The Institution of Engineering and Technology

National Aeronautics and Space Administration

NASA

Design Techniques for Lightweight Aircraft Motor Drives

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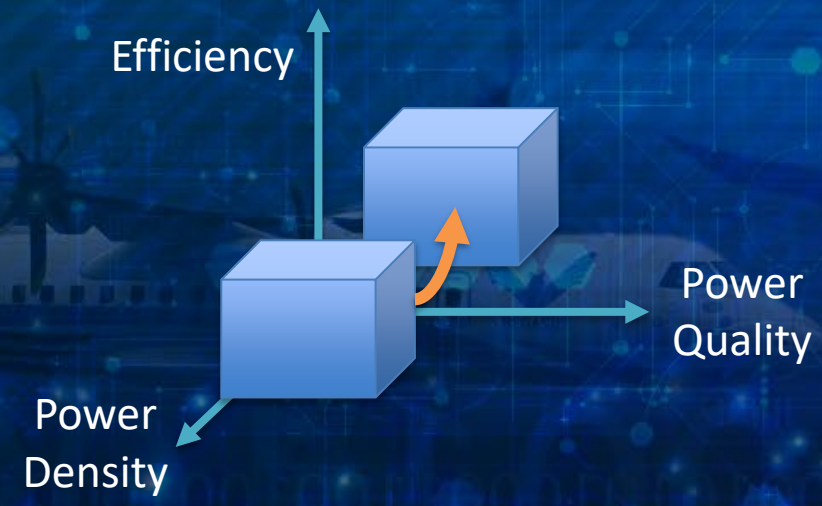
Design Space

Driver	Explanation
Power Density	Closes Gap Between EAP and Conventional Aircraft
Efficiency	Reduce Thermal Load, Significant Weight Driver
Power Quality	Compatibility with SoA Low Inductance Motors

Trade Space



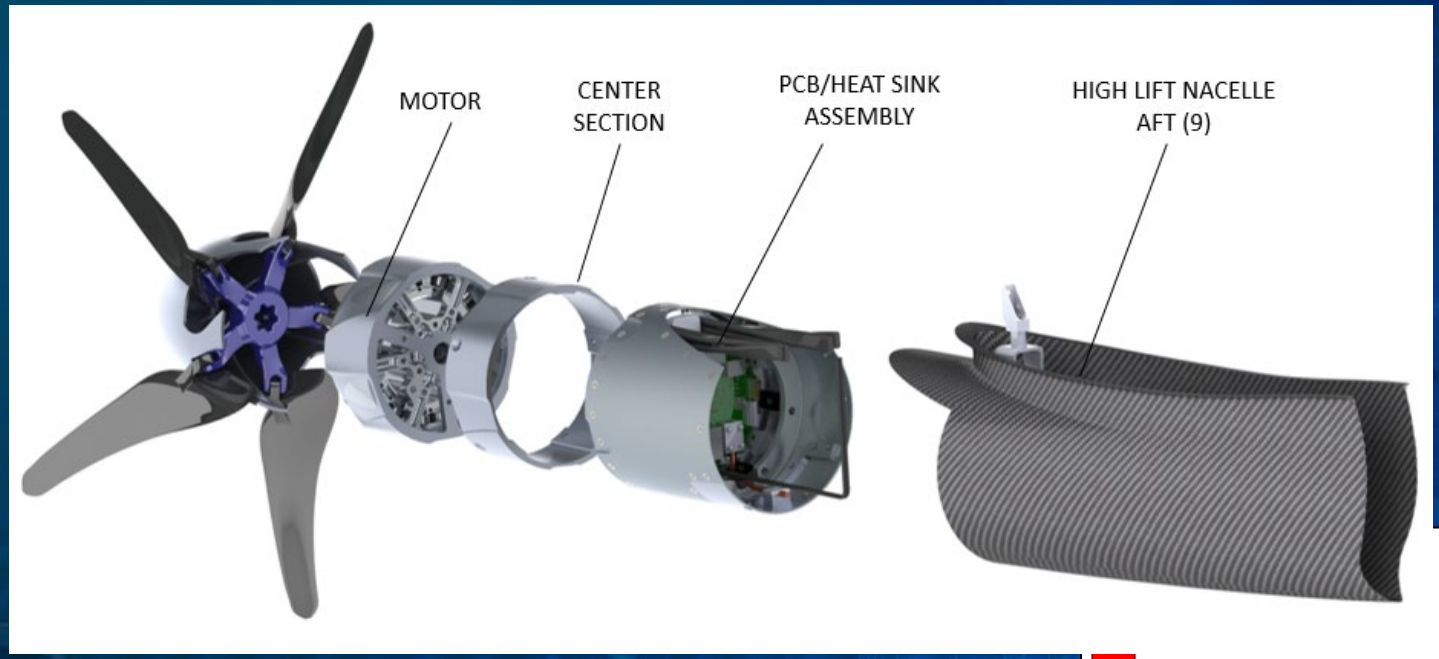
Trade Space Improvements

- Testing – Reduce Unknowns
- Design
- Materials Improvements

Limit Trade Space By Imposing Additional Requirements

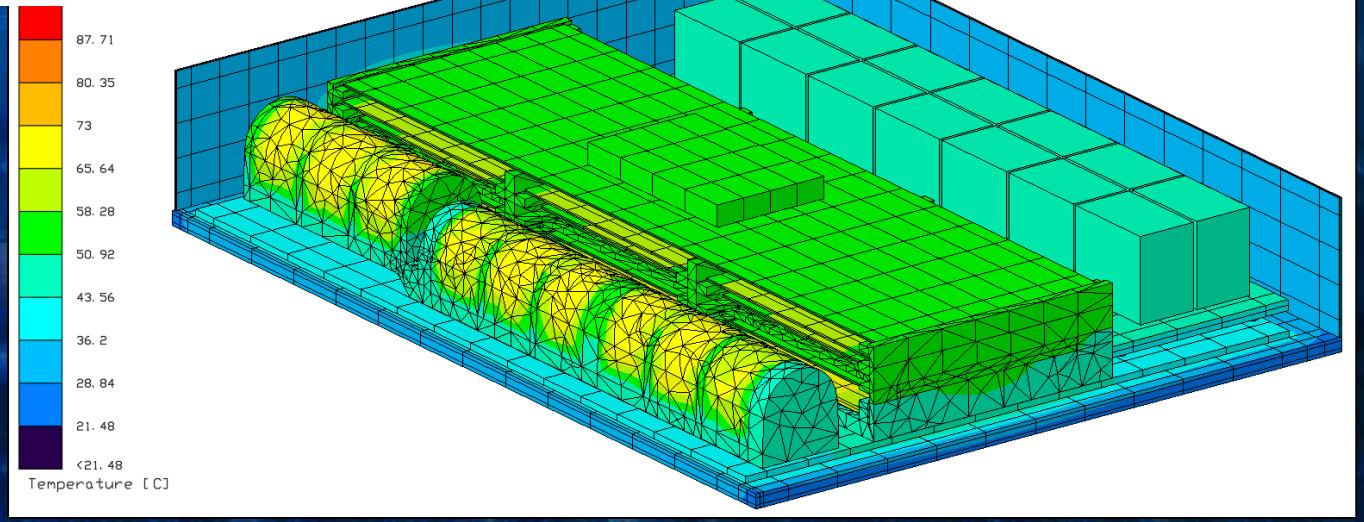
- High Altitude Capability
- Redundancy

Integrated Thermal + Structural

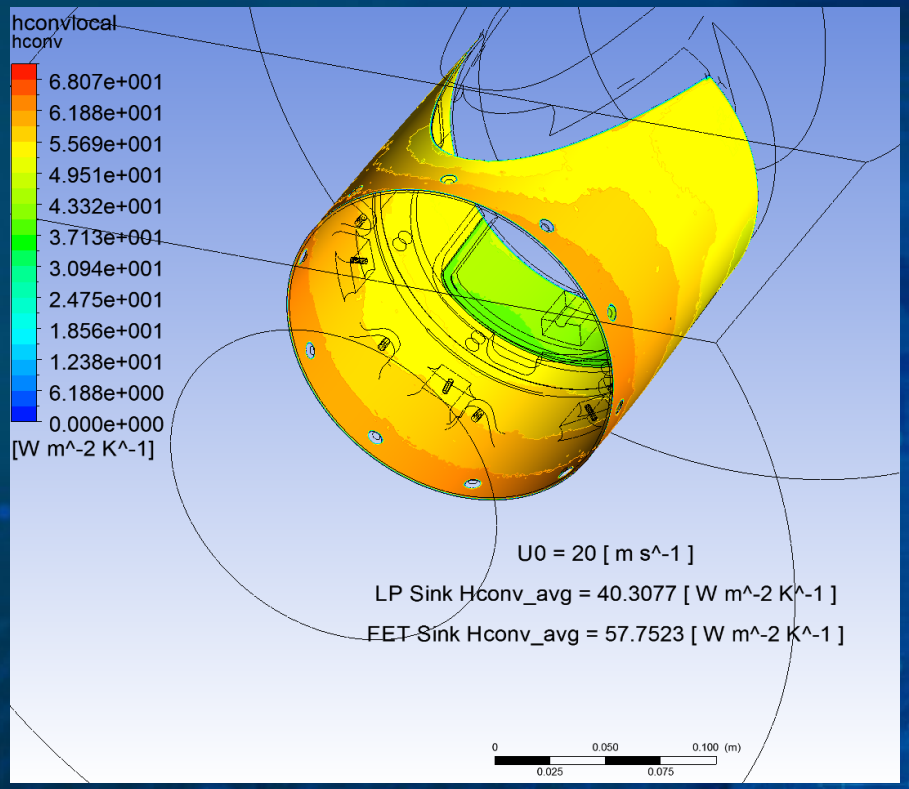


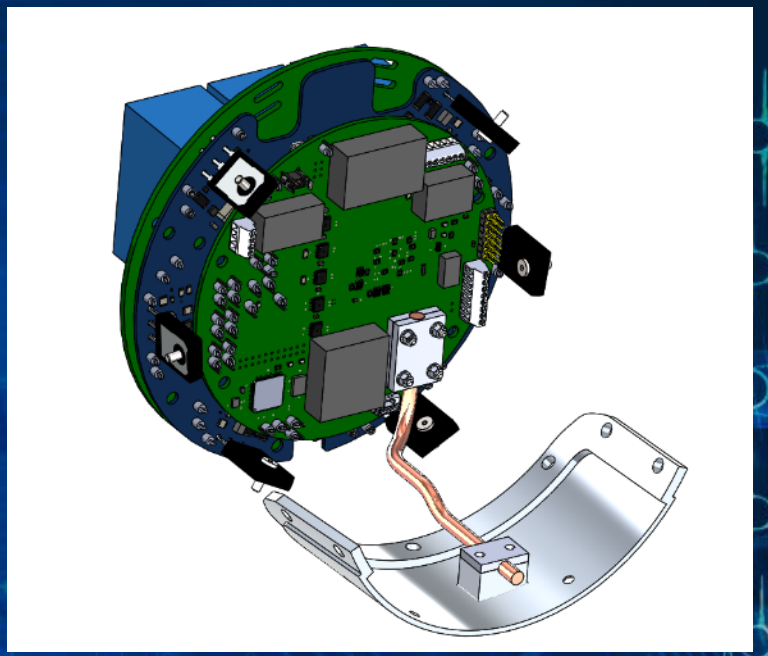
Outer Mold Line Cooling
Drastic Mass Improvement in Thermal System
Requires High Efficiency

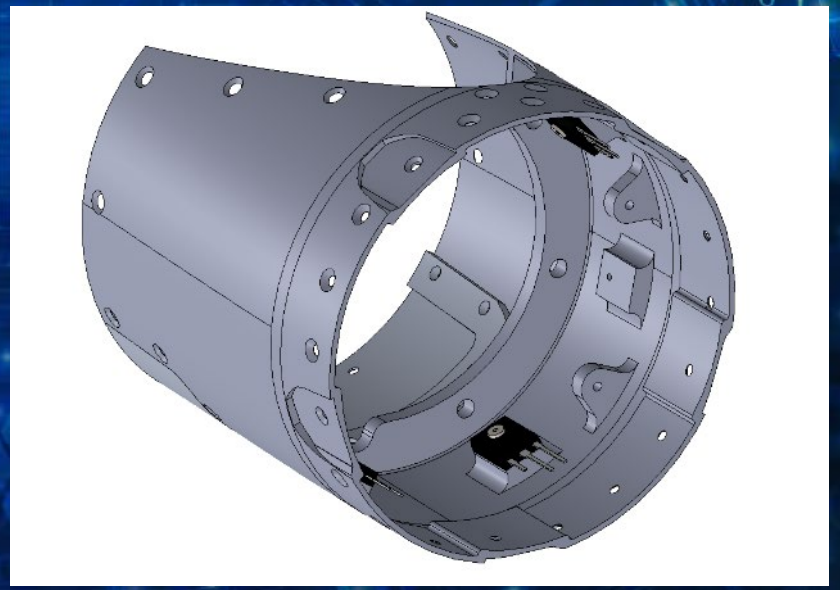
Tight Integration of Internal Structures and Thermal System



Integrated Thermal + Structural





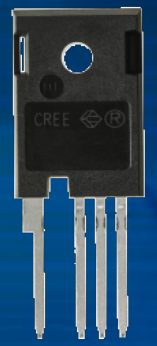


Separate High and Low Temperature Zones

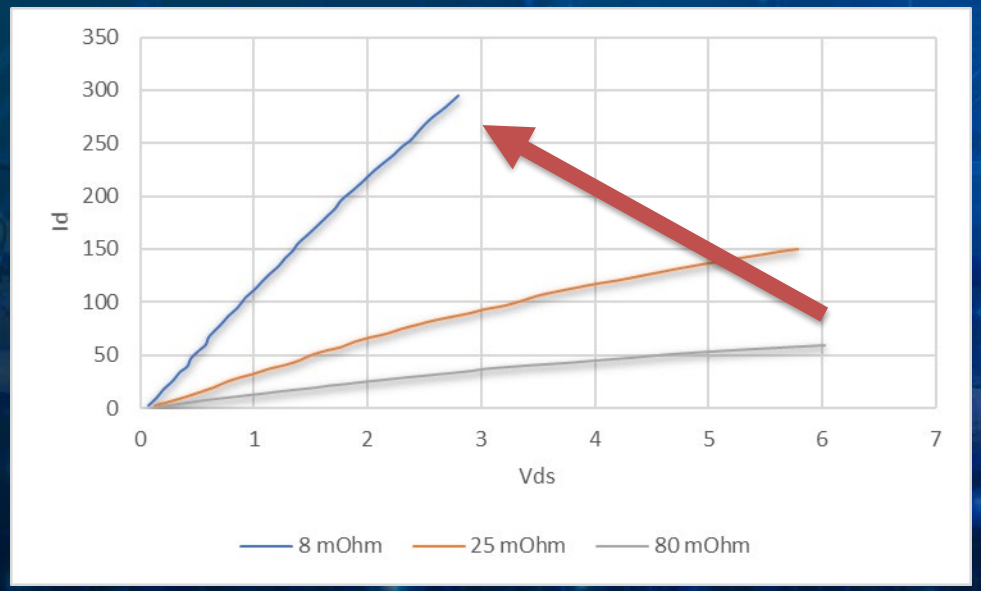
Avionics vs. Power Electronics

Switches

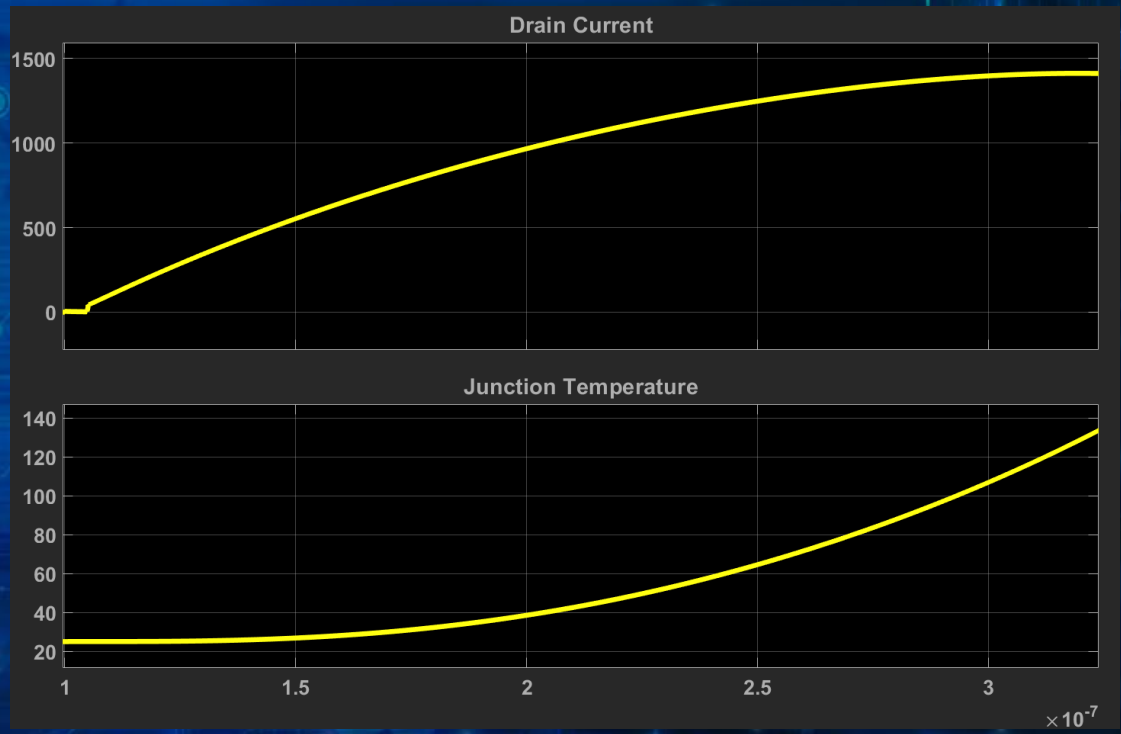
- Silicon Carbide
  - Higher Voltage Packages
  - Lower Conduction Losses
  - Lower Switching Losses



Lower Conduction Losses
Short Circuit Susceptibility



Fault Current Quickly Grows
Desaturation Protection Insufficient
CT Based Methods Required

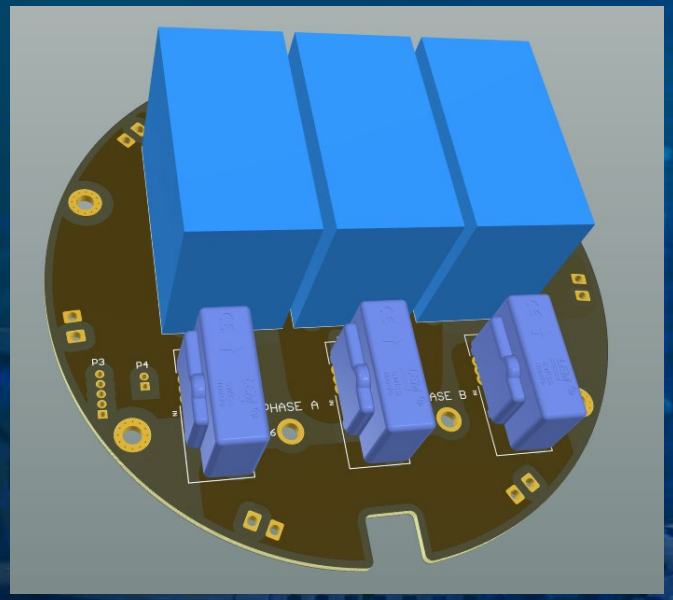


200 ns

Switching Noise

Fast Switching Causes Current and Voltage Pulses

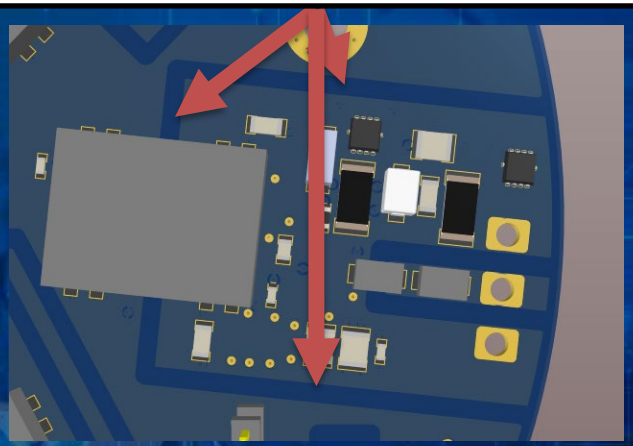
Minimize di/dt Effects
Minimizing Inductance



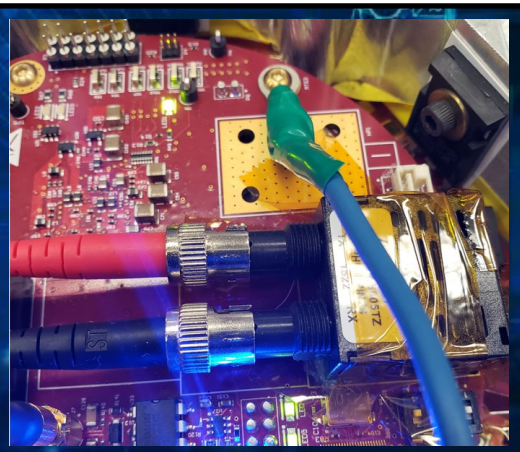
Wide power planes
Bus decoupling capacitors
Tight integration

Minimize dv/dt Effects
Common Mode Current

Cut-out for Isolated Regions
Reduce Coupling Capacitance



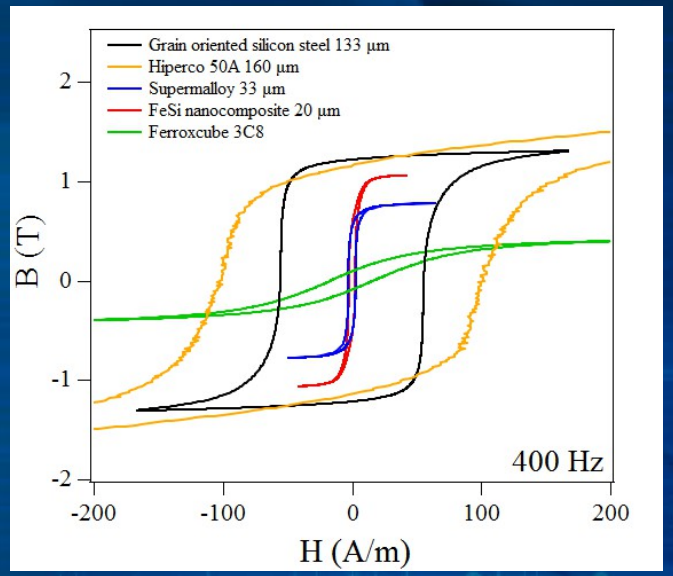
Isolated or Differential Interfaces
Optical Communications

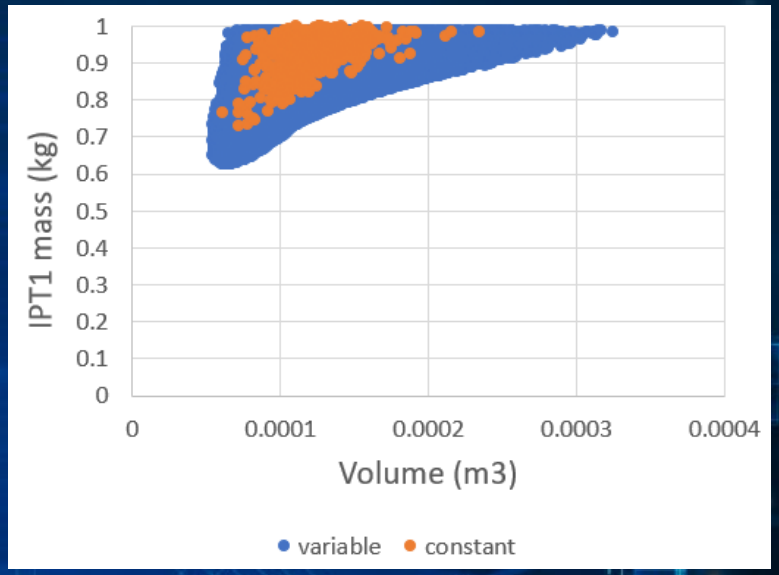


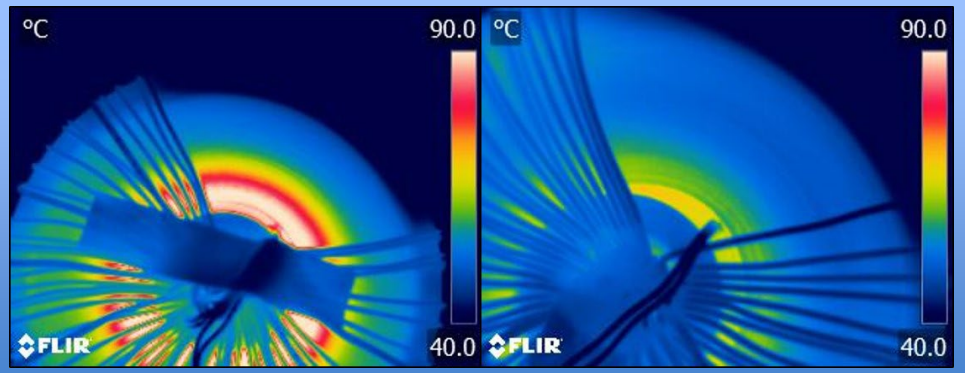
dv/dt Is Severe Enough, a Few pF's Causes Issues

Magnetics

- Optimized Design
  - Magnetic properties
  - Complex designs
- GRC Material
  - High flux saturation
  - Low core loss

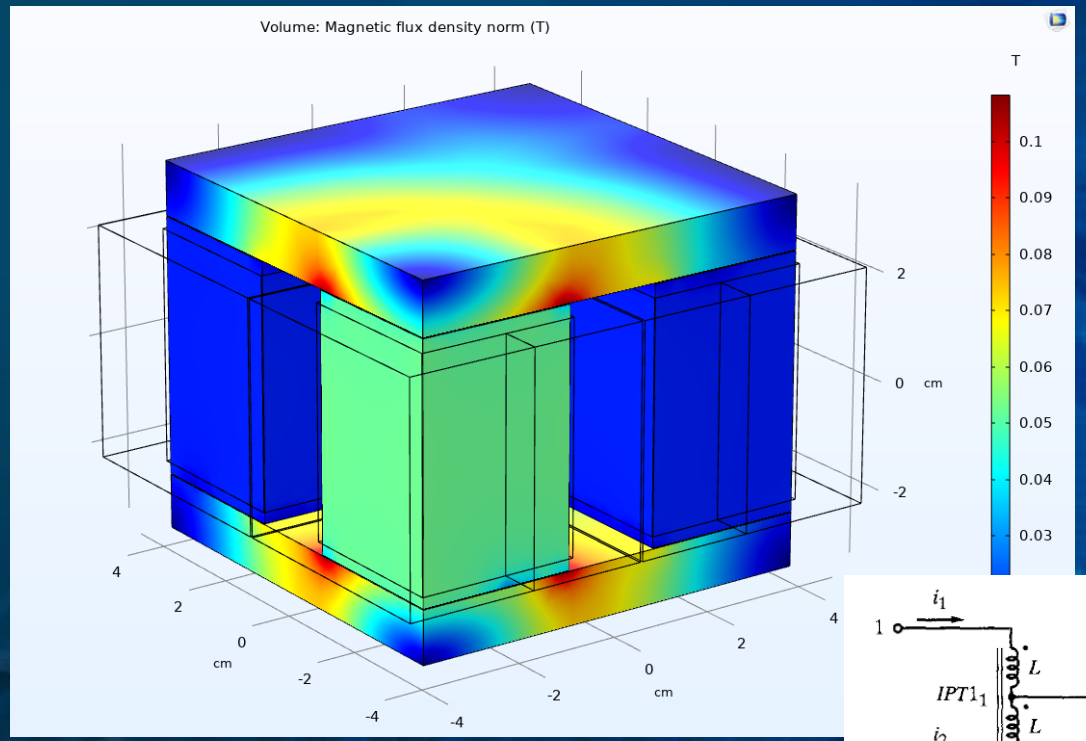






Constant-permeability core Graded-permeability core

Magnetics



AC Line Filtering

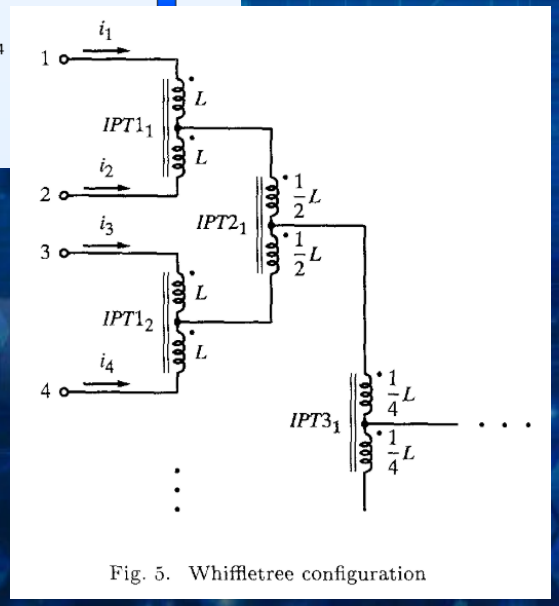
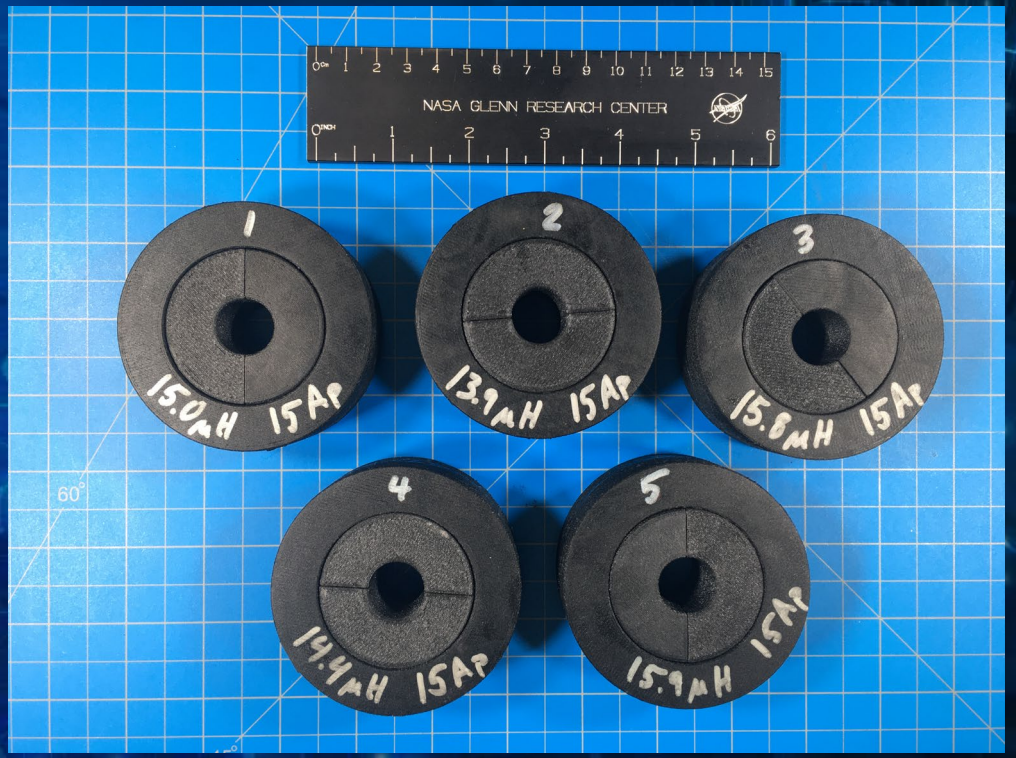
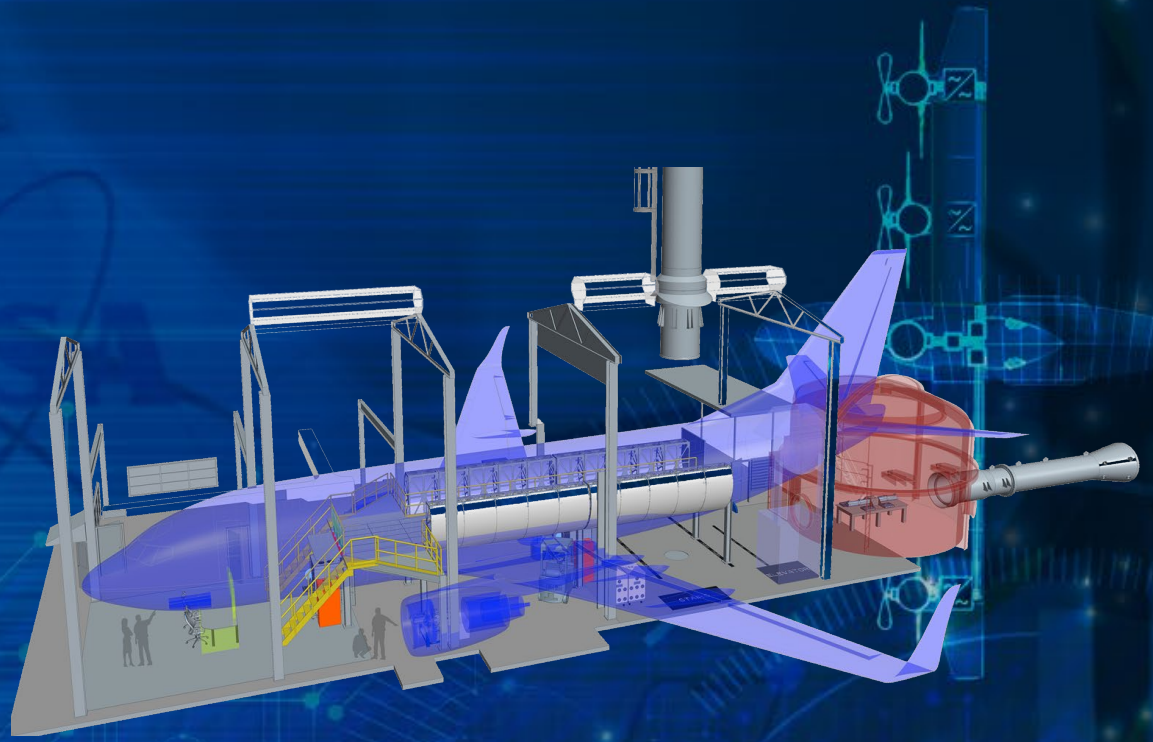


Fig. 5. Whiffletree configuration

Common Mode Chokes



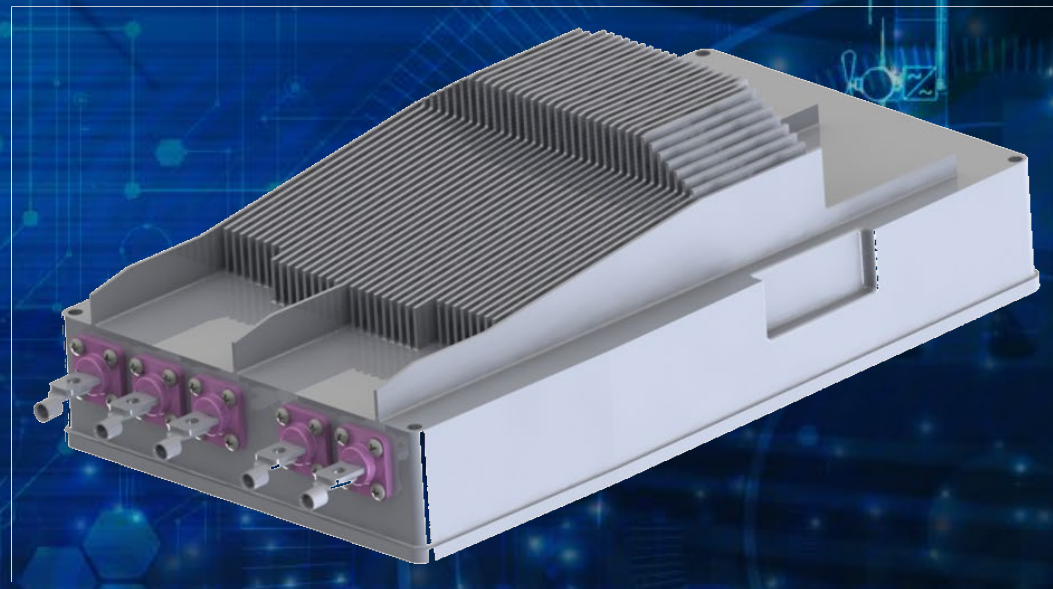
Ongoing EAP Motor Drive Work at NASA



X-57 Cruise Motor Controller

Cruise Motor Controller

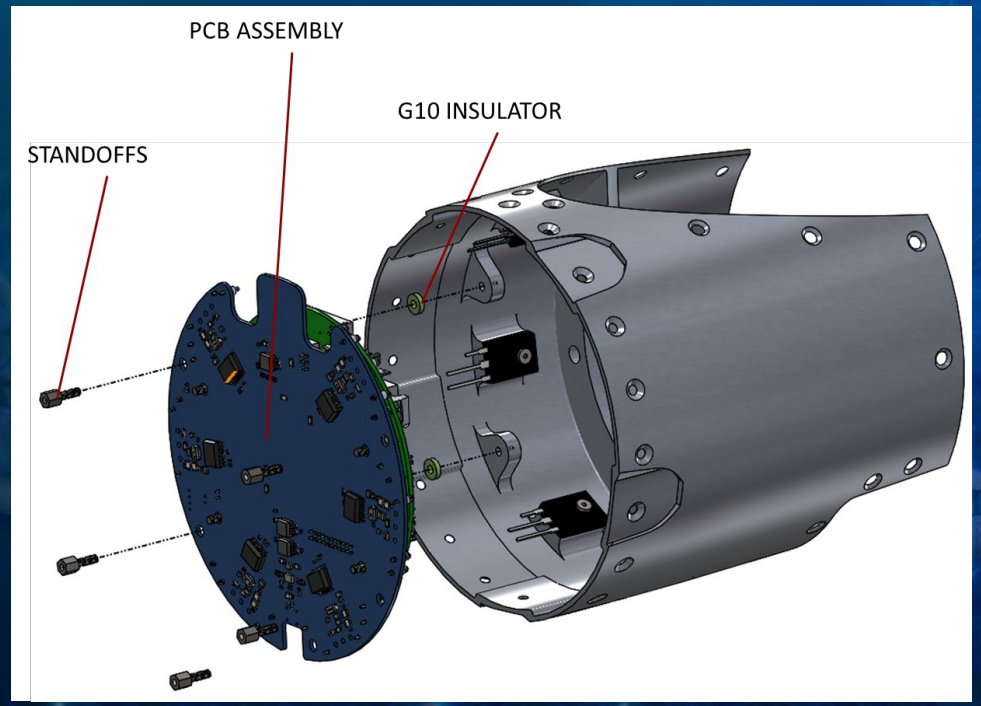
- 2x 3-phase motor
- Independent 36kW inverters
- Cooling fins integrated into case
- Separate high and low temperature zones
- Silicon Carbide MOSFETs
- Isolated CAN communication
- GRC magnetics for CM choke
- Internal differential signaling near power stage

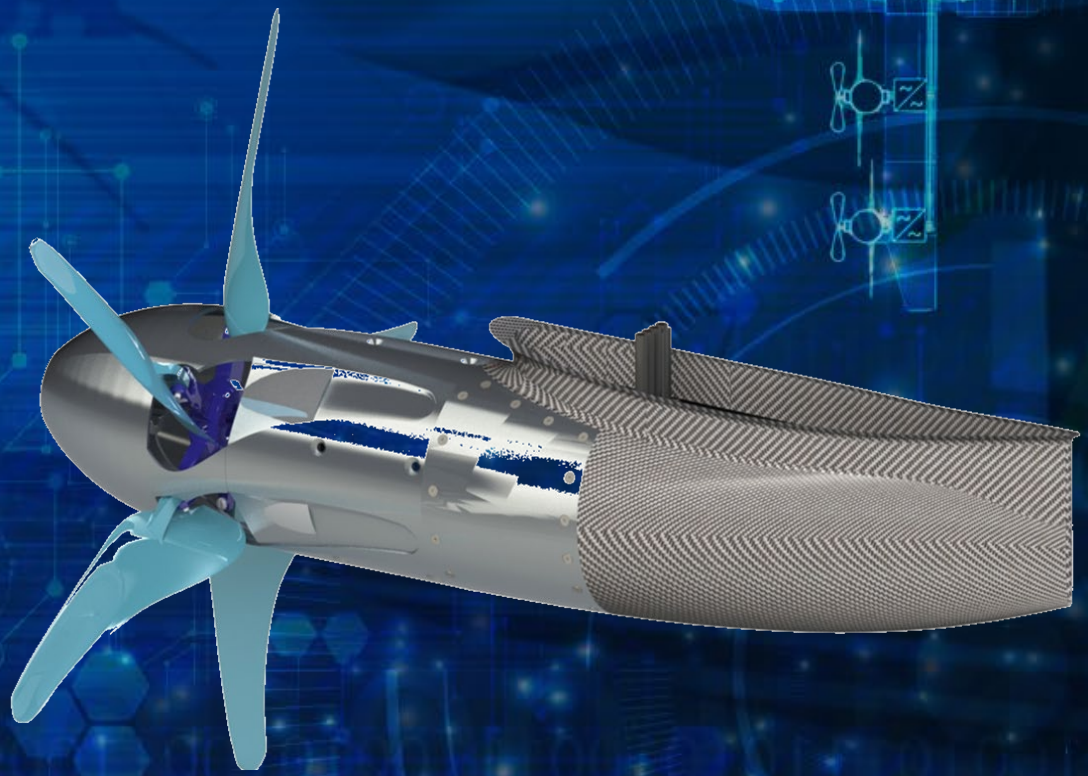


X-57 High Lift Motor Controller

High Lift Motor Controller

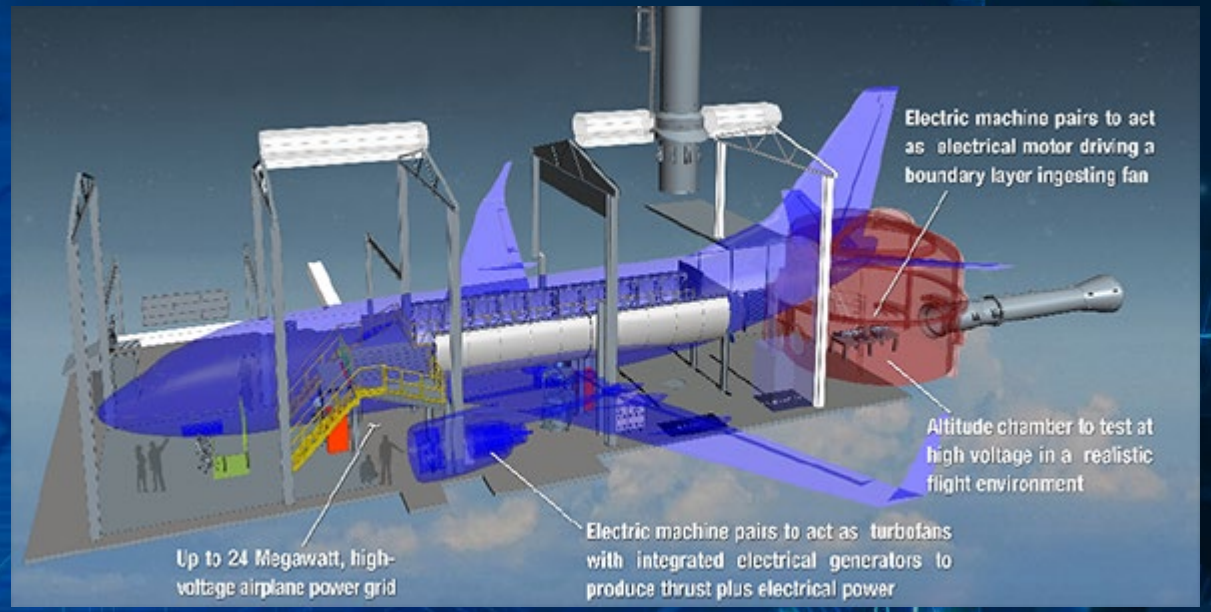
- 12kW inverter
- Silicon Carbide MOSFETs
- Outer mold line cooling
- Separate low and high temperature zones
- Optical communication

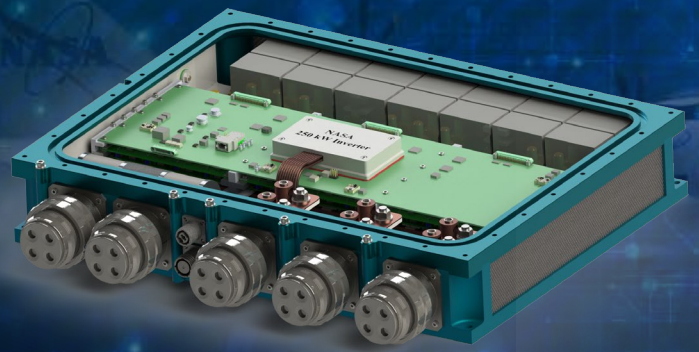


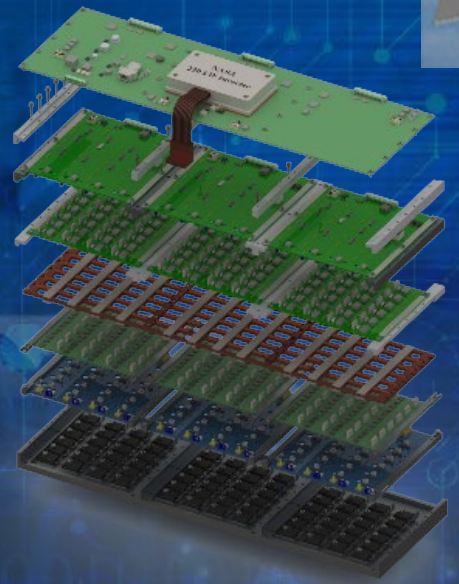


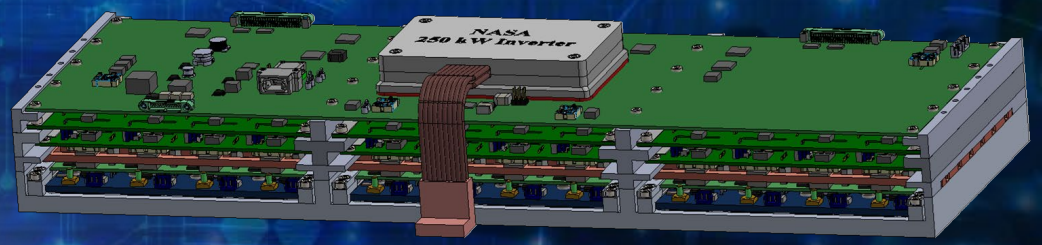
AATT Advanced Power Electronics

- 250kW, 1kV inverter
- Silicon carbide MOSFETs
- Multilevel, interleaved
- Optical communications
- Altitude capable
- Tightly integrated thermal and structural design





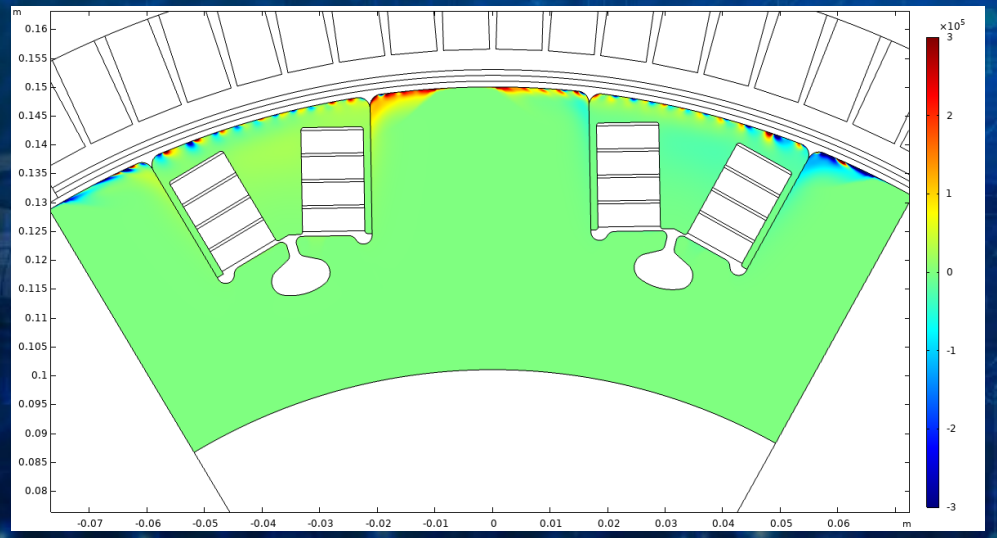


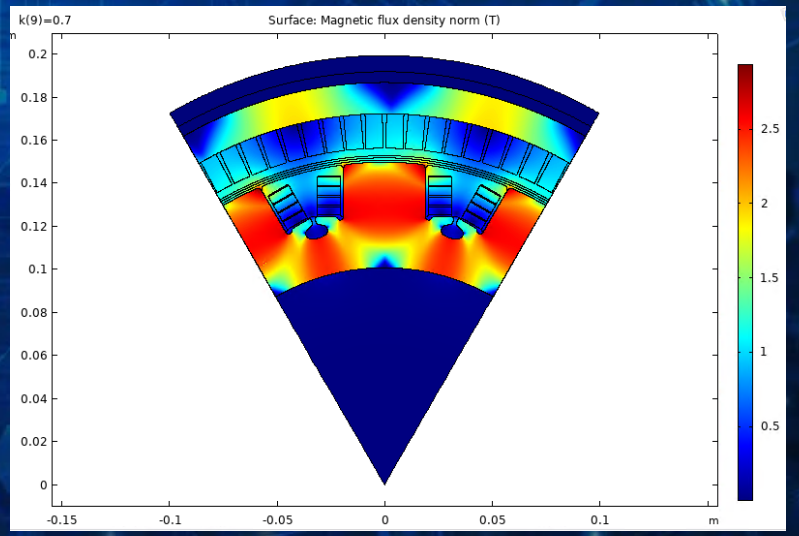


AATT HEMM

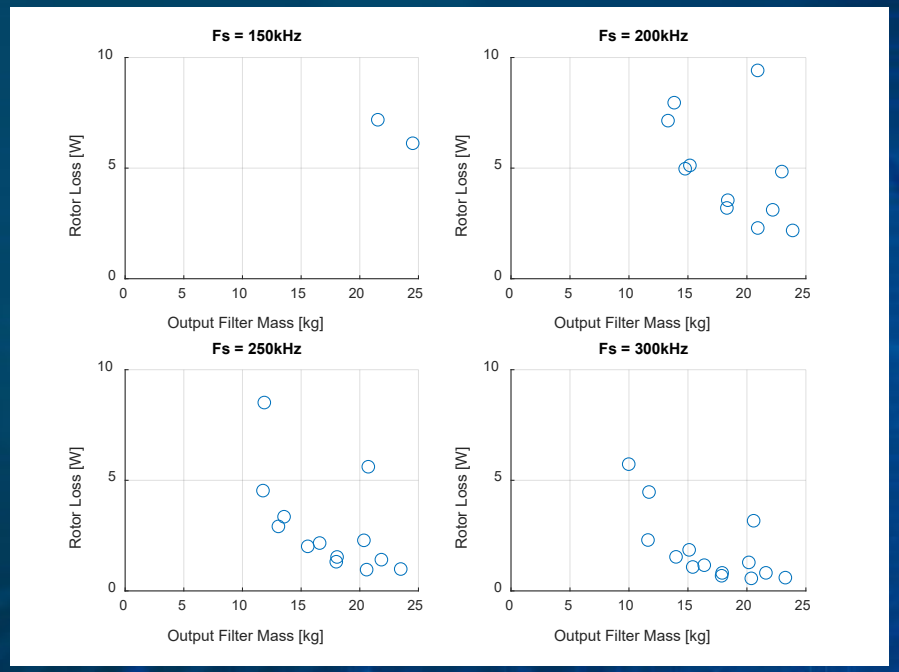
High Efficiency Megawatt Motor

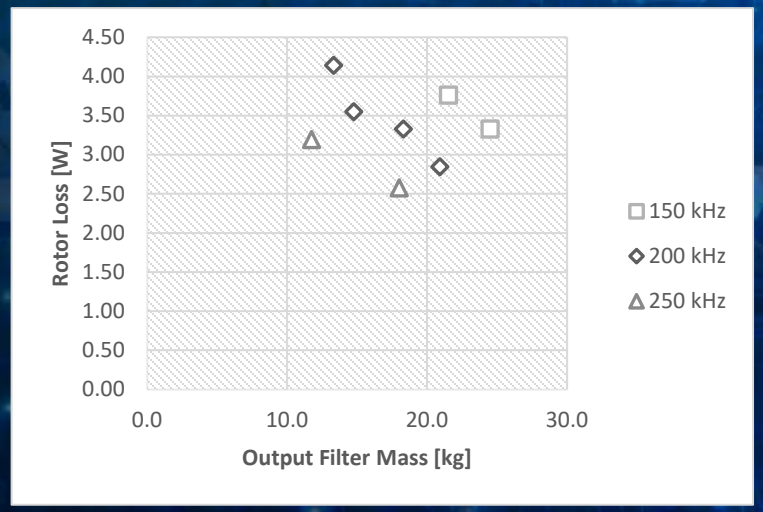
- 1.4 MW
- 9 phases
- Cryocooler cooled superconducting field windings
- Strict stator current ripple requirements
  - Complex filtering requirements



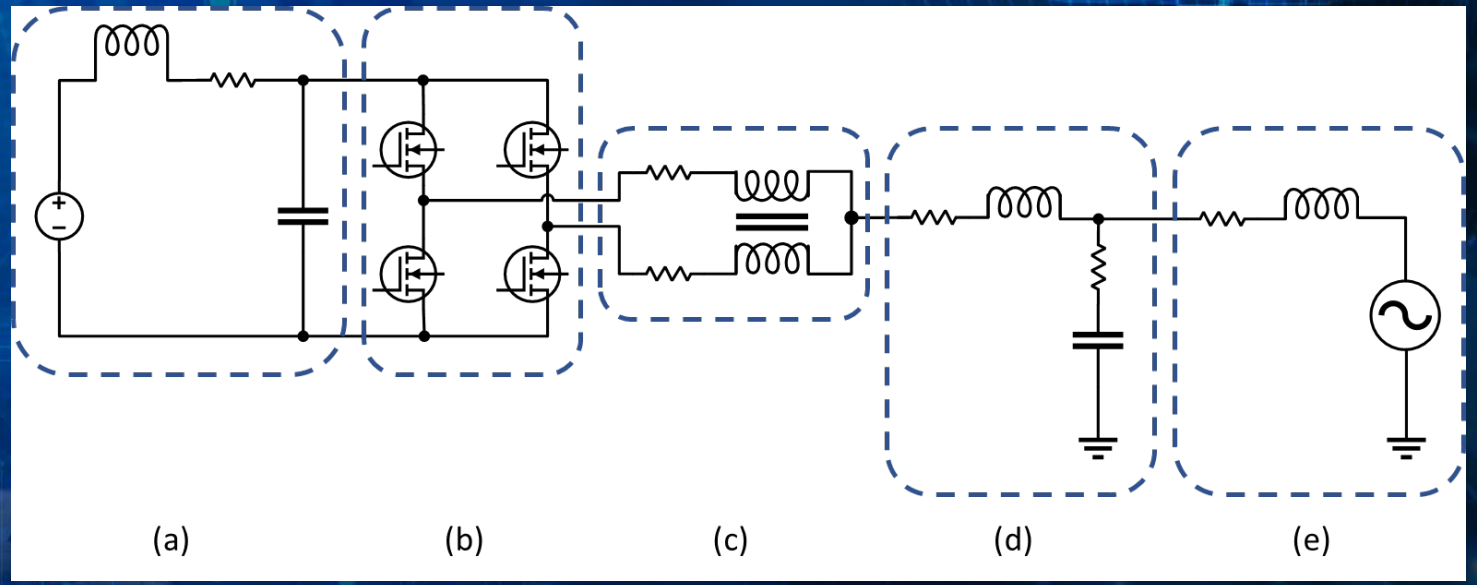


AATT HEMM





Resonant Inverter = Lightweight Output Filter



Conclusion

For More Information
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Thank you to the image contributors: Sean McCormick, Erik Stalcup, Alex Leary, Andrew Smith, Ryan Edwards, Susanah Kowalewski, Bradley French, Ariel Dimston, and Thomas Tallerico