MATLAB Concept model assessment

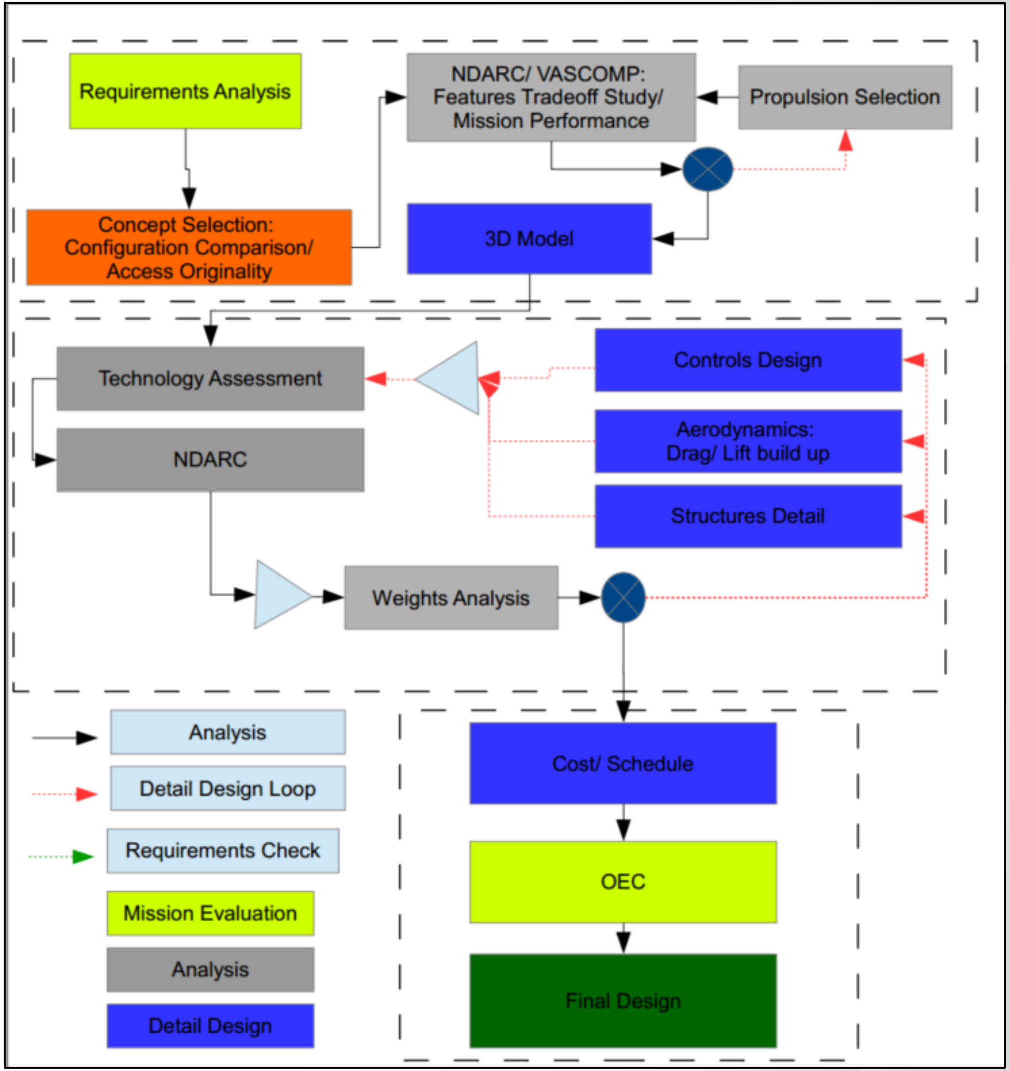
   Outcome: Overall Concept Chosen, general dimensions and features assigned to concept

2) Concept Refinement & Detailed Assessment
   - ❑ NASA Design and Analysis of Rotorcraft (NDARC) sizing program used iteratively to determine performance and sizing characteristics
   - ❑ CAD Modeling, Structural Analysis, & Control Design refined NDARC results in iterative process
   - ❑ System Requirements Evaluation

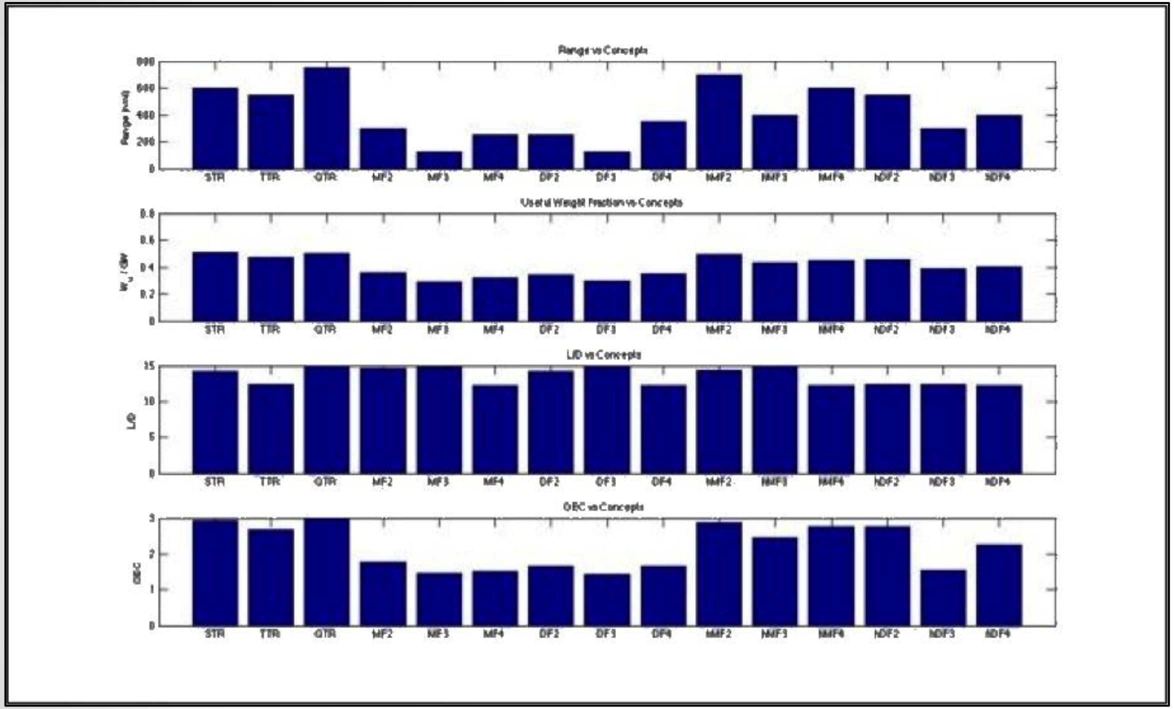
   Outcome: Initial Detailed Design & Configuration

3) Detailed Design Refinement by iterative process
   - ❑ Complex CAD models developed
   - ❑ Higher fidelity Control Systems Simulations tested
   - ❑ Manufacturing & Cost Assessment Completed
   - ❑ NDARC Refinement from more detailed design
   - ❑ System Requirements Evaluation

   Outcome: Refined Design & Final Concept



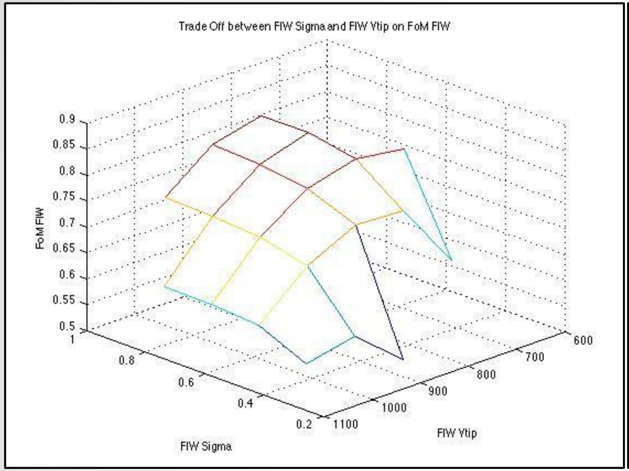
MatLab Initial Concept Selection

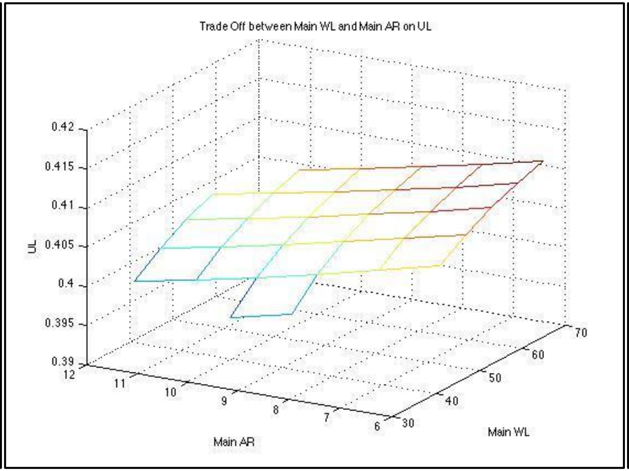


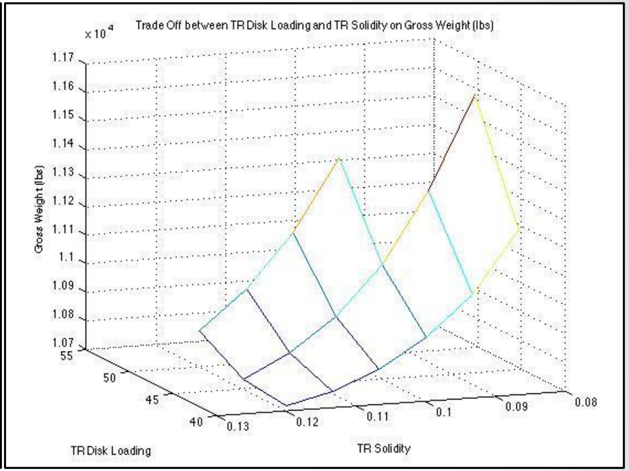
- Initial trade study performed on several concept ideas
- Overall Evaluation Criteria developed and used to select best configuration for development
- This analysis yielded a concept utilizing dual FIW lifting devices and Tilt Rotor configuration

$$OEC = \frac{12000}{1.2 * GW} + \frac{MissionRange}{1000} + \frac{L}{D * 10} + C; C = \frac{W_u}{GW}\ if\ W_u \geq 0.4, else\ C = -0.5$$

Brief Trade-Off Review







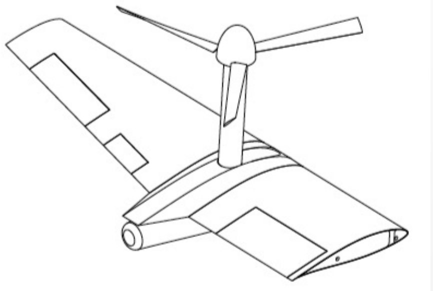
- Multiple trade studies were conducted on major design parameters to narrow range of considered options

- Presented are a small subset of these studies
  - FIW Solidity and FIW Tip Speed vs FIW Figure of Merit
  - Main Wing Loading and Aspect Ratio vs Useful Load
  - TR Disk Loading and TR Solidity vs Gross Weight

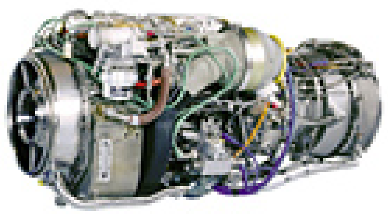
Selected Concept Design Parameters

Wing	Canard	FIW	TR
Wing Loading: 45	Wing Loading: 71	Radius: 2.41 ft	Disk Loading: 49.5
Aspect Ratio: 10	Aspect Ratio: 4	Solidity: 0.67	Solidity: 0.114
Taper: 0.5	Taper: 0.3	V_{tip} = 700 ft/s	V_{tip} = 845 ft/s

The above design parameters were a result of the optimization process that took place after concept selection.



Powerplant - GE T700/CT7



- Same "off-the-shelf" engine model used for all engines
  - Reduces design complexity
  - Reduces maintenance costs
- Chosen based on project power requirements
  - Needs to exceed required power without wasteful surplus

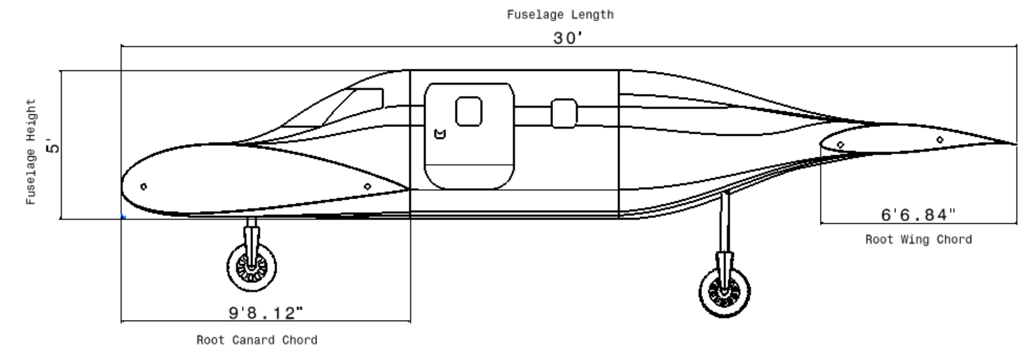
Trade Study Approximations

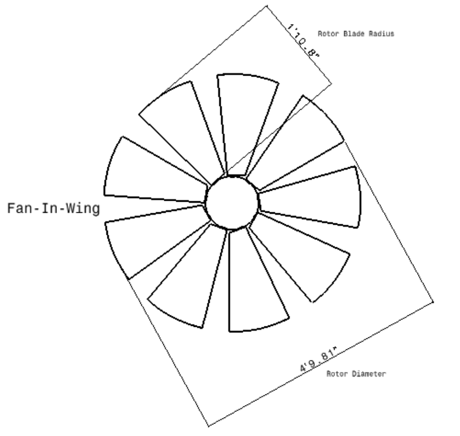
Installed Horsepower	1400-1800 (hp)
SFC	0.41 (lb / shp-hr)
Dry Weight	325 - 375 (lbs)

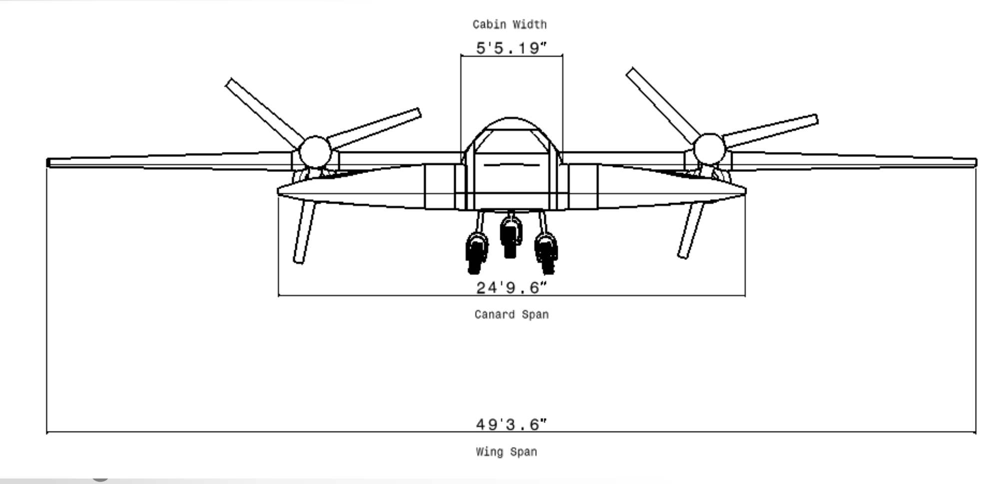
Engine Specifications

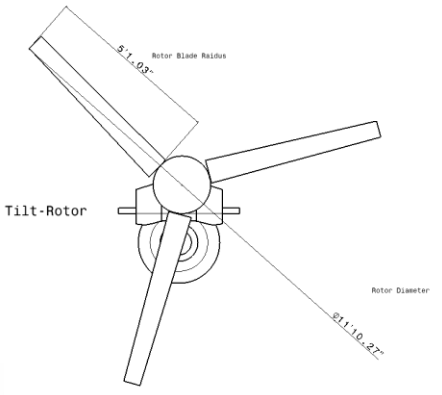
Installed Horsepower	1625-1890 (hp)
SFC	0.462-0.475 (lb / shp-hr)
Dry Weight	429 - 456 (lbs)

Aircraft Dimensions



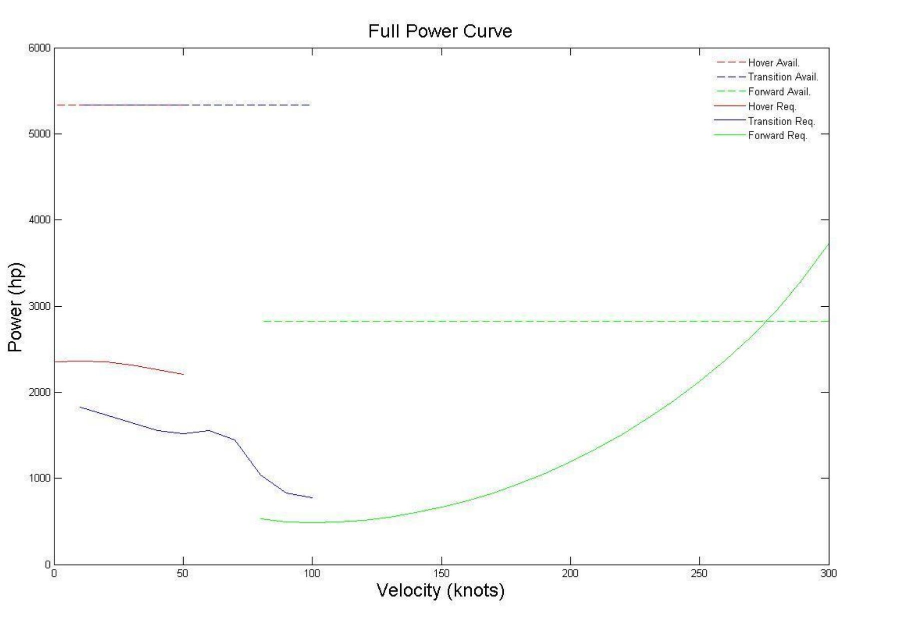






Performance

Max Range	638 (nmi)
Max Hover Time	91 minutes
Max Velocity	320 (kts)
Cruise Altitude	20,000 (ft)
Hover Ceiling	18,000 (ft)
Service Ceiling	40,000 (ft)



SLS Power Curves

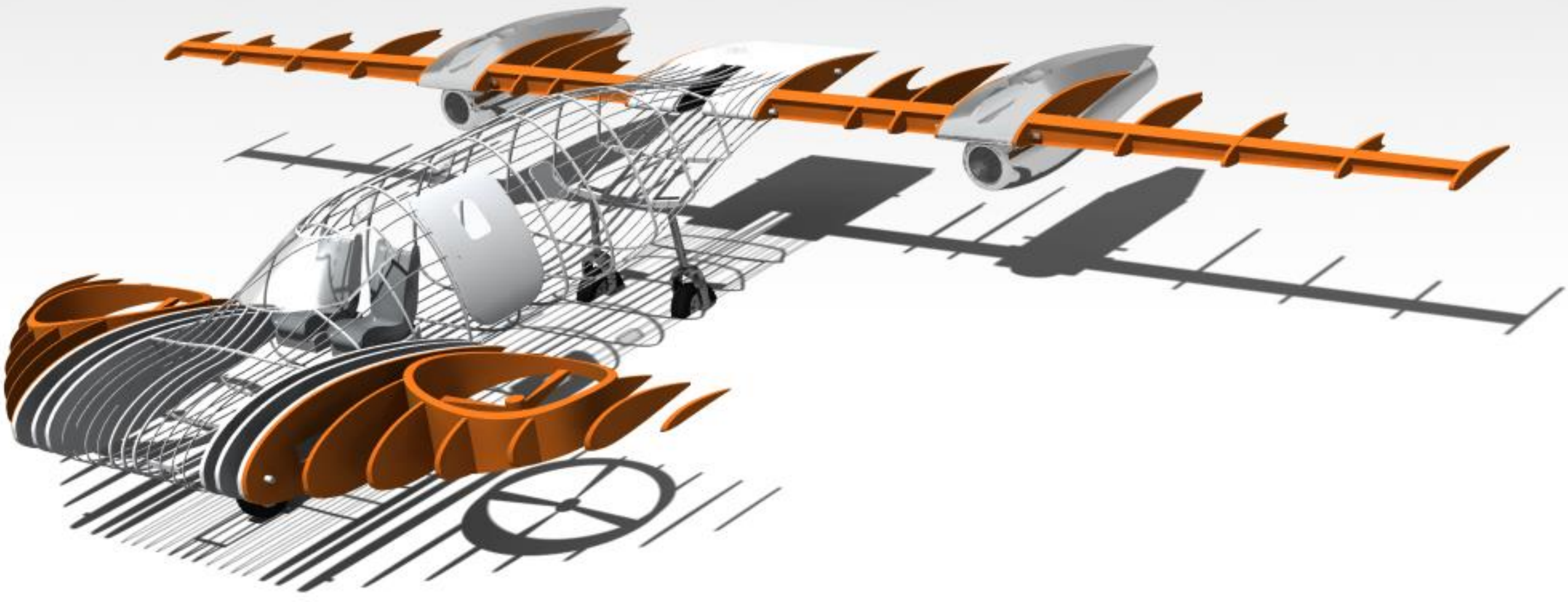
- Design optimization resulted in these performance and flight characteristics.

Weight Breakdowns

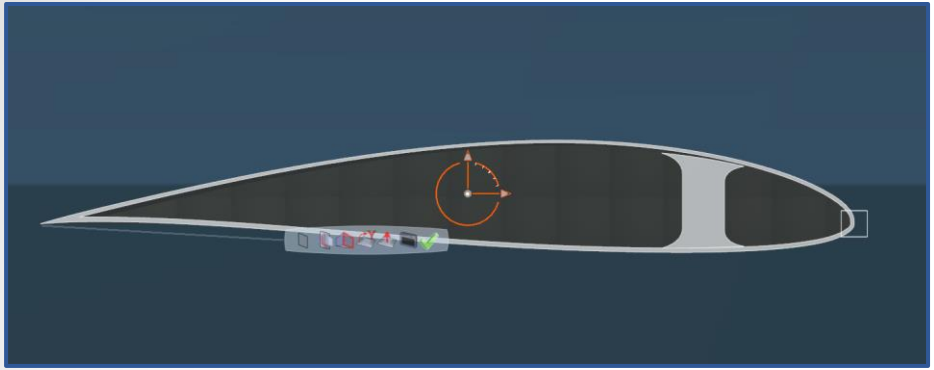
High Level Weights	Weight (lbs)	% of GW
Gross Weight	10925.53	N/A
Operating Weight	7266.695	66.5111441
Empty Weight	6786.695	62.1177645
Usable Fuel	1689.139	15.4604765
Payload Weight	1737.673	15.9047021
Useful Load	4226.812	38.6874779

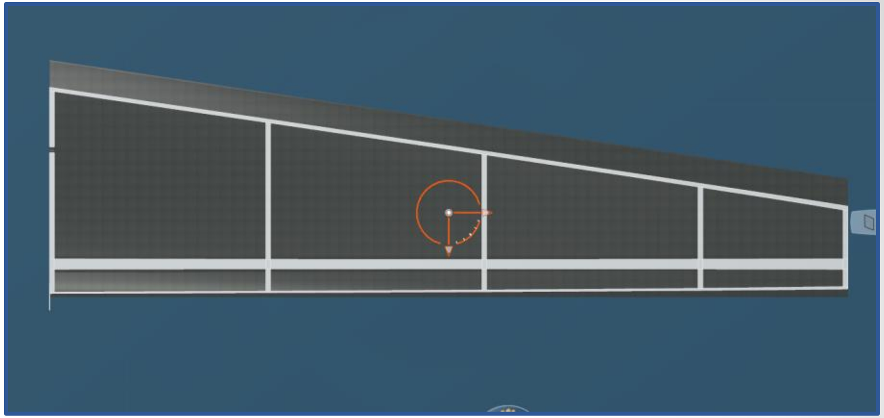
- An Extensive weight breakdown exists in the paper detailing the component weights given by NDARC in Mil Standard 1374 format
- The aircraft significantly undercuts the maximum gross weight given in the RFP. This means the aircraft has some room during the next design phase to increase in weight, as is often the case, and still meet gross weight requirements.

Structures



Structures





- In order to meet weight requirements a large percentage of composites was assumed. The skin, structure and some moving components were all assumed to at least 90% by volume
- Optimization technology factors were also considered given the advancement in topology optimization tools such as HyperWorks by Altair and other such tools.
- The results was assumed technology factor savings of at most 31% weight savings over traditional structures.

Controls

Pitch	Hover: Longitudinal Cyclic Control Forward Flight: Inner Elevons
Roll	Hover: Lateral cyclic controls Forward Flight: Outer Elevons
Yaw	Hover: Rotor Differential Forward Flight: Rotor Flaps

- In order for the aircraft to be considered feasible control schemes were created for all flight modes and transition. The feasibility of all the schemes are proven in other concepts and real aircraft, though not necessarily used together.

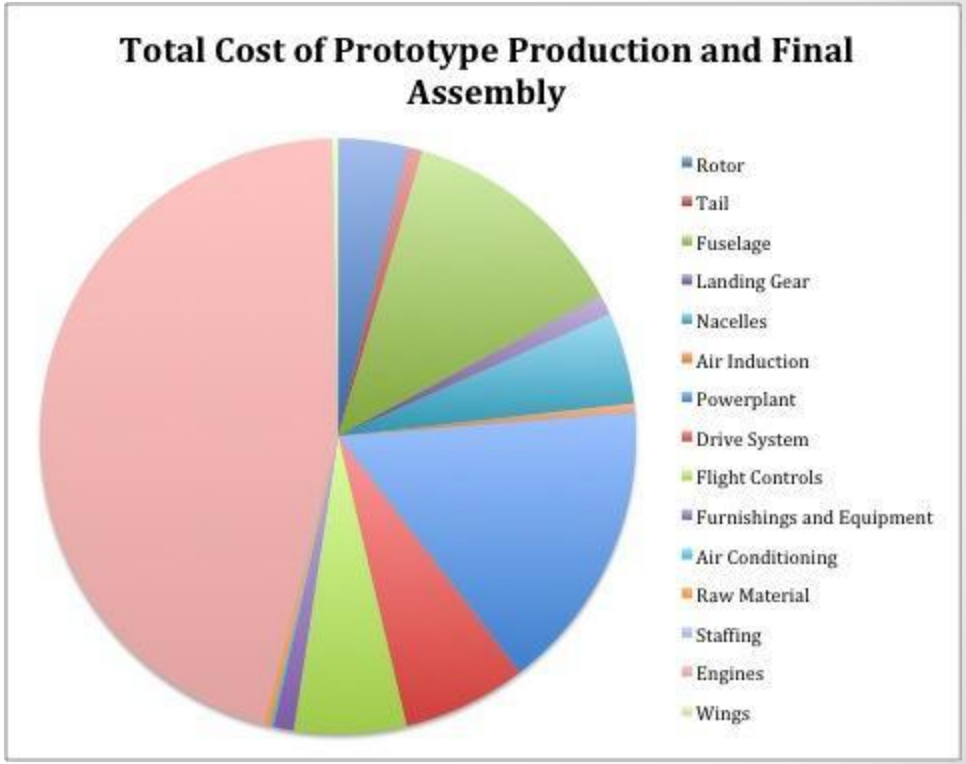
Cost Analysis

- Cost was a major consideration during the development. Decisions such as the number of engines, the rotor technology and other options were all based partly on perceived cost effects.
- A cost model was then used on the final configuration resulting in the costs seen on the next slide.

Cost Analysis

Rotor	$263,960
Tail	$52,263
Fuselage	$874,244
Landing Gear	$75,886
Nacelles	$344,741
Air Induction	$33,011
Power plant	$1,099,961
Drive System	$466,423
Flight Controls	$421,387
Furnishings and Equipment	$76,730
Air Conditioning	$12,015
Raw Material	20,921.80
Staffing	242,000.00
Engines	$3,167,333
Wings	23,500
Net Total	$7,756,784

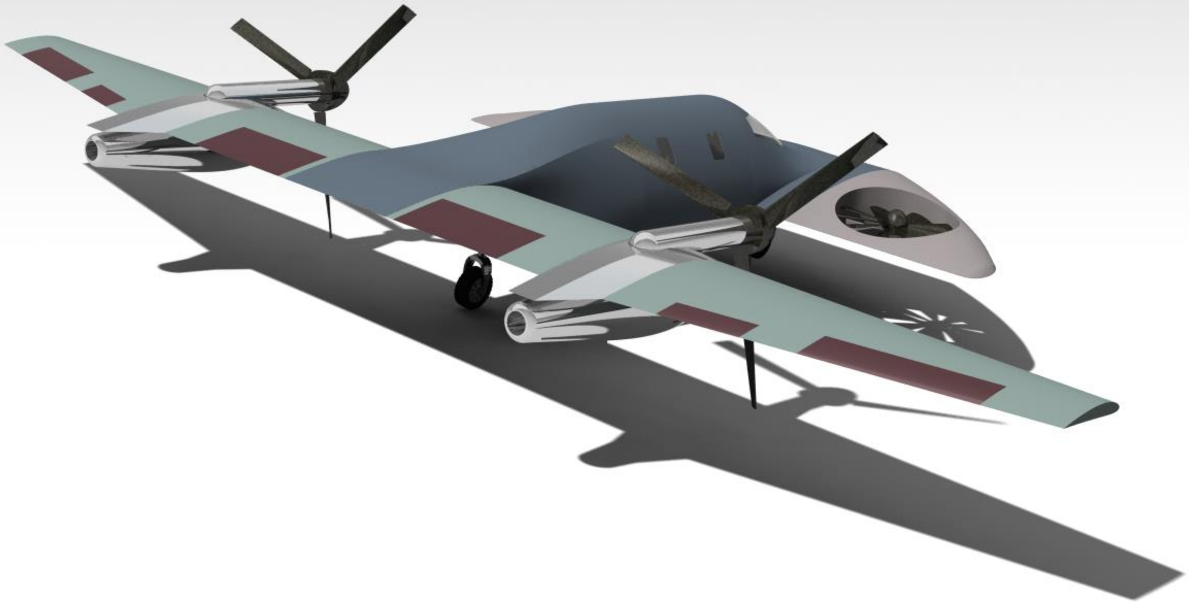
Based on four month assembly cycle



Forward Flight Configuration

Hover Configuration

Unpainted Model



Conclusions

The HammerHead is an innovative and unique approach to a challenging competition. A intricate concept selection and optimization process led to the design of FIW lifting devices in combination with Tilt-Rotors in a canard configuration