

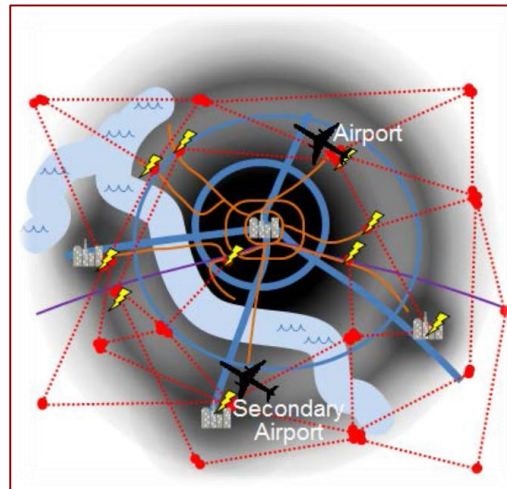
Power, Energy Storage and Conversion for Aircraft



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NASA Glenn Research Center
Cleveland, OH
July 19, 2018

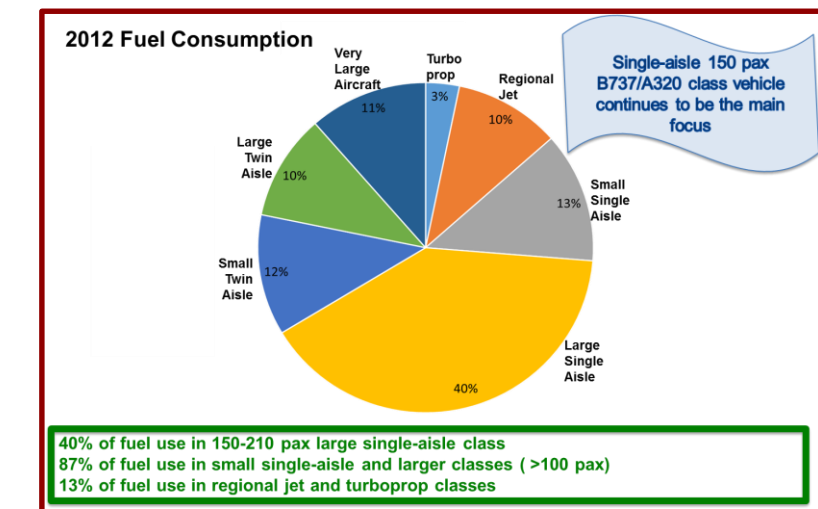
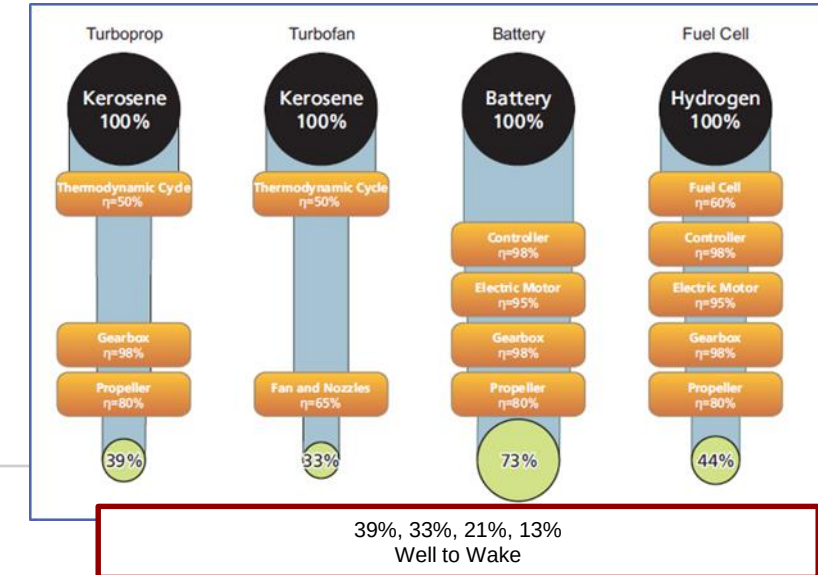
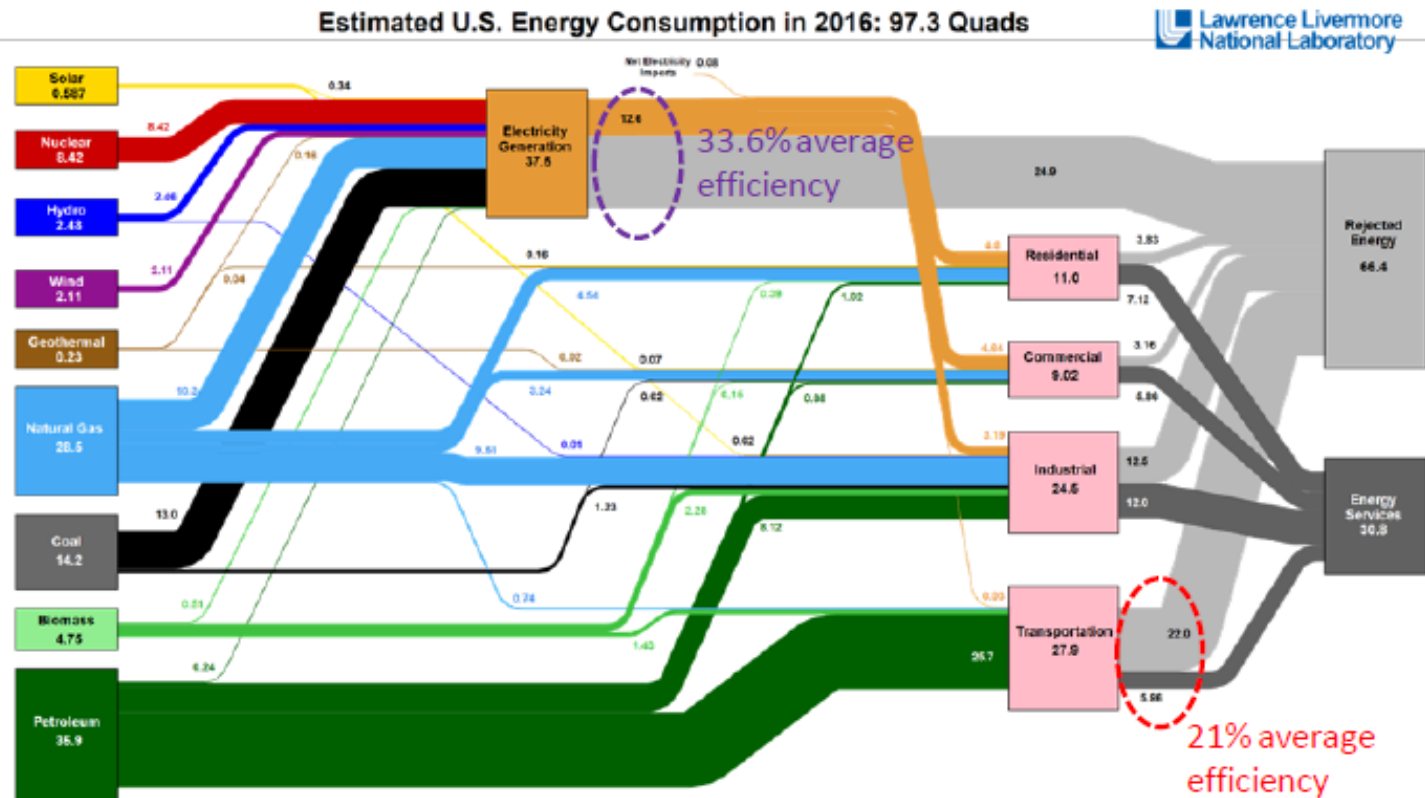
Electrically Enhanced Propulsion

- Why electric?
 - Fewer emissions
 - Quieter flight
 - Fuel savings
 - New mobility options
 - Better utilization of infrastructure



Energy Consumption

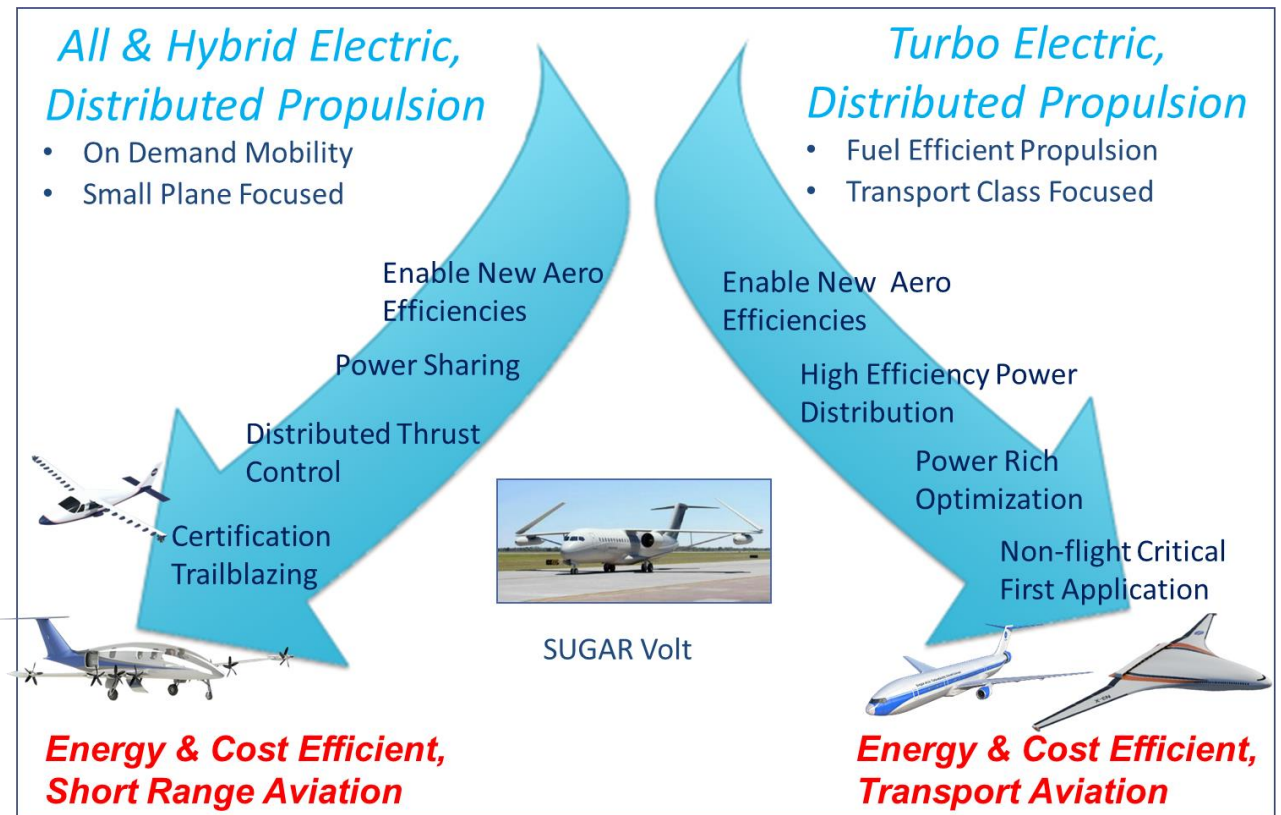
U.S. Energy Consumption & Waste, 2016



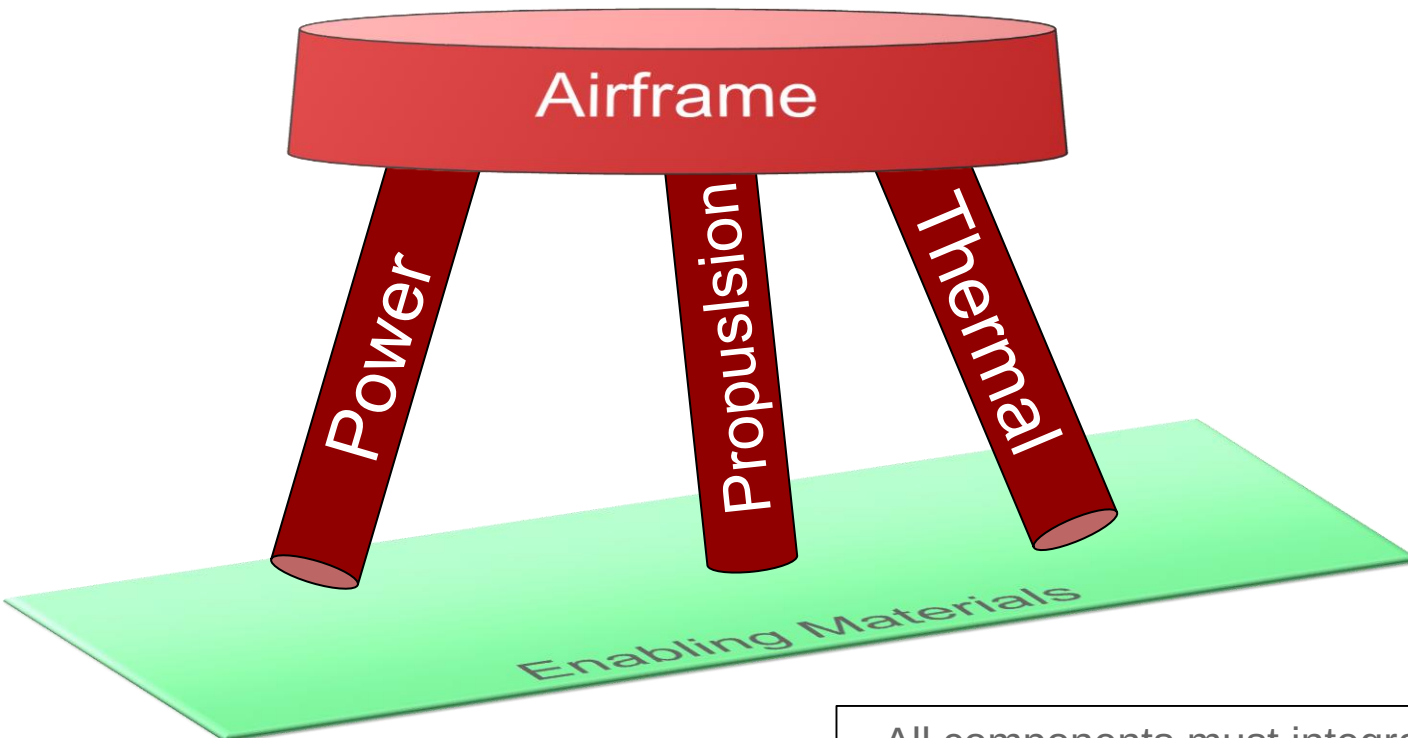
Vehicle Classes

Unmanned Aerial Systems (UAS)
Personal Air Vehicles (PAV)
Logistic Delivery Vehicles (LDV) – <589 kg
Ultralight
General Aviation
Regional Jet
Single, Double-Aisle
Blended Wing Body, Truss-Braced Wing Body

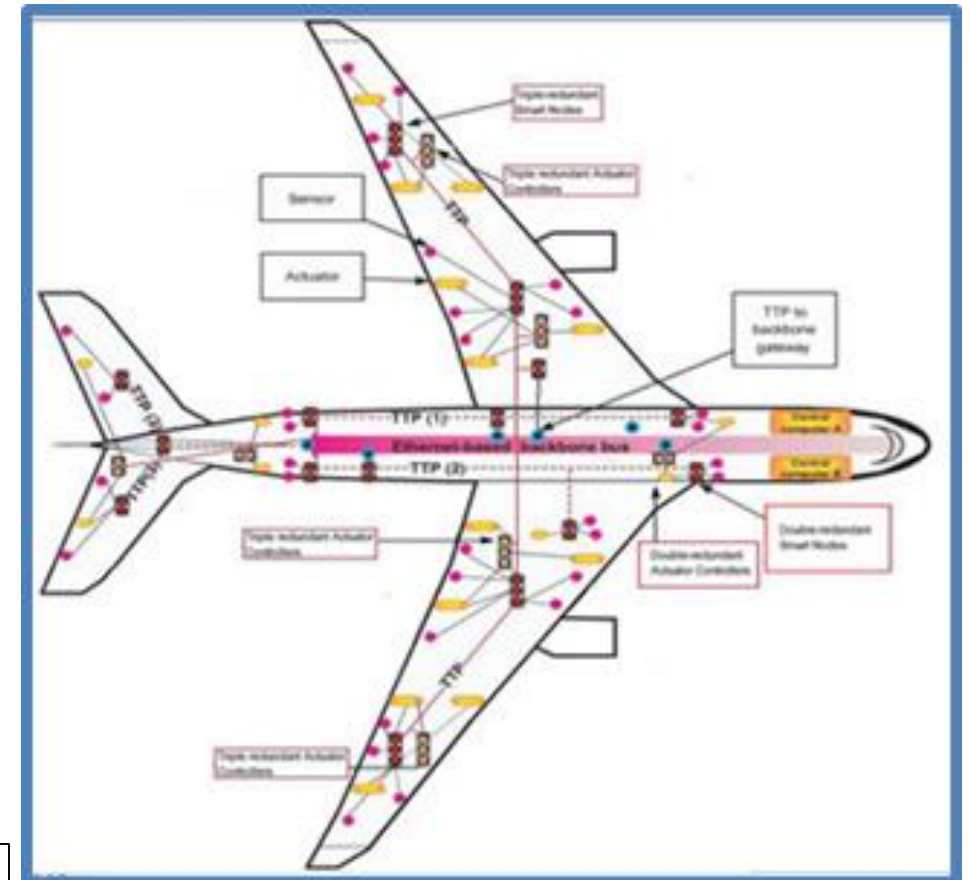
VEHICLE CONFIGURATION EXAMPLES



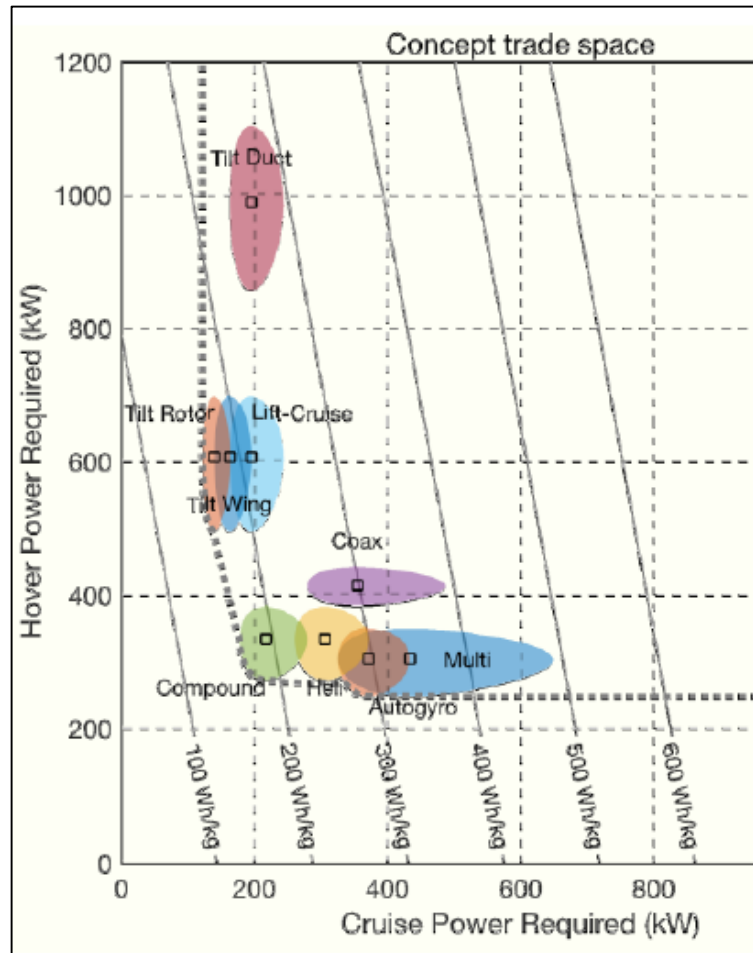
Power, Propulsion, Thermal, Airframe Integration



All components must integrate



eVTOL Power Required



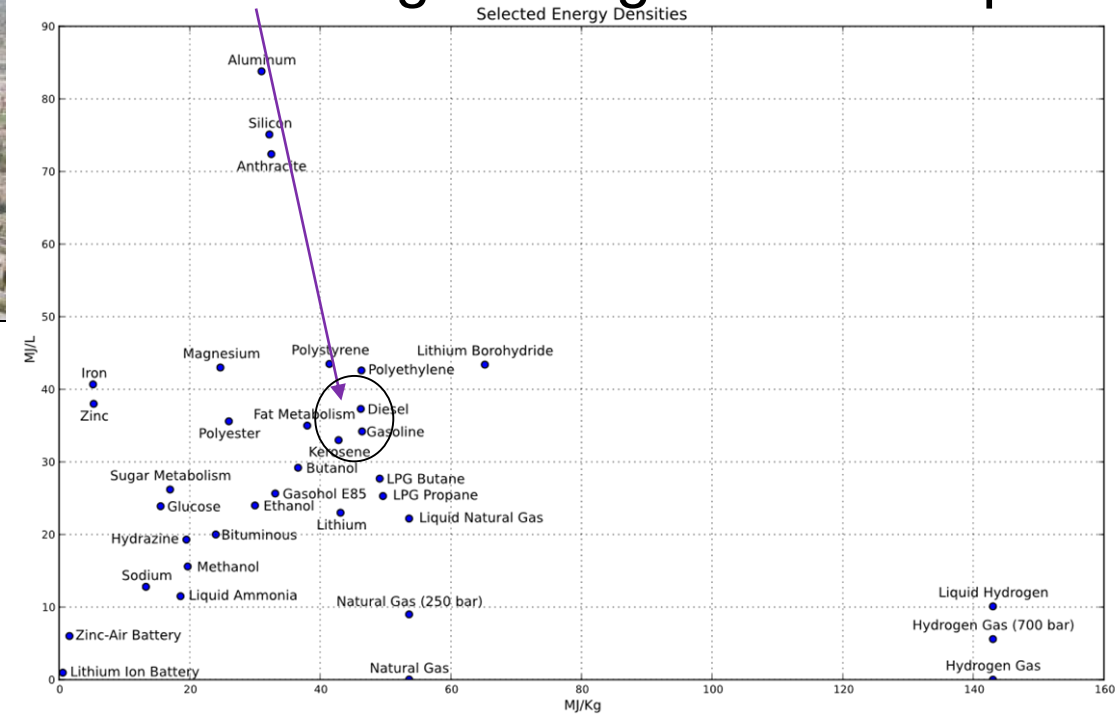
Aircraft Energy Options



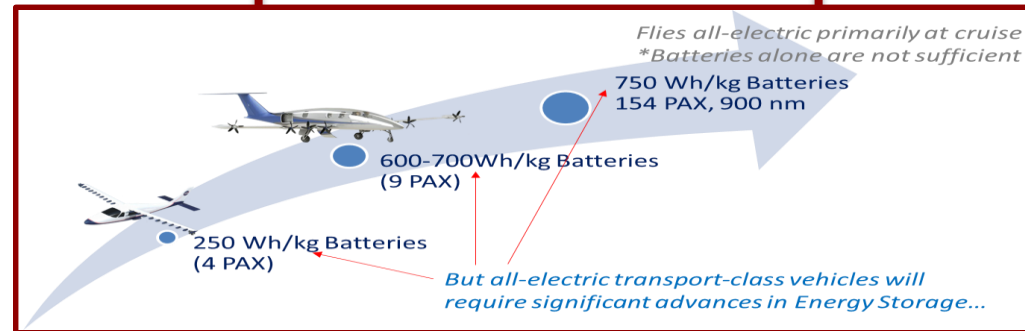
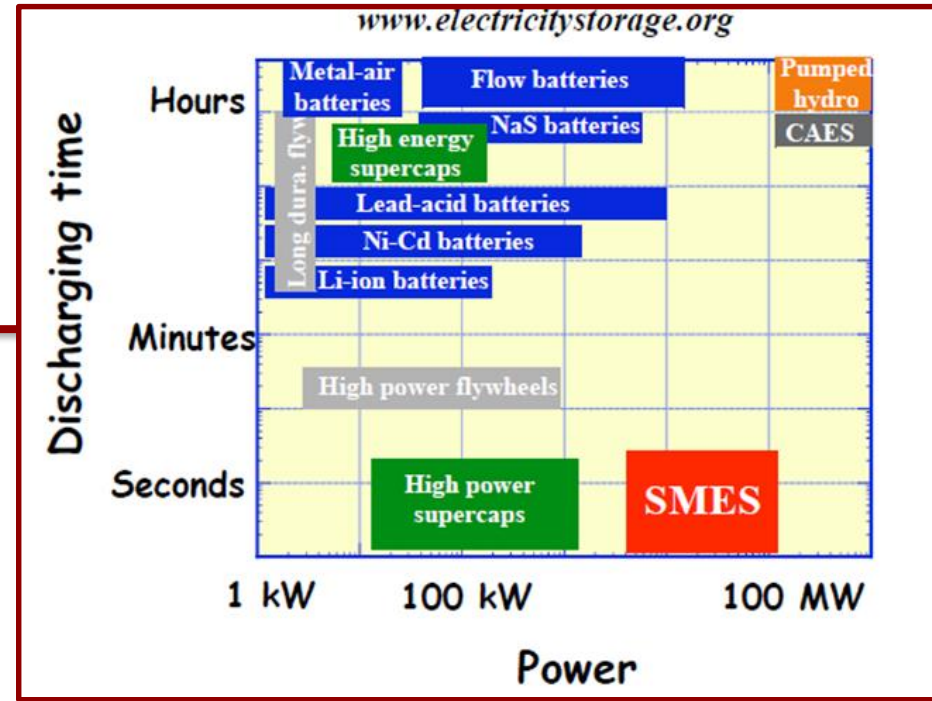
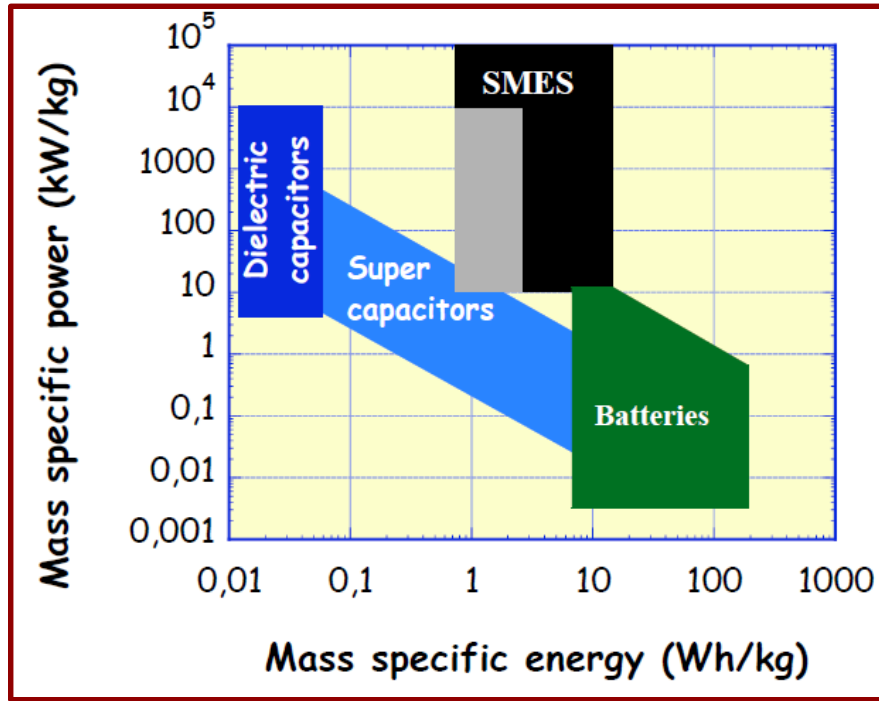
☐ 1 kg coal	8 kWh
☐ 1 kg wood	4 kWh
☐ 1 kg oil	10 - 12 kWh
☐ 1 kg natural gas	10 - 14 kWh
☐ 1 kg enriched uranium	600 000 kWh
☐ 1 kg of water - 1000 m fall	0.003 kWh ←
☐ 1 kg Pb battery	0.03 kWh
☐ 1 kg lithium battery	0.2 kWh

(1 kWh : kinetic energy of a 10 ton truck at 100 km/h)

Jet Fuel is Light-Weight and Compact

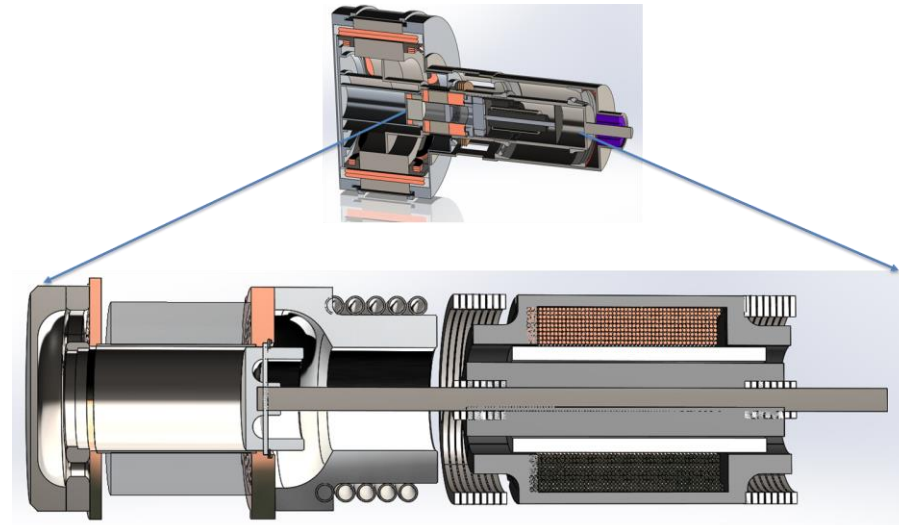
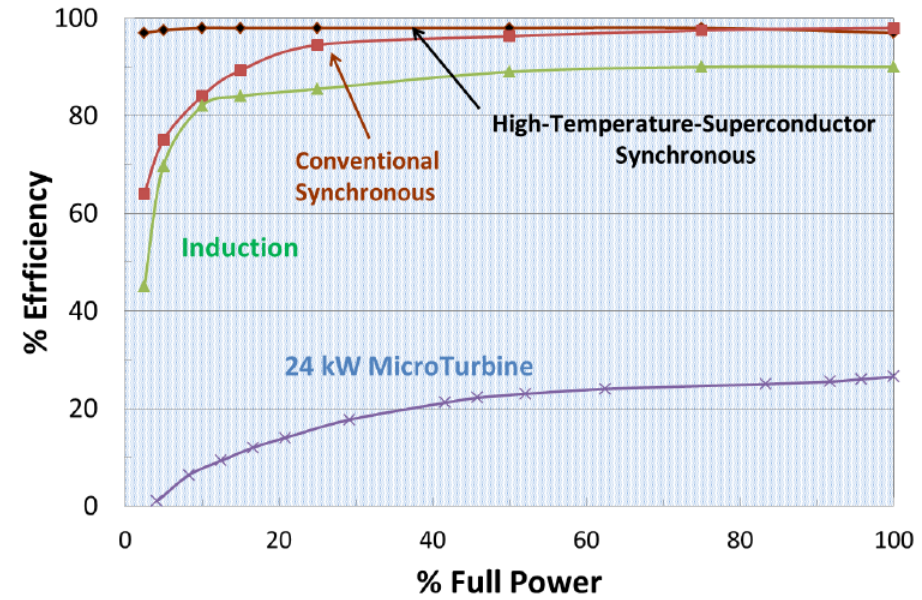
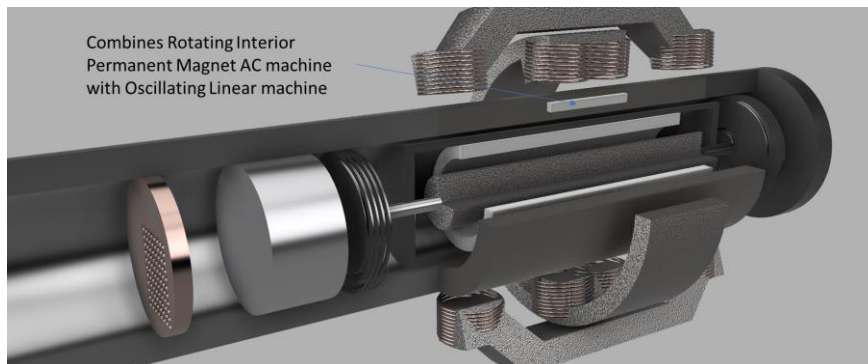
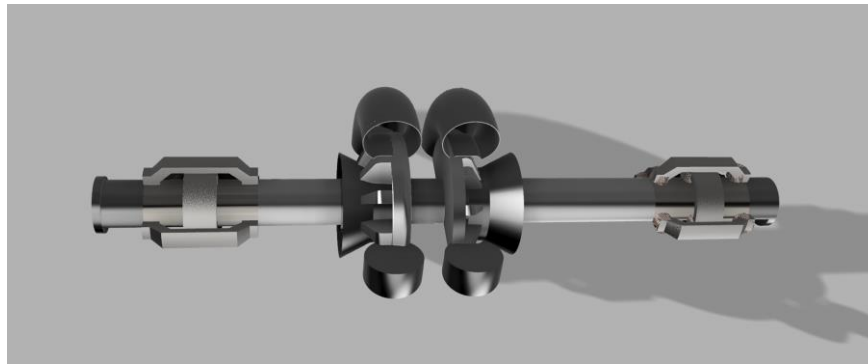
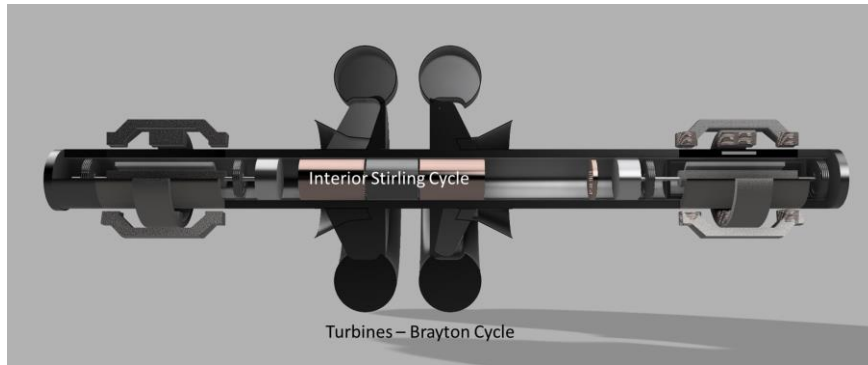


Energy Storage



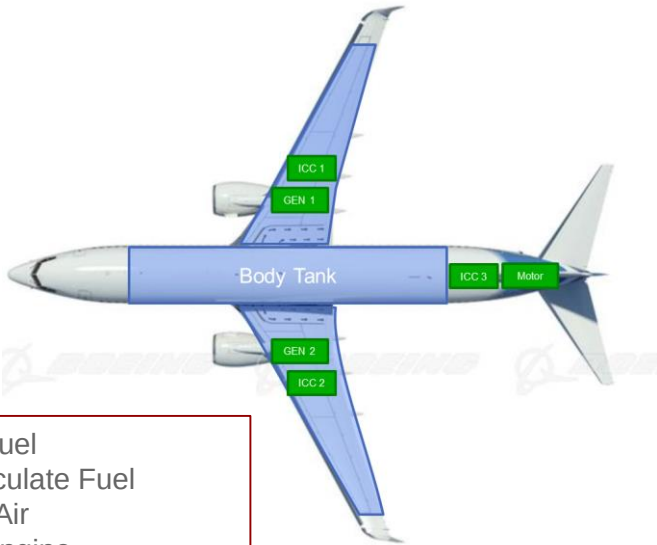
Can choose high energy or power, mass is a challenge

Turbo-electric Power Generation

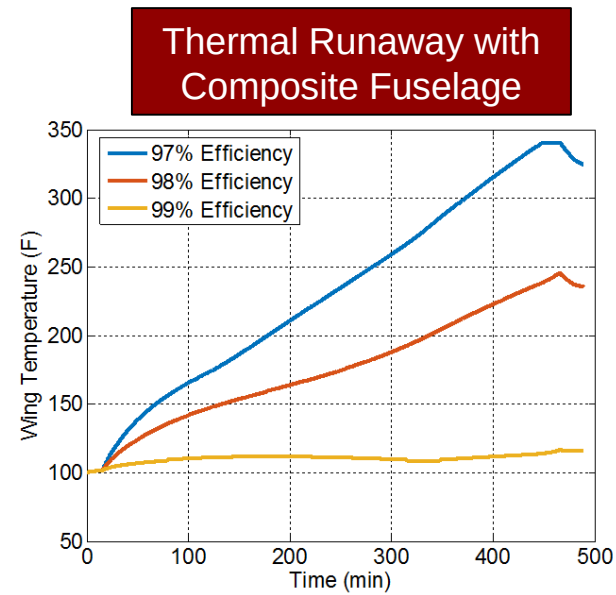
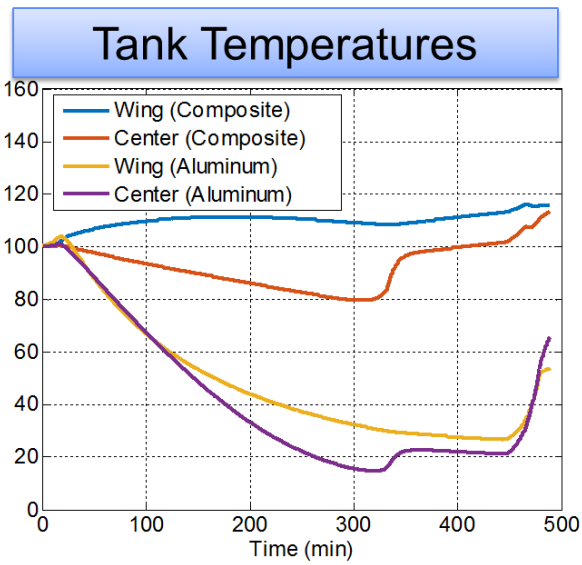
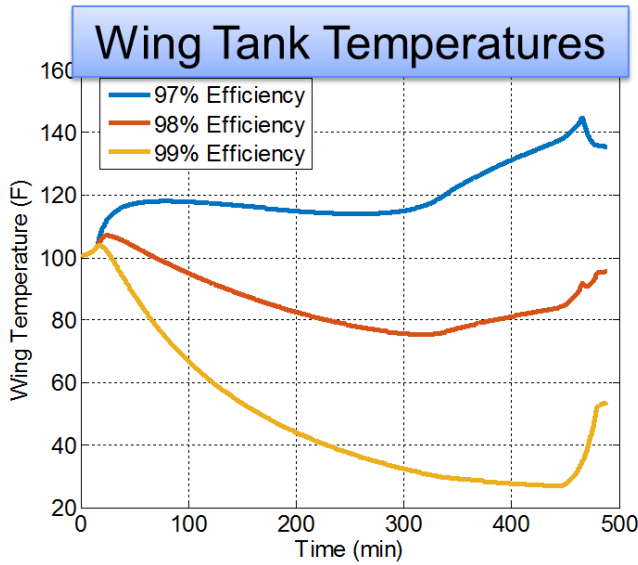
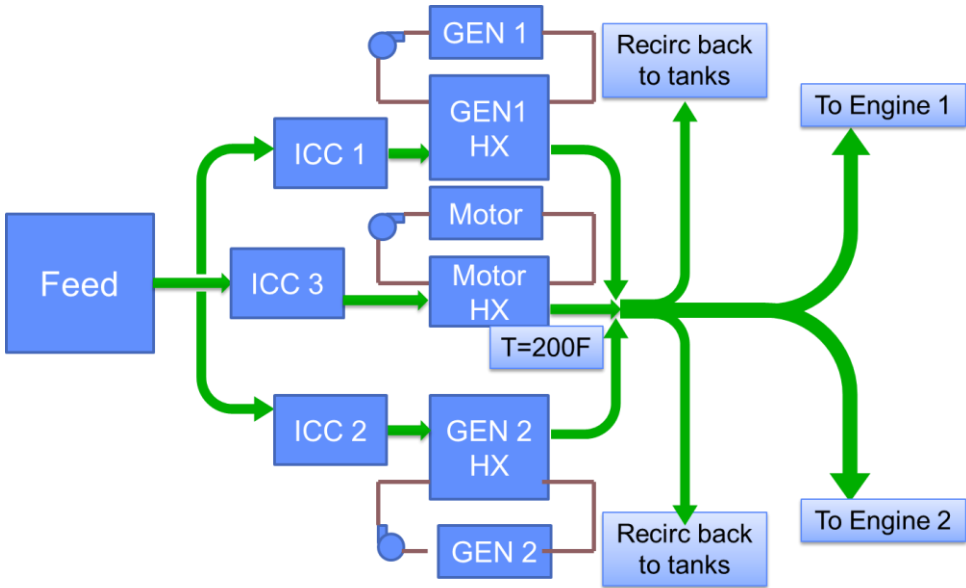


Stirling and Brayton (Strayton) Engine and Superconducting Motor

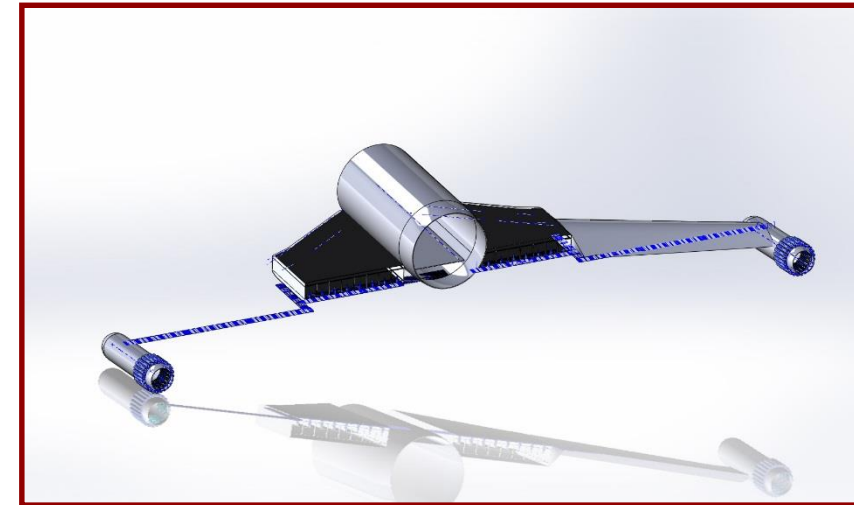
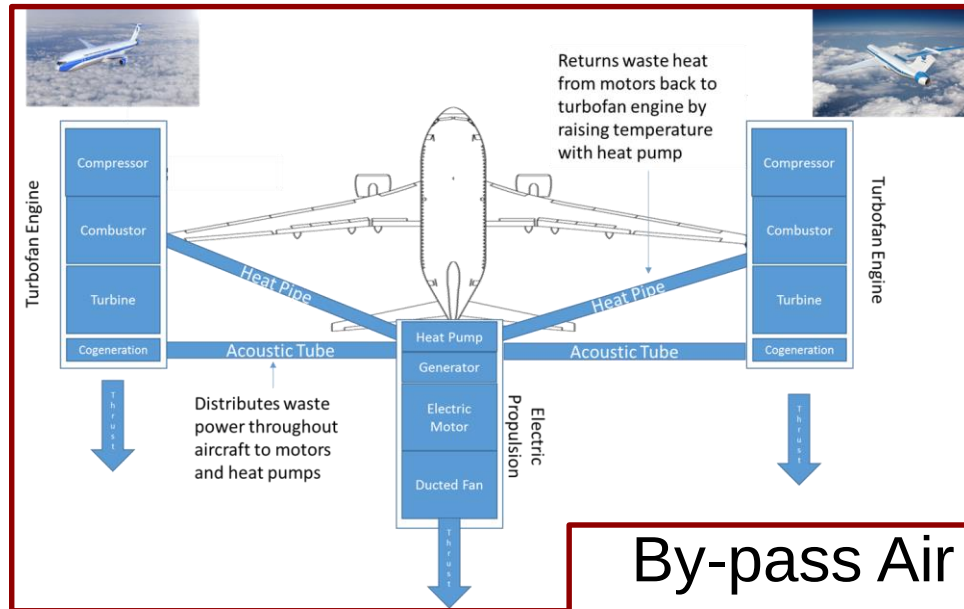
Thermal Limits



Into Fuel
Recirculate Fuel
Ram Air
Into Engine
Vapor-Compression



Thermal Energy Conversion and Recycling

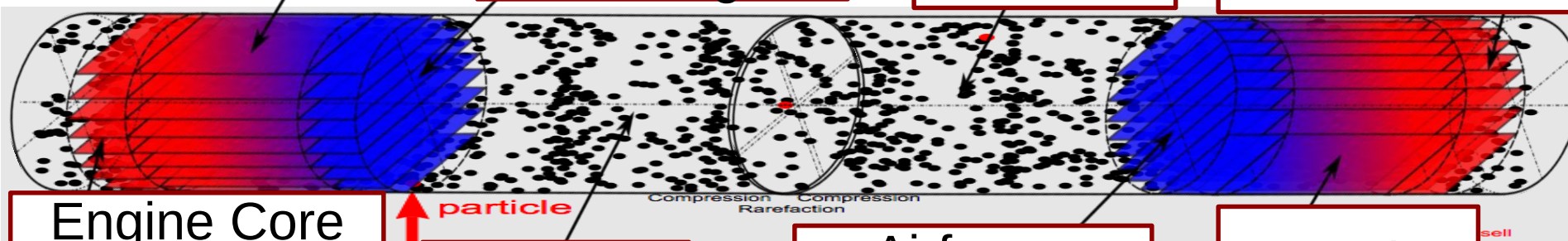


Stack

By-pass Air
Heat
Exchanger

Resonator

Heat Pipe
Exchanger



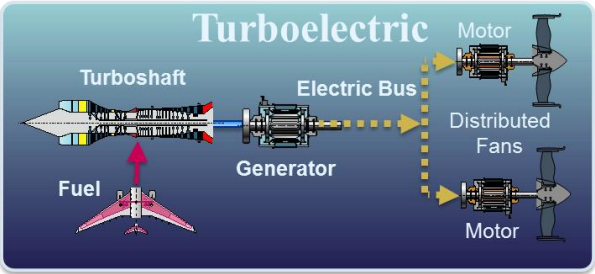
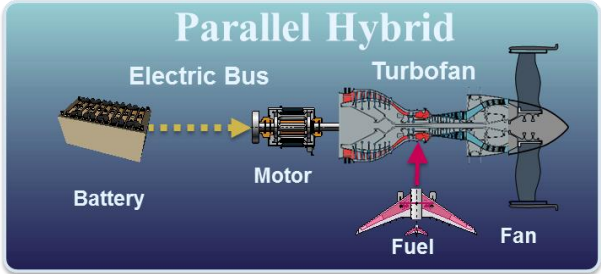
Engine Core
Heat
Exchanger

Resonator

Airframe
Heat
Exchanger

Stack

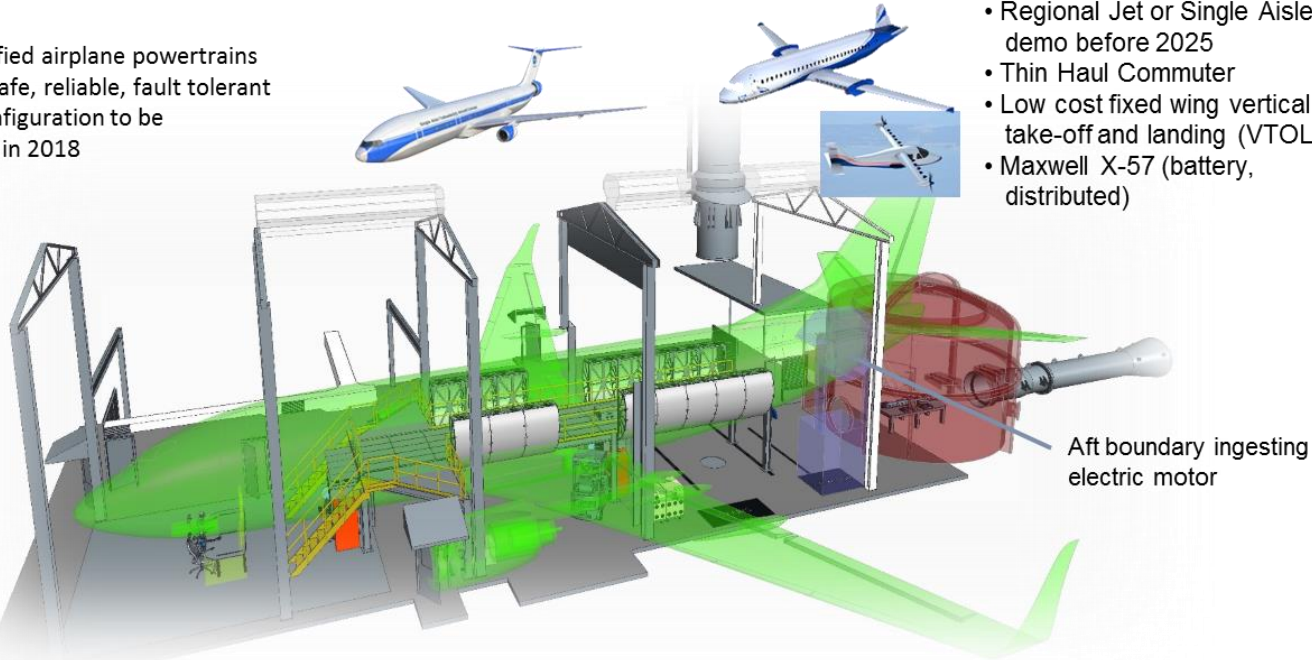
Technology Summary



Technology: Vehicle and propulsion concepts and benefits studies

- Design and test electrified airplane powertrains that are flightweight, safe, reliable, fault tolerant
- NASA's STARC-ABL configuration to be tested in NEAT testbed in 2018 at full power

Full-Scale Ground Tests: NASA Electric Aircraft Testbed (NEAT)

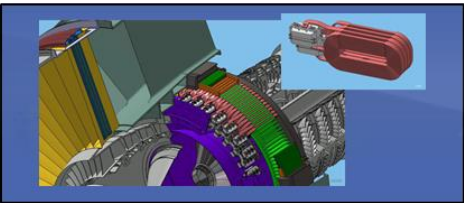


X-Planes: Near and Mid-term

- Regional Jet or Single Aisle demo before 2025
- Thin Haul Commuter
- Low cost fixed wing vertical take-off and landing (VTOL)
- Maxwell X-57 (battery, distributed)

Technology: Powertrain Components

- Electric machines
- Power electronics
- Integrated turbines, generators
- Controls
- Transmission



Technology: Enabling Materials and Devices

- Insulation
- Conductors
- Magnetic materials
- Power electronics devices



Energy Storage	Electrical Distribution	Turbine Integration	Aircraft Integration
Battery Energy Density	High Voltage Distribution	Fan Operability with different shaft control	Stowing fuel & batteries; swapping batteries
Battery System Cooling	Thermal Mgt. of low quality heat	Small Core development and control	Aft propulsor design & integration
	Power/Fault Management	Mech. Integration	Integrated Controls
	Machine Efficiency & Power	Hi Power Extraction	
	Robust Power Elec.		
Parallel Hybrid Specific	Common to Both		Turboelectric Specific

