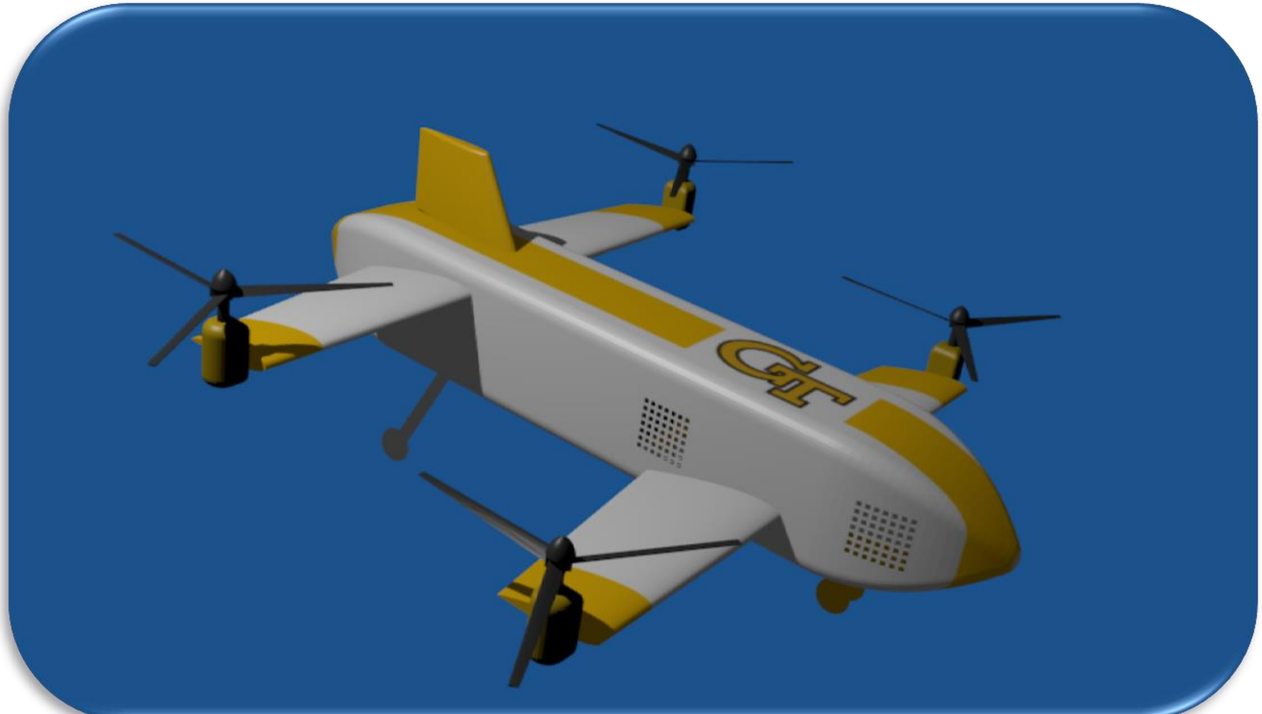
Air Buzz



32nd Annual AHS International Student Design Competition

MIDDLE EAST TECHNICAL UNIVERSITY

Georgia Tech

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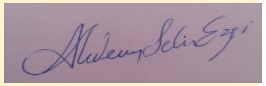
Ezgi Selin Akdemir	esakdemir@gmail.com	Undergraduate	Middle East Technical University	
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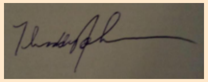
Thaddeus Johnson	tjohnson49@gatech.edu	Undergraduate	Georgia Institute of Technology	
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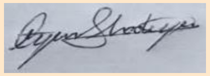
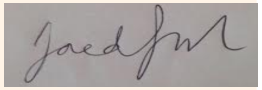
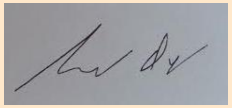
Olutoyin Shodiya	oshodiya3@gatech.edu	Undergraduate	Georgia Institute of Technology	
Jared Smith	jsmith380@gatech.edu	Undergraduate	Georgia Institute of Technology	
Sean Sweeny	ssweeny3@gatech.edu	Undergraduate	Georgia Institute of Technology	
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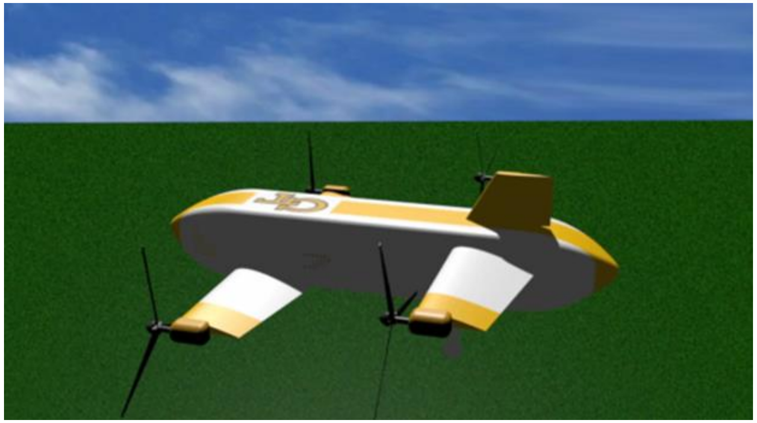
Air Buzz is the newest and most innovative package delivery UAV. The state-of-the-art design couples speed and efficiency with a reduced environmental footprint. As a quad tilt-rotor, Air Buzz is designed to surpass quad-copters and traditional helicopters of its size in cruise speed, therefore decreasing package delivery time and increasing efficiency. Air Buzz is not only practical, but also affordable. It is primarily made from carbon fiber, a very durable material. The fuselage allows for internal carriage of the payload and a single attachment point is present for the use when oversize packages are carried via an external sling load. Not only does Air Buzz perform the package delivery mission quickly, it does so while leaving a smaller environmental footprint. The hybrid-electric propulsion system allows for reduced emissions of gases such as CO_2 and also provides an element of safety in case of a failure of either the battery or internal combustion engine system. For added safety, a parachute is added to the aircraft. The parachute deploys in the event of a total power failure or other catastrophic event. In addition, the noise produced by Air Buzz and its rotors is lower than OSHA (Occupational Safety and Health Administration) requirements. All of these factors make Air Buzz the best option for package delivery in an urban and suburban setting.

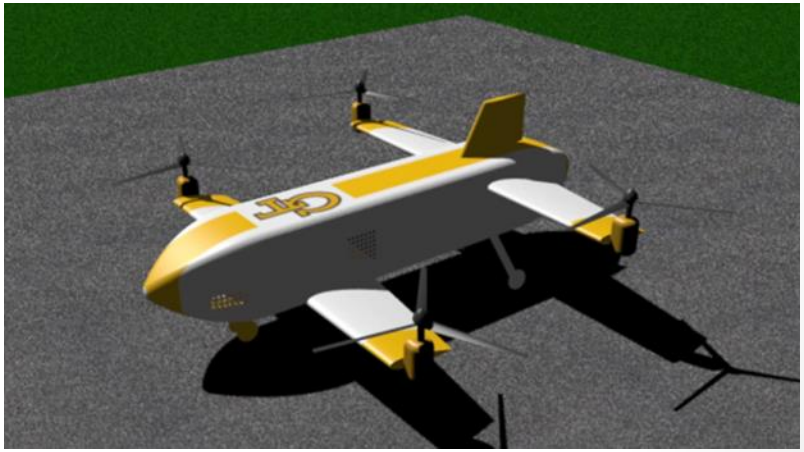


Concept Summary

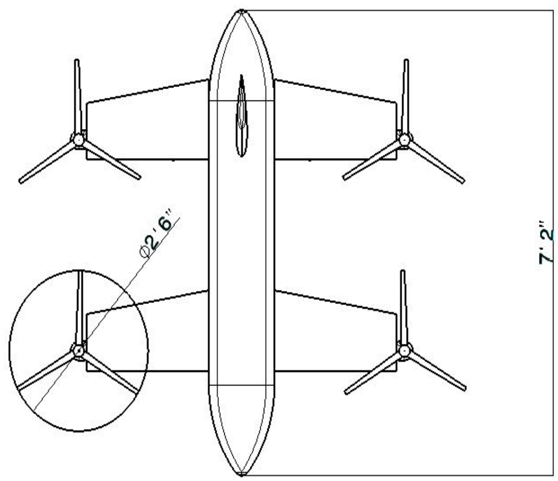
Air Buzz not only meets but exceeds specifications required by the RFP. The hybrid electric propulsion system is capable of producing 12.5 HP with a requirement of 9.47 HP required for takeoff at 110% maximum gross weight. While traveling at the velocity of best range, 133 ft/s, Air Buzz is capable of delivering 33 packages per day. The tilt-rotor concept allows for the 1-minute hover segments to be performed while allowing for speed in the forward flight configuration. Landing gear also provides the optimal design for package delivery.

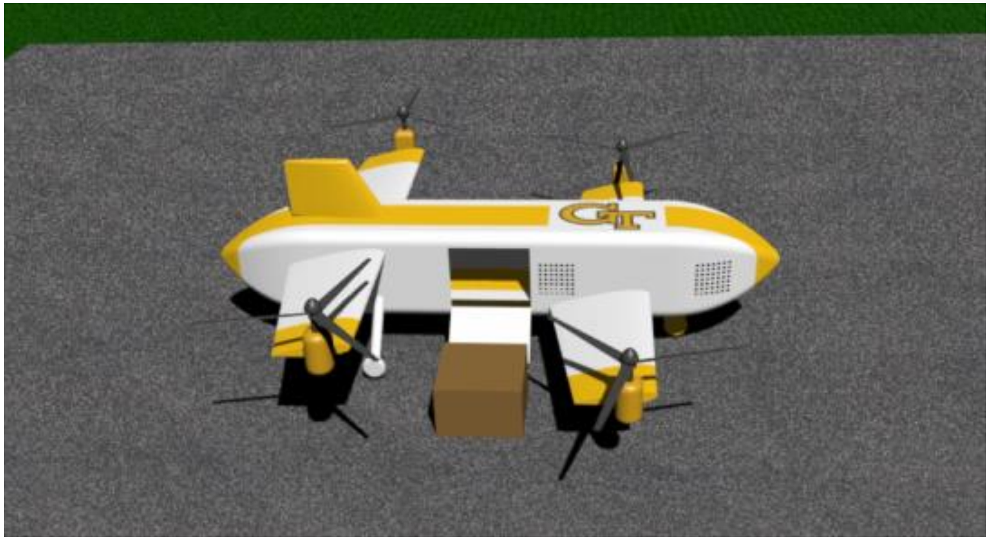
Technical Specifications	
Gross Weight	80.8 lb
Payload Capacity	13 lb
Maximum Range*	55 miles
Velocity of Best Range	133 ft/s
Propulsion System	Hybrid-electric

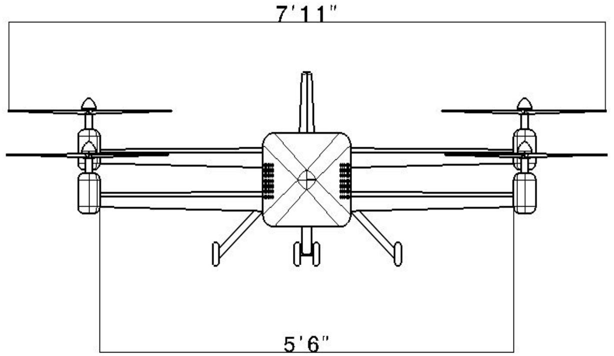
*Maximum Range without charging batteries in-flight

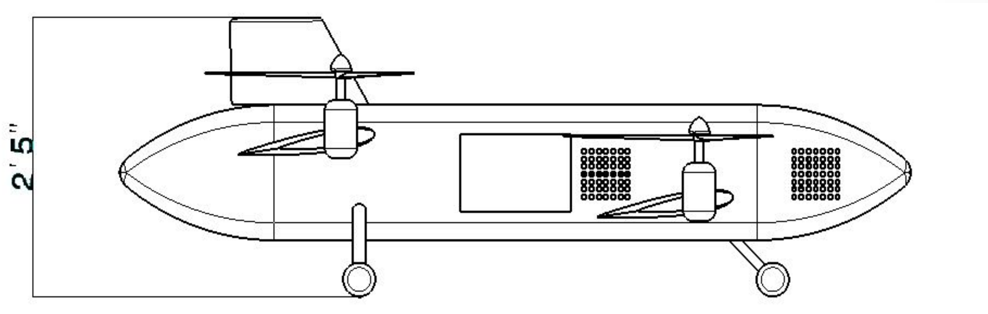


Aircraft Dimensions

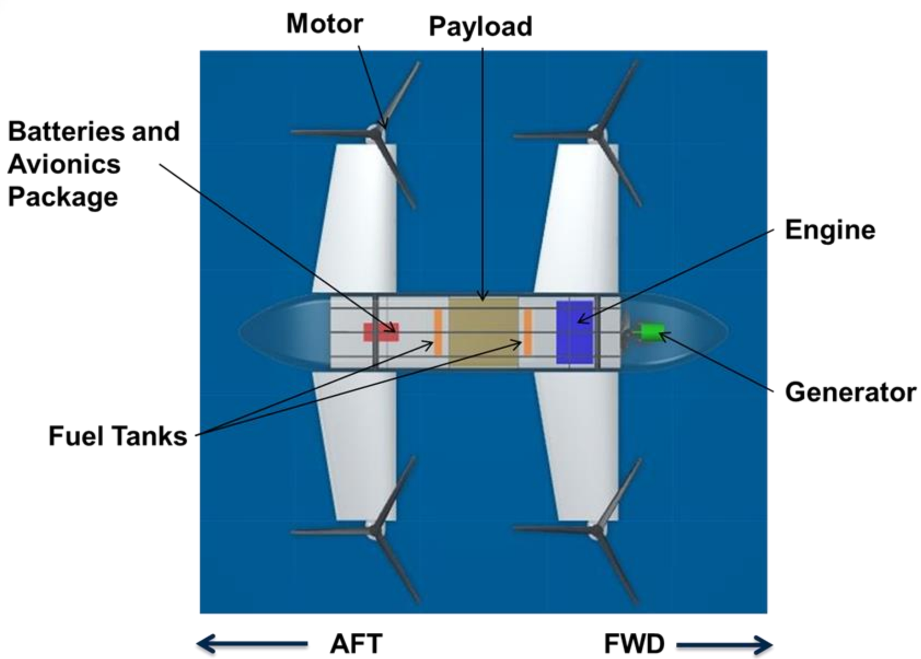


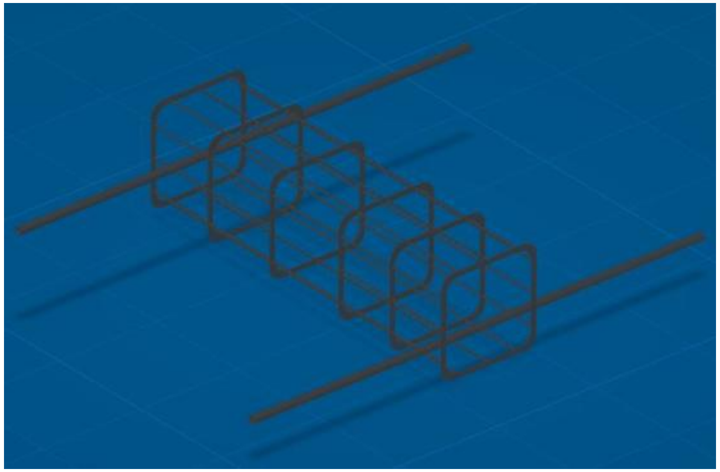






Internal Structure





The internal payload is loaded into the package compartment of Air Buzz's fuselage. The package compartment is located at the center of gravity. Bulkheads and strings are used for structural fuselage support. In addition, two carbon fiber spars provide structural integrity to the wings.

Component and Weight Summary

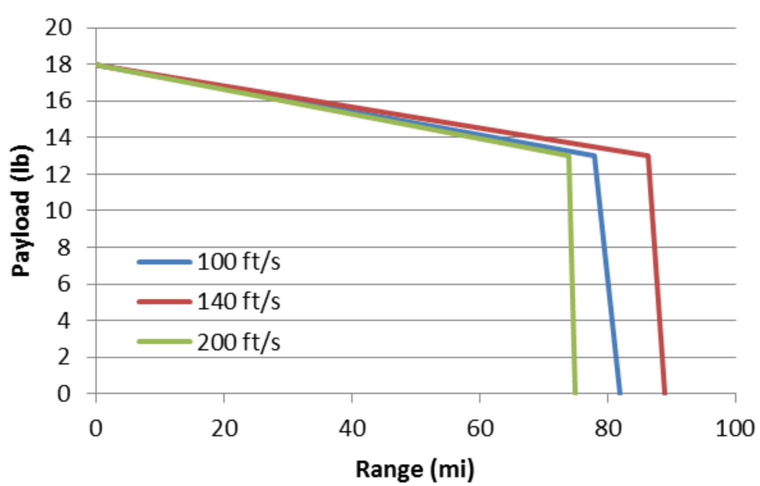
Rotors	Number	Radius	Root Cutout	Blades	Root Chord	Tip Chord	Root Twist	Vtip	Airfoil dCL/da	Airfoil Cd0
	4	1.25 ft	10.0%	3	1.5 in	.75 in	20	700. ft/s	0.1106 /deg	0.01621
Wings	Number	Span	Mean Chord	TR	AR	AOI	CL0	dCL/da		
	2	5.5 ft	1.05 ft	0.7	5.238	8	0.167	0.073 /deg		
Drag	Wing CD0	Wing e	Fuselage FE	Drag Multiplier	Hover Dv/GW					
	0.00848	0.85	0.2568 ft^2	1.1	6.55%					
Propulsion	Engine SFC	Generator η	Motor η							
	0.85 lb/(hp-hr)	0.92	0.94							
Weight	WE	GW								
	62.8 lb	80.8 lb								

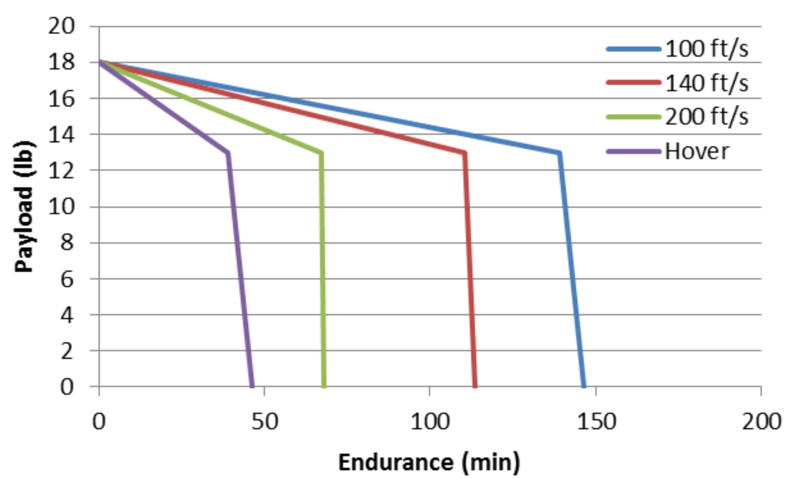
Weight Breakdwon	
Component	**Weight (lb)**
Payload	13
Fuel	5
Fuselage/Payload Container	5.8
Wing (2)	12.9
Vertical Tail	5
Hub/Nacelle (2)	6
Rotors (4)	3
Landing Gear	1.5
Engine/Shafting/Fan	8.6
Generator	2.4
Batteries (6)	5.7
Motors (4)	7.4
Winch	3
Avionics/Misc	1.5
Total (Gross Weight)	**80.8**

Trade Studies and Performance Outcome

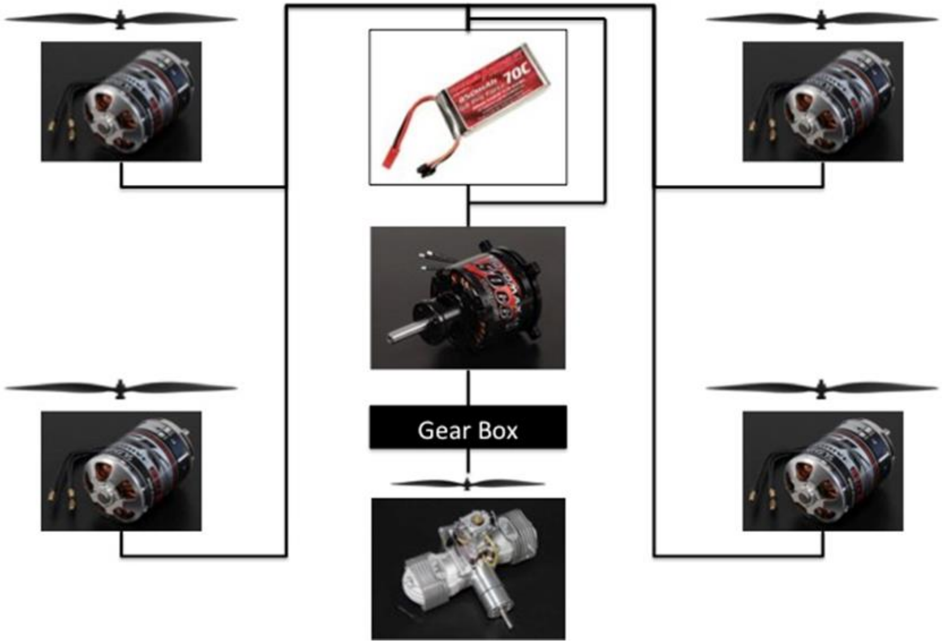
A program was created to conduct trades studies for the aircraft. Wing span, rotor radius, and empty-to-gross weight ratio were some of the parameters that were iterated through the sizing process. Additionally, the velocities of best range and endurance values were swept through the varying configurations. The resulting power and fuel requirements are shown in the table below. Aircraft performance was analyzed with MATLAB as well as a blade element momentum theory model and then validated with QPROP software.

		Hover		VBR				VBE			
Weight (lb)		Power (hp)	lb/hr	Speed (ft/s)	Power (hp)	lb/hr	Miles/lb	Speed (ft/s)	Power (hp)	lb/hr	Miles/lb
Empty	57.80	6.67	6.56	133	5.15	5.06	17.92	68	3.63	3.56	13.01
Gross	75.80	8.59	8.44	139	5.61	5.52	17.18	78	3.99	3.92	13.55
110% Gross	83.38	9.47	9.31	141	5.81	5.71	16.84	82	4.16	4.09	13.68





Propulsion System



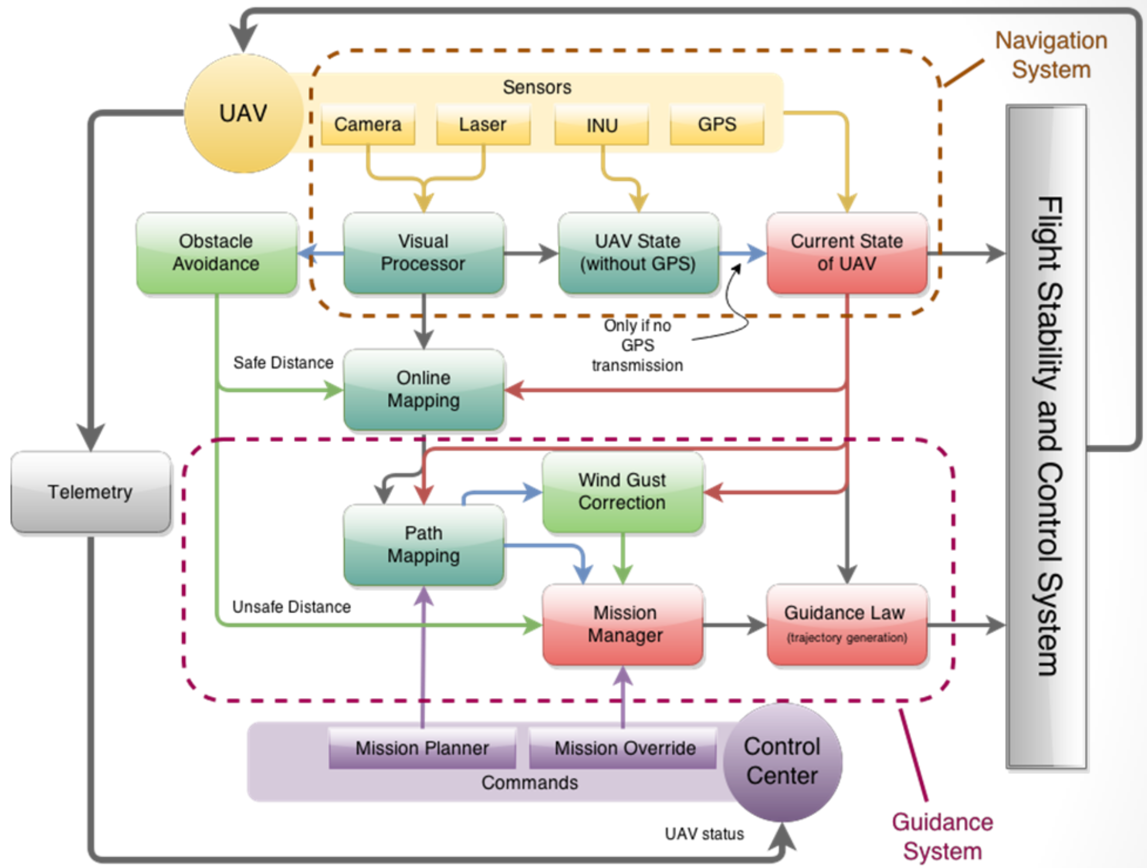
Propulsion System Schematic

The hybrid-electric propulsion system offers a combination of an environmentally friendly and reliable system. It is comprise of off-the-shelf parts and allows for batteries to be charges in forward flight when the engine is operating. The system also allows for redundant power sources in the event of a single system power failure.

Component	Name	Weight	Maximum Power	Efficiency	Optimal Conditions
Engine	JC120 Evo	6.61 lb	12.5 HP @ 8000RPM	5 lb/(HP*hr)	6.1 HP @ 6000 RPM
Generator	Turnigy RotoMax 50cc	2.38 lb	7.1 HP	92%	6 HP
Battery (x4)	ThunderPower	2.85 lb	185 Whr 70C	N/A	6 HP for 4.9 Minutes
Motor	Turnigy Aerodrive SK3	1.85 lb	3.06 HP	94%	2.75 HP

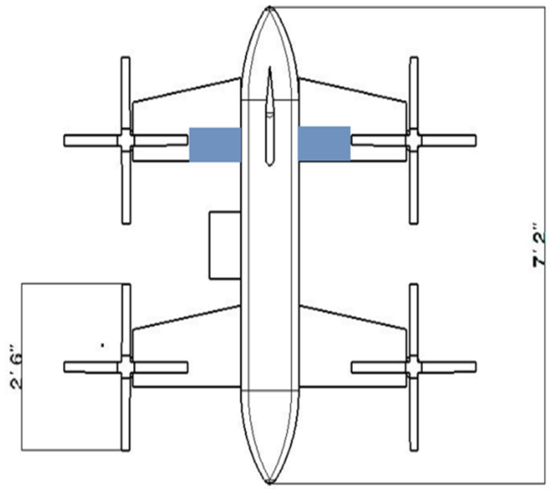
Guidance, Navigation, & Control

The guidance, navigation, and control (GNC) of the vehicle consists of both online and offline mapping for efficient and effective route control for the vehicle. The vehicle will determine routes via a system of waypoints. The vehicle will be able to sense obstacles as well as external forces, such as the wind, and be able to correct for them. In the event of an emergency, the mission can be overridden and flow by a human pilot.

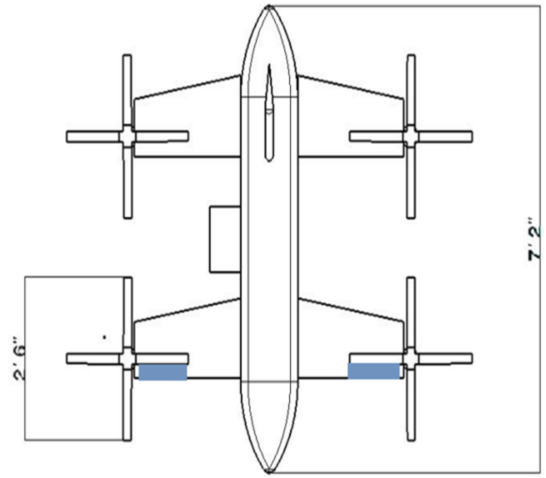


Guidance and Navigation Architecture

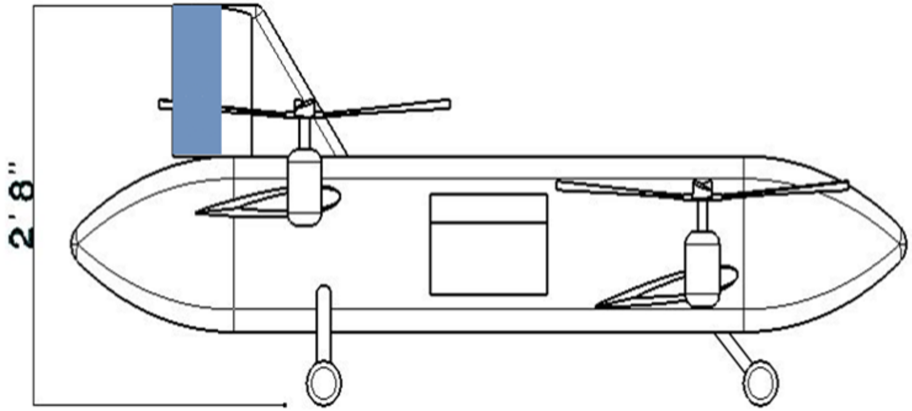
Control Surfaces – Forward Flight



Elevators are located on the front wings for longitudinal trim.



Ailerons are located on the rear wings. The size and position is limited by adverse yaw, aileron stall, and distance from wingtip.



The rudder is located on the vertical tail. It is required for asymmetric power, coordinated turns, and adverse yaw negation.

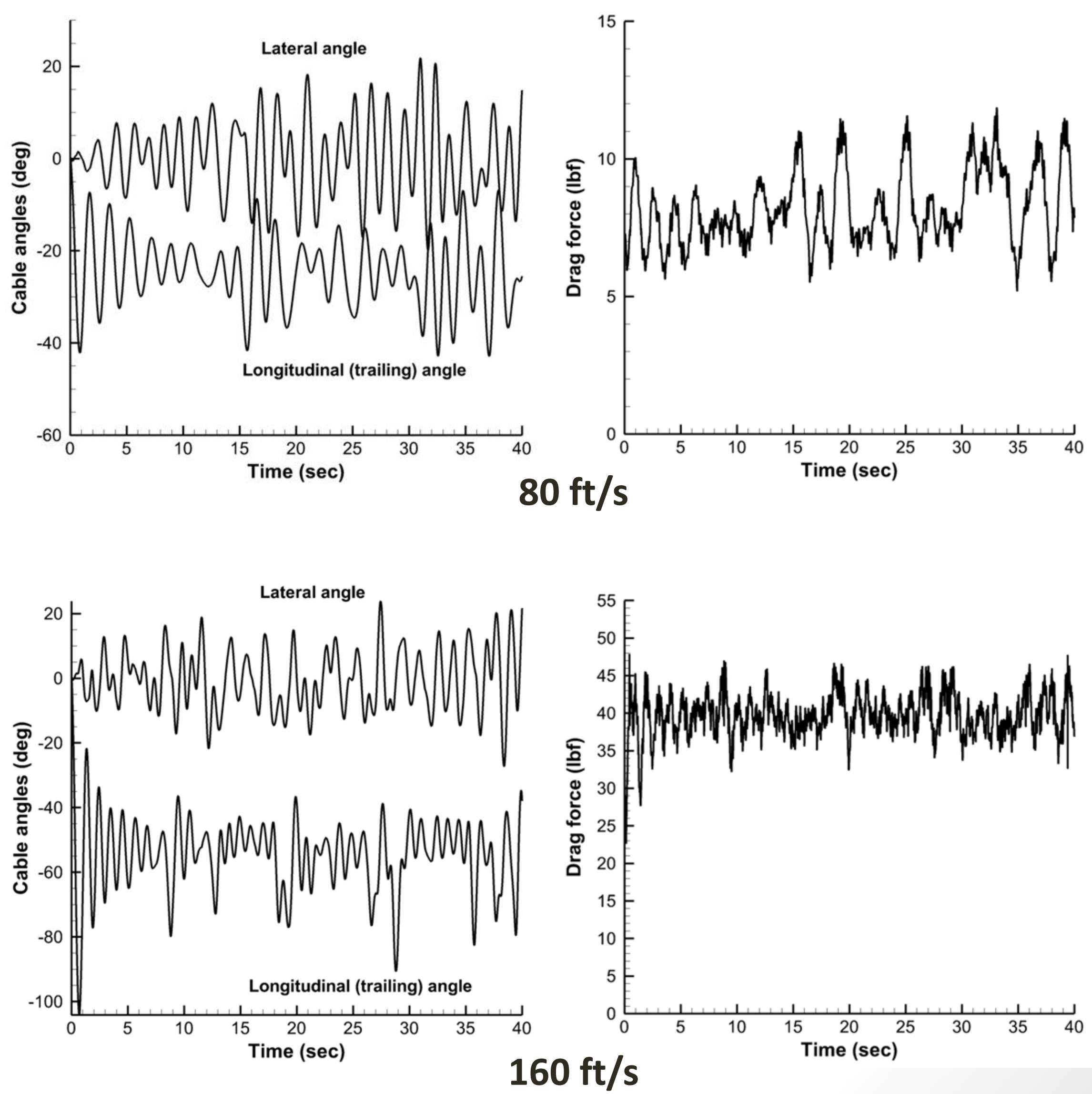
Control Surfaces - Hover

Air Buzz utilizes individual RPM control for each rotor for cyclic, collective, and yaw control in hover.

- Collective - Vertical height control : collective change in RPM of all rotors
- Cyclic - Pitch control: differential RPM change between front and back rotors
- Cyclic - Roll control: differential RPM change between right and left side rotors
- Yaw control: differential RPM change between the two diagonal sets of rotors

Sling Load Considerations

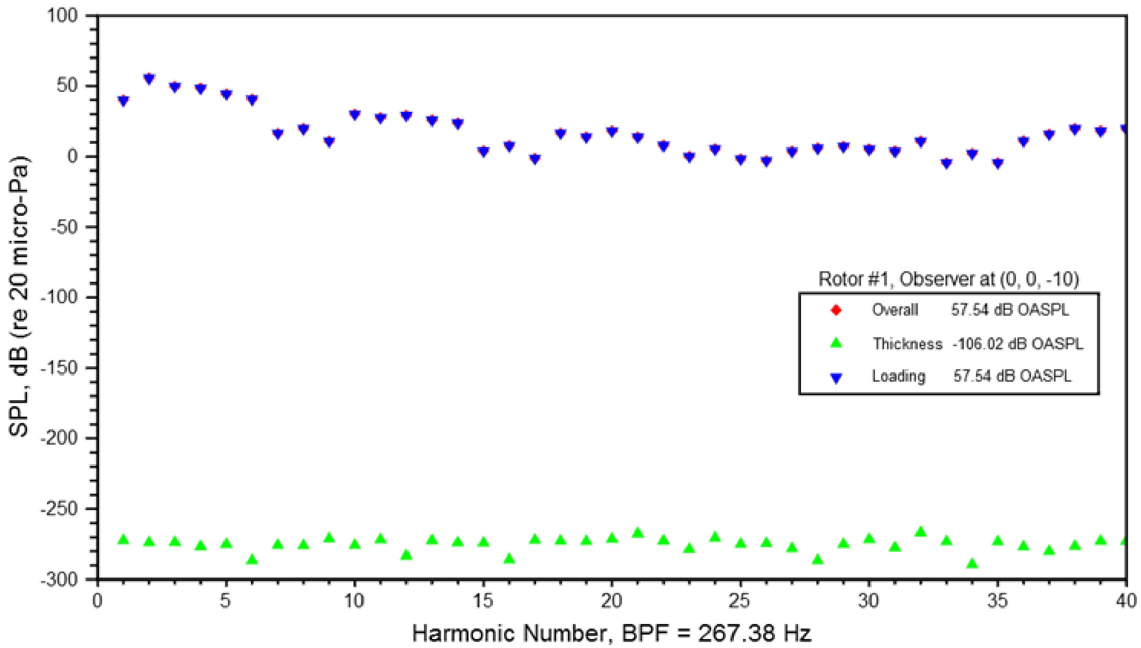
A sling load is used to carry packages that are larger than 12 in x 8 in x 12 in. The external sling load is attached using a gimbal at the single attachment point. Analysis of the stability of the sling load is conducted and it is found that the sling load is stable at a forward flight speed of 80 ft/s but not 160 ft/s. However, there are solutions to this problem, such as using a controller to stability the load or adding a fin to the cargo container.



Acoustic Signature

Evaluation of the acoustic signature was performed using RotCFD. The total noise output of the aircraft is 63.56 dB. This noise level falls within the appropriate exposure standards of the Occupational Safety and Health Administration (OSHA).

Overall Acoustic Sound Pressure Levels



Safety


http://www.protectuav.com/1.html

In the event of a total power failure, a parachute is placed at the rear of the fuselage. It deploys in the event of an emergency in order to assist the vehicle in landing safely and minimizing damage to the vehicle as well as objects and people on the ground. The parachute is manufactured by ProtectUAV and is made especially for small UAVs. The parachute can be deployed up to 10 times during its lifespan.

Landing System	Standard Descent Rates	
	1000 ft MSL	6500 ft MSL
	1000 ft/min	1100 ft/min

UAV MTOW (lb)	Chute Size (ft^2)	Volume (in^2)	Mass (lb)
121	22.604	189.17	2.43

Material Breakdown

Structural Component	Material Type
Fuselage Bulkhead	carbon fiber sheet
Fuselage Stringer	carbon fiber rod
Fuselage Covering	fiberglass sheet
Wing Spar	carbon fiber tube
Wing Ribs	carbon fiber sheet
Wing Foam	polystyrene foam
Wing Covering	carbon fiber sheet

Carbon fiber was chosen for the structural members of the aircraft because of its durability and light weight. Polystyrene foam is chosen to fill the interior of the wings and a fiberglass covering will be applied to the fuselage for increased strength. The materials used also allow for Air Buzz to be affordable while the increased reliability decreases the possibility for future maintenance costs.

Specific Part	Count	Material	Cost ($)
Fuselage Bulkhead	8	carbon fiber	77.29
Fuselage Stringer	12	carbon fiber	432.00
Wing Spar	2	carbon fiber	300.00
Wing Foam	4	polystyrene	100.00
Fiberglass Covering		fiberglass	14.00
Remaining Parts (Nose,Tail, etc.)			500.00
Parachute	1	(ProtectUAV)	1850.00
			3273.29

Propulsion and Manufacturing Cost

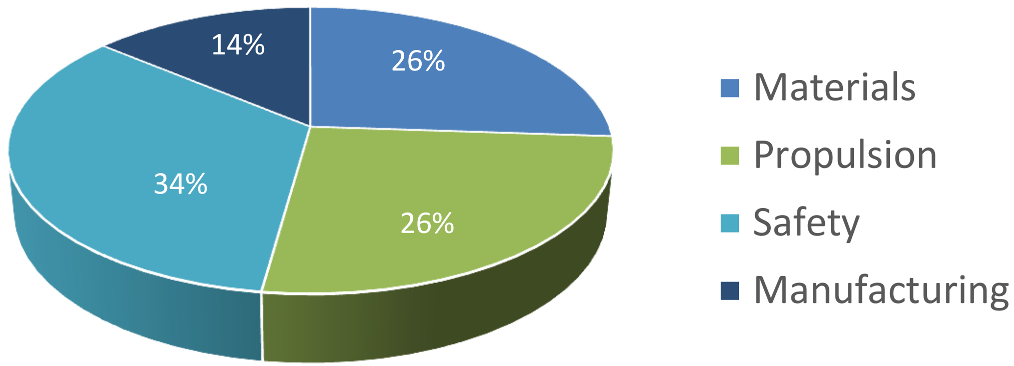
Manufacturing Cost

Process	**Time (hr)**	**Cost (USD)**
Fuselage Bulkhead & Stringer Assembly	15	285
Wing Assembly	10	190
Wing Assembly to Fuselage	8	152
Avionics & Safety Package Installation	5	95
Skin Application	2	38
Total	**40**	**760**

Propulsion System Cost

Specific Part	**Count**	**Cost (USD)**
Scorpion HK-5020-450 Brushless Motor	4	1160.56
ZIPPY Compact 6200 mAh LiPo Pack Battery	1	45.64
Turnigy RotoMax Brushless Motor (Generator)	1	192.30
JC Evo 120cc (IC Engine)	1	453.31
Total		**1851.81**

Total Aircraft Cost Breakdown



Total Aircraft Cost = $5885.10
Overhead Costs = $1177.02

Air Buzz Life Cycle Cost

Operational Period (years)	Cost/Unit (USD)
1	18,238.42
3	54,714.26