Group AF: All-Electric Air Tractor

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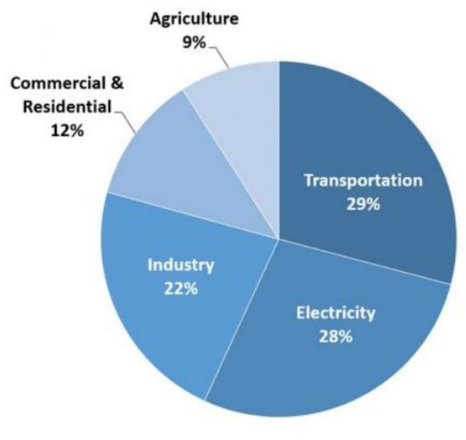
Introduction

Problem Statement: **The goal is to provide a conversion plan for transforming a popular gas-powered agricultural airplane, the Air Tractor 502B, to full-electric using our industry sponsor's electric motor, the Magni-500.**

Motivation/Background

Aviation accounts for almost 11% of transportation CO2 emissions in the U.S. Aviation CO2 emissions are also the fasted growing and hardest to eliminate due the low specific energy of batteries.



Total Emissions in 2017 = 6,457 Million Metric Tons of CO_2

Customer Specification: **A successful conversion would involve a total conversion cost lower than the overhaul cost of the current PT6 engine, and the aircraft maintaining its current maneuverability, pilot interface, airframe, and outside structure. However, the resulting mission profile may deviate from the typical profile of the current model.**

Testbed Plane

Maximum Takeoff Weight	Empty Weight	Hopper Capacity	Wing Span	Typical Use	Range
9400 lbs.	4546 lbs.	500 gal 3850 lbs.	52 feet	Agricultural Spraying	620 miles

Regulations

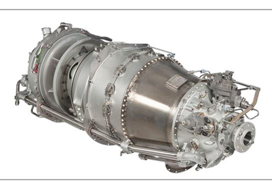
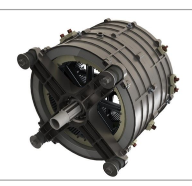
Batteries/Electrification
- AC 20-184

Engine Mount
- FAA FAR Part 23.303: Factor of Safety
- FAA FAR Part 23.361: Engine Torque
- FAA FAR Part 23.371: Gyroscopic Loads
- FAA FAR Part 23.561: Ultimate Inertial Forces

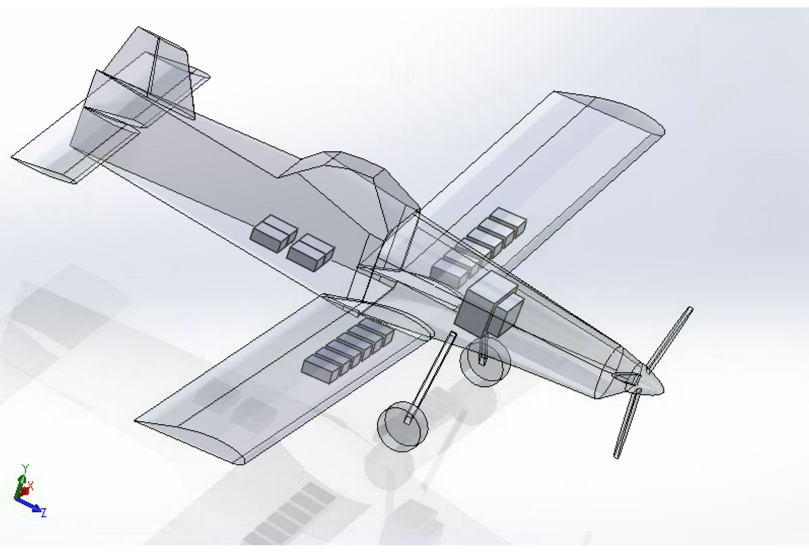
Roadmap for Certification

- Commercial use requires a 30 minute reserve
- Experimental certification until battery technology improves
- Commercial use 5-10 years out

Engine Comparison

Parameter	PT6A-15AG	Magni500
Weight	315 lbs	282 lbs
Power	680 shp	750 shp
Length	~61 in	~21 in
Diameter	~17.1 in (based on Quincy measurements)	~21.5 in
Operating Speed	2200 RPM	1900-3000 RPM
Image		

Power Supply



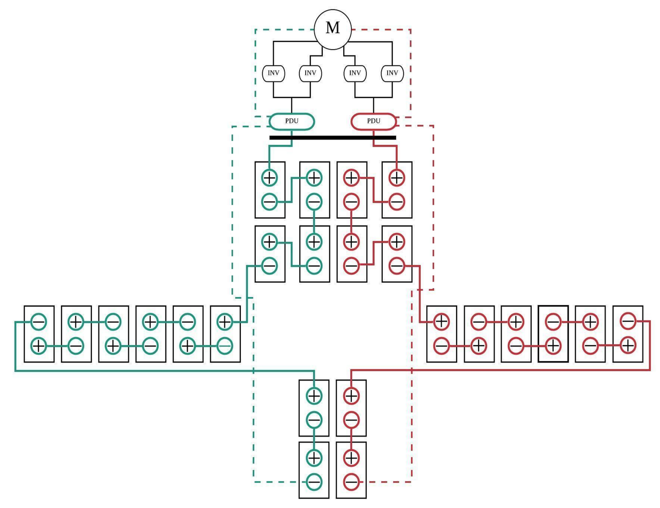
Total of 24 batteries: 12 in wings, 4 in aft, 8 in front

EvoTraction Battery	48 VDC/300 Ah/15 kWh
Specific Power	203 Wh/kg
Max Current	900 A
Protection Class	IP67
Additional Features	Imbedded BMS; 2 CAN ports

Conversion Design

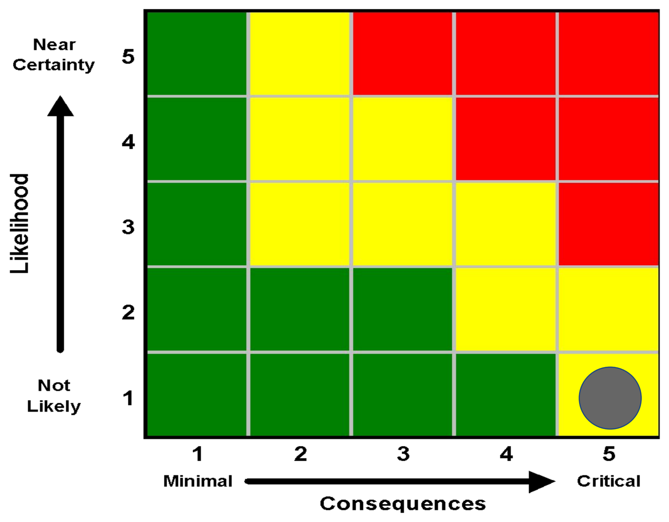
Electrical Circuit Design

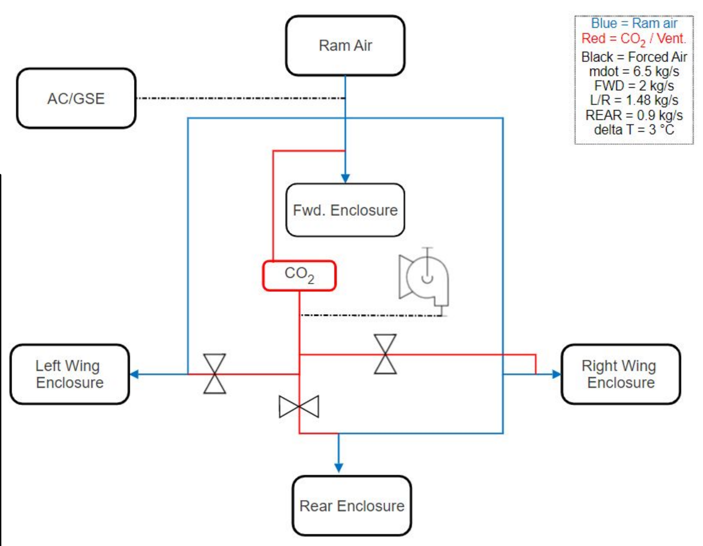
Double stack battery configuration
- 576 V and max of 900 Amp through each stack
- Two stacks share a common busbar



Combustion Risk:

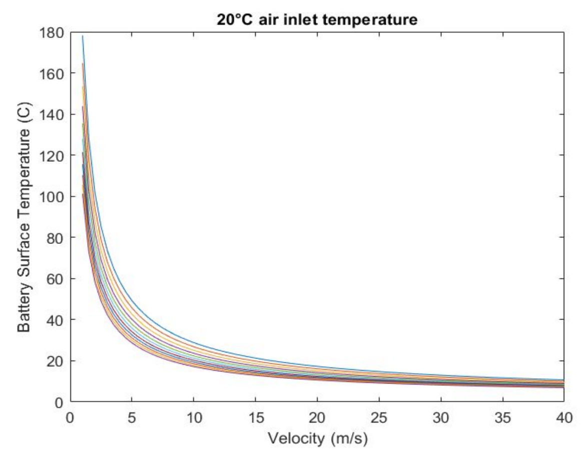
- Low likelihood: 1 in 10 million to 1 in 1 million
- Dire consequences: Thermal runaway, external oxygen supply for combustion not necessary, combustion persists
- Causes: Puncture, impact, vibration, overcharging and over heat





Thermal Management

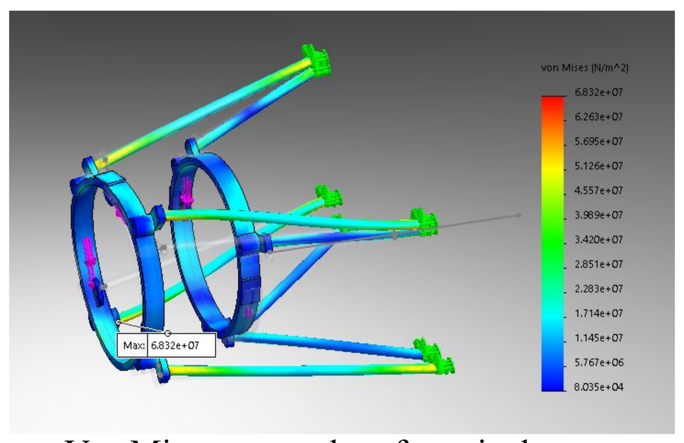
- Passive air cooling
  - Ram air used for cooling batteries in-flight
  - GSE used for cooling during ground operations
- Upper diagram shows aircraft level air cooling schematic
- Plot displays sufficient cooling of batteries if air velocity between the batteries is greater than 3 m/s
  - Width of channel between batteries: 20mm



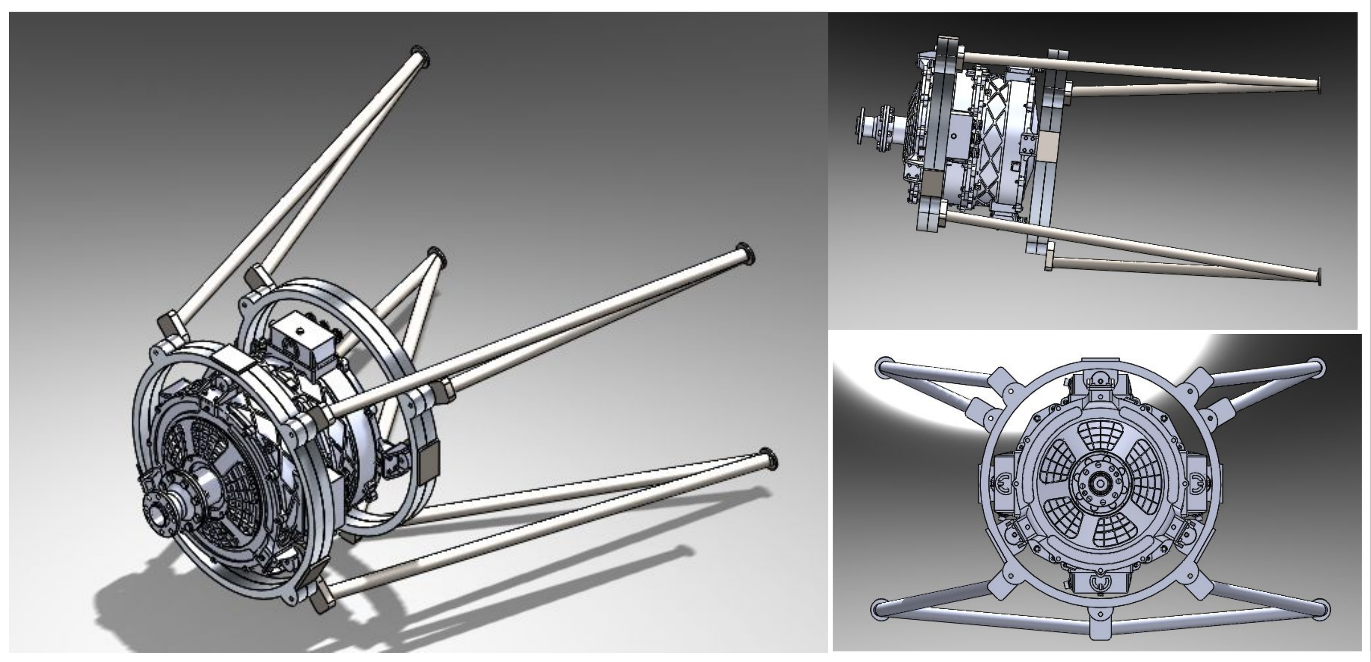
Mounting the Engine

Custom Engine Mount

- Analyzed against gyroscopic loading, engine torque, and ultimate inertial forces
- Yield factor of safety ~ 1.63 to 8.19
- Constructed out of 6061-T6 Aluminum and 4130 Alloy Chromoly Steel



Von Mises stress plot of nominal torque simulation



Final CAD model of Magni-500 engine mount, showing isometric (left), right (upper right) and front (bottom right) views

Aircraft Performance and Future Outlook

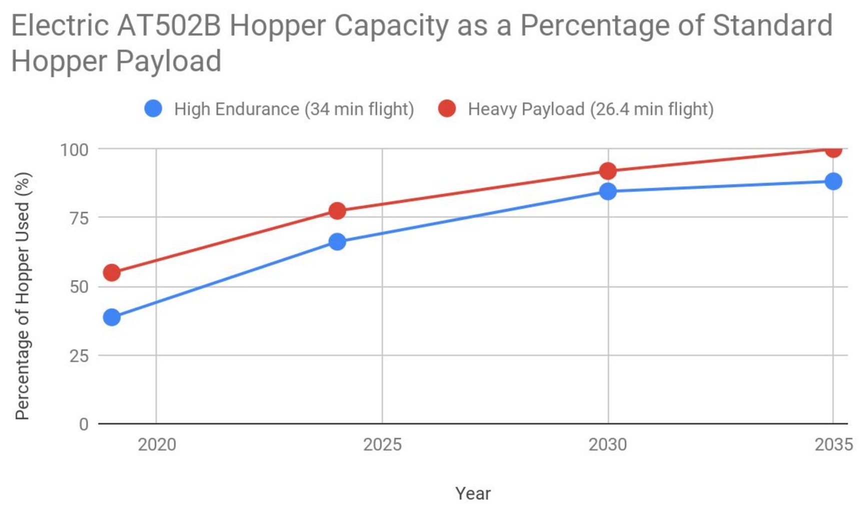
Power Consumption Model

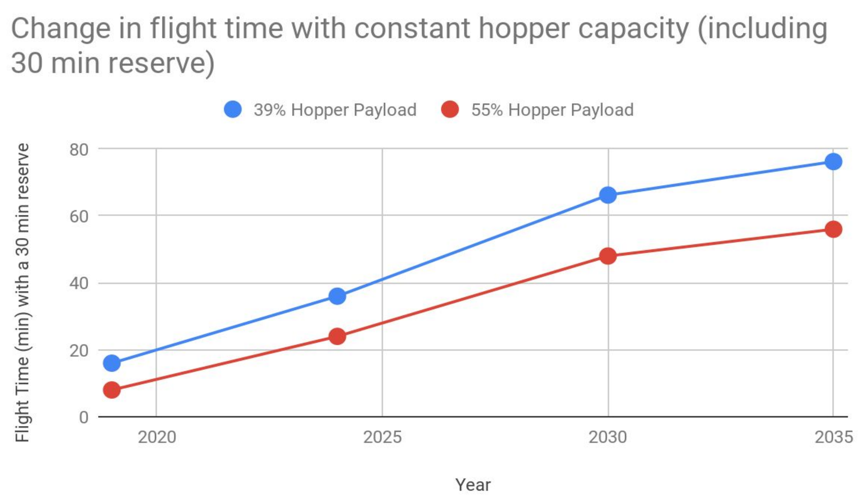
Flight profile developed with the help of agricultural pilot

Battery Configuration	High Endurance	Heavy Payload
Endurance	34 minutes	26.4 minutes
Usable Hopper %	39 %	55 %
Cruise Time	29 minutes	21.4 minutes
Reserve Flight Time	10 minutes	8 minutes

Future Performance

- Aircraft will charge completely in 10 to 15 minutes
- Reserve calculated using 60% throttle
- Plots assume battery technology advances as predicted by Roland Berger
- Flight time and hopper capacity are trade offs (customer to specify based on their needs)
- Models include efficiency of motor, inverters, and batteries as well as energy consumed by avionics and lights



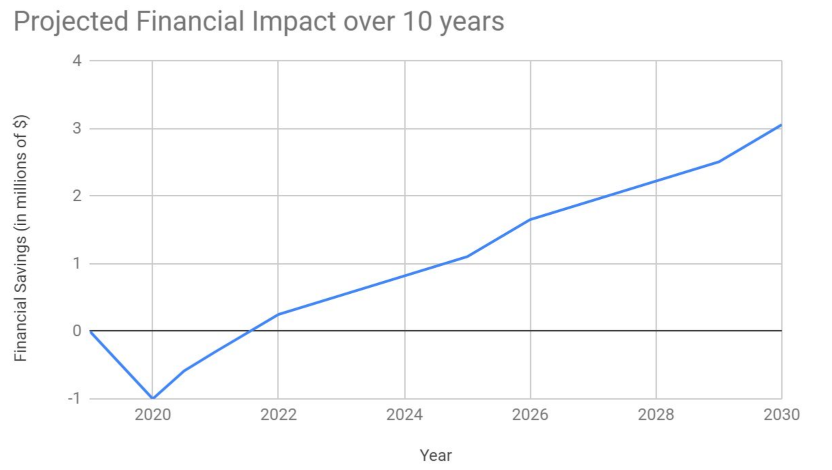


Conversion Finances

Part	Quantity	Cost
Batteries	24	$180,000
Cable	175 ft	$2000
Motor & 4 inverters	1	$560,000
Motor mount	1	$30,000
Motor coolant system	1	$5,000
Climate control	1	$11,500
Cockpit display	1	$1,200
Battery enclosures	6	$500
Miscellaneous	-	$10,000
Labor	250 hrs	$30,000
Total	-	$860,000
Fast Chargers	2	$150,000

Assumptions

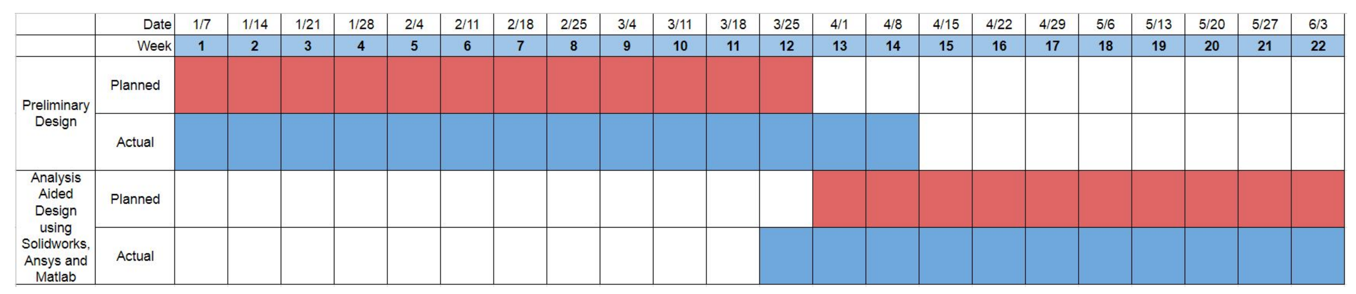
- Less overhauls save $265,000 every 4 years
- Fuel savings amount to $285,000/year
- Pilot flies 85 hrs/month for 6 months



Impacts

Immediate: Experimental and private operations
Future: Limited commercial use in 5-7 years, widespread use in 10-15 years

Schedule and Budget



Final Budget

Expense Item	Budgeted Amount	(team member name)	Estimated Purchase Date		Actual Purchase Date	Actual Expenditure		Total Remaining in Budget
Textbook, Electric Aircraft	$115	Michael	1/10/2019		1/10/2019	$115		$490
UCar Rental	$180	Ahrif	3/3/2019		3/3/2019	$150		$340
Per Diem	$100	Team	3/3/2019		3/3/2019	$60		$280
UCar Rental	$150	Ahrif	4/22/2019		4/22/2019	$150		$130
Per Diem	$60	Team	4/22/2019		4/22/2019	$60		$70
Total	$605					$535		$70

References
United States Environmental Protection Agency, "Sources of Greenhouse Gas Emissions," https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions
"AT-502B." Air Tractor, airtractor.com/aircraft/at-502b/

Acknowledgements
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