SOLVE FOR X.

Technology Advancement in Aerial Robotics

Presented by:

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Outline

- My background
- Historical context for electric propulsion
- How UAVs emerged
- Current UAS classes
- Future UAS designs
- UAS regulations
- UAS use cases

Biography

Purdue University 2006
Bachelor of Science in
Aeronautical Engineering

US Marine Corps
Captain, USMCR
MOS: Field Artillery
Deployed to Afghanistan in 2011

NASA Langley Research Center
Aerospace Engineer
Lead Greased Lightning Project

Advanced Aircraft Company
Founder & CEO
Hercules UAS & Greased Lightning UAS

NASA Greased Lightning UAS

A New Paradigm of Design

- Advances in propulsion systems have always led to a change in vehicle design
- The vehicle design must be adapted to best capitalize on the benefits of the new propulsion system
- A retrofit of an existing vehicle with new propulsion system frequently leads to a loss in performance

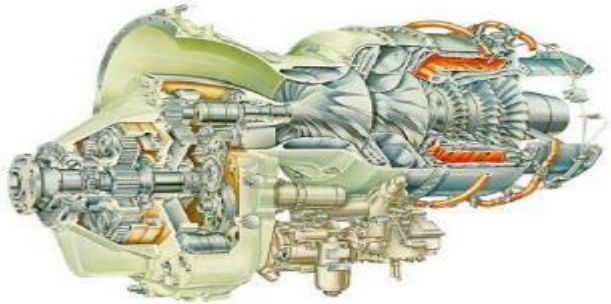
1936 Supermarine Spitfire

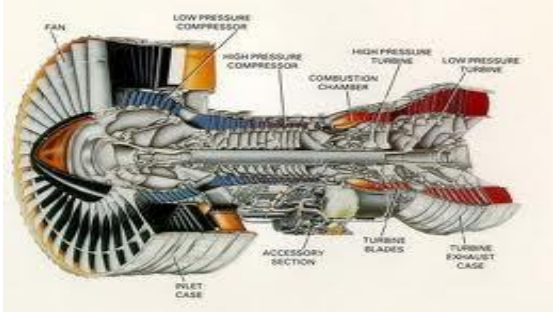
1941 Gloster E28

1947 North American F86

Why is electric propulsion different?

- Electric propulsion is nearly a scale free technology
  - Compare a 10 hp, 100 hp, and 1000 hp combustion engine
  - **Combustion propulsion** → Efficiency and power to weight (P/W) **improve** with larger scale (both reciprocating and turbine)
  - **Electric propulsion** → Efficiency and P/W are **nearly constant**





Electric Propulsion at the Propulsion System Level

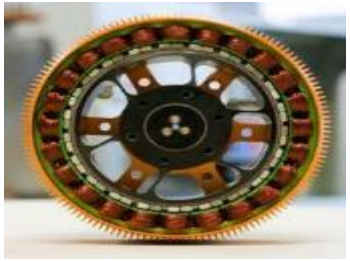
Benefits

- Higher P/W
- Greater Efficiency
- Lower Cooling Drag
- Lower Maintenance
- Greater Reliability
- Lower Noise

Challenges

- Energy Density of Energy Storage Subsystem
  - Batteries, Super Capacitors, Flywheels, etc.
  - Improving Every Day

Tiger Motors U8
Power: ~1.1 kw (~1.5 hp)



Joby JM1
Power: 13 kw (17 hp)

EMRAX 268
Power: 74 kw (99 hp)

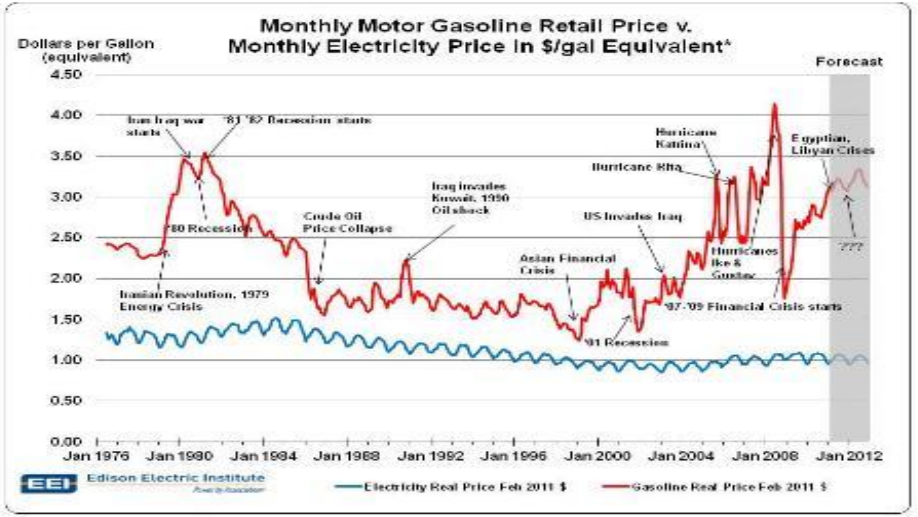
Electric Propulsion at the Aircraft System Level

Benefits

- Lower operating cost
  - >40% Less expensive energy
  - ~3x Less energy consumed
  - Lower motor maintenance
- Consistent energy cost
- Higher aircraft L/D
  - ~10x Less cooling drag
  - Reduced installation losses
  - Enables more efficient aircraft configurations
- Zero emissions
  - From the aircraft if all electric
- Greater reliability
- Lower noise

Challenges

- Higher weight aircraft
  - Heavy energy storage systems
- Aircraft does not reduce weight



How did UAS emerge?

Distributed Electric Propulsion (DEP)

Closed Loop Controls

Current UAS Classes

Fixed Wing

- Benefits
  - Long range and endurance
- Shortcomings
  - Requires runway or catapult
  - Training intensive
  - Significant logistical burden

Multi-Rotor

- Benefits
  - Operates out of confined areas
  - Easy to fly
  - Easy to transport
- Shortcomings
  - Limited range and endurance

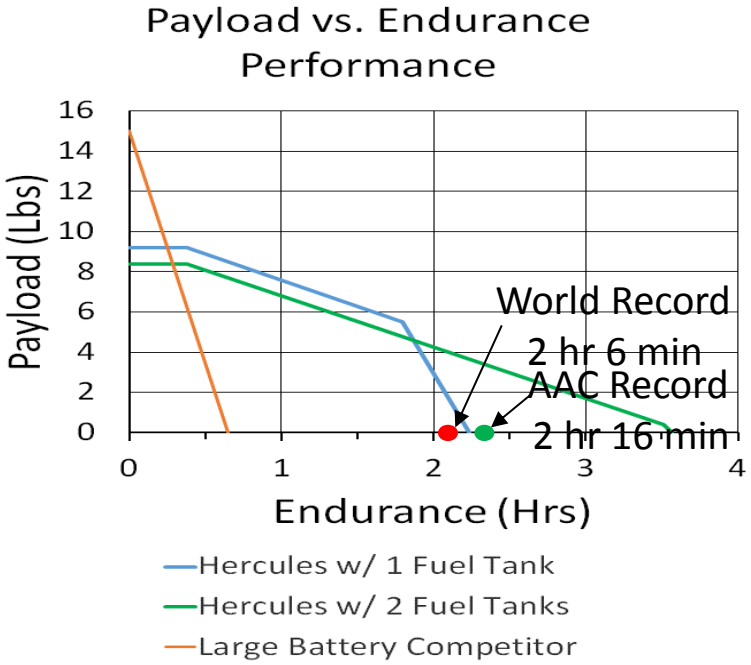
Hybrid Quad

- Benefits
  - Long range and endurance
  - Operates out of confined areas
- Shortcomings
  - Cost
  - Limited hover ability
  - Compromised performance

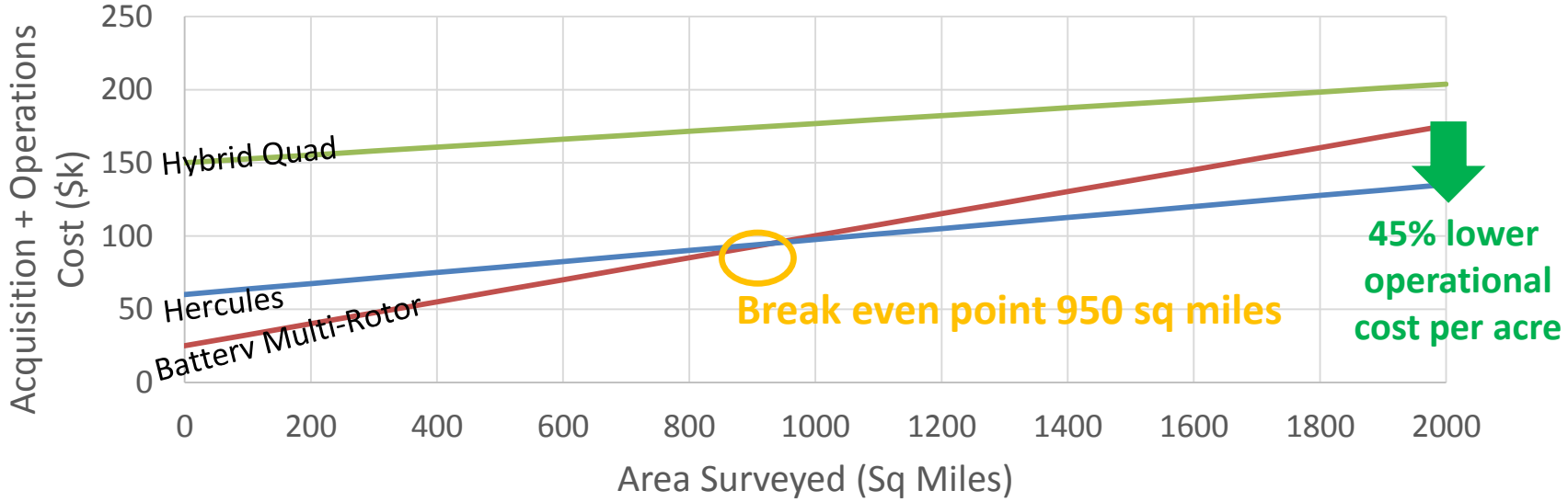
Hercules Breaks the Tradeoff

- VTOL
- Advanced Aerodynamic Design
- Hybrid Electric Propulsion

- Value Proposition:
  - Ease of use of a multi-rotor with the flight time of a fixed wing
  - Longer endurance → Lower data acquisition cost per acre



VTOL UAS Breakeven Analysis

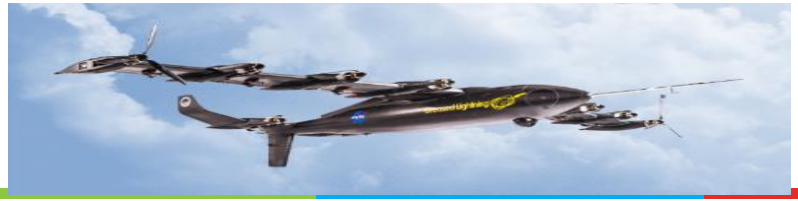


The UAS operator could break even in 11 weeks.

950 sq miles can be surveyed in 56 days with 8 hr work days.

Greased Lightning UAS

- Applications
  - Linear Inspection
  - Package Delivery
- Value Proposition:
  - True “No Compromises” VTOL
  - Free of launch and recovery equipment
  - 2x improvement in speed
  - 4x improvement in range
  - 1 distribution center per metropolitan area



Credit: NASA

https://www.youtube.com/watch?v=kXql26sF5uc

UAS Regulations

Today

- Indoors
  - No regulations
- Outdoors
  - FAA Part 107
    - Enacted August 29, 2016
    - Weight < 55 lbs
      - External loads allowed
    - Altitude < 400 ft above ground level (AGL)
    - Speed < 100 mph
    - Within visual line of sight (VLOS) (~1 mile)
    - Daytime with 3 miles visibility
    - Class G airspace
      - Operations in Class B, C, D & E need ATC approval
    - Operations not allowed over people

Future Predictions

- Indoors
  - No regulations
- Outdoors
  - 1 - 2 years → Rural inspection missions
    - Beyond visual line of sight (B-VLOS)
  - 3 to 5 years → Urban package delivery
    - Beyond visual line of sight (B-VLOS)
    - Operations over people
    - Congested airspace deconfliction

UAS Use Case Assessment

1. List major steps of how you operate your business today.
2. Quantify the costs of these steps.
3. Brainstorm what tasks can be modified/replaced by using UAS.
4. Develop some concept of operations to accomplish these tasks with a UAS.
5. Estimate the costs of completing these tasks.
6. Compare with the costs of how your business runs today.

UAS Use Cases

Inventory Management

Package Delivery

ISO Container Tracking

Facility Security

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