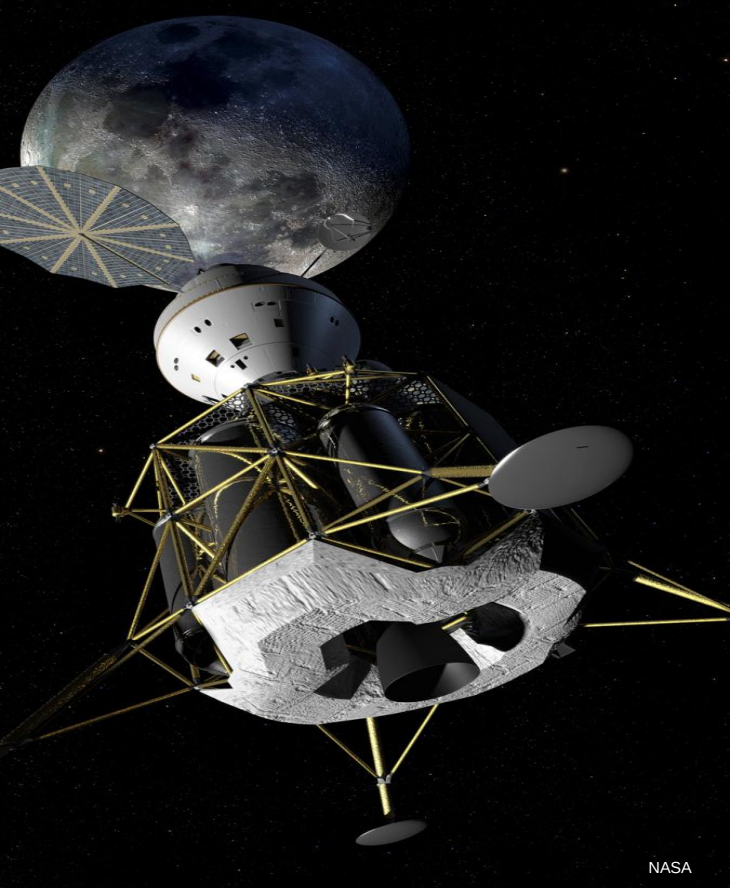
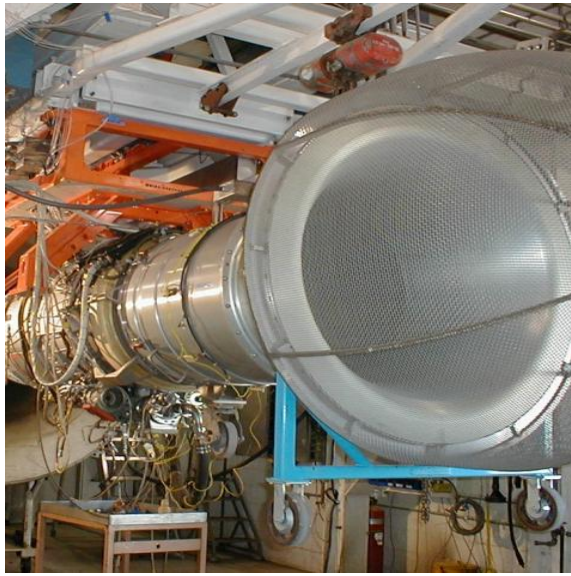
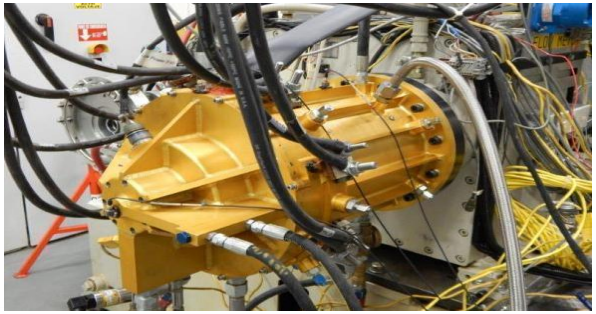






Cristian Anghel
Technology Fellow
Oct 18 2015

HYBRID ELECTRIC PROPULSION TECHNOLOGIES
1MW HIGH EFFICIENCY GENERATOR

Honeywell

Summary

- Motivation for hybrid electric propulsion
- Electric power overview
- Power Generation
- Power Conversion Power Distribution
- High power, high efficiency MW generator
- 200kW generator
- Turbine Engines Overview
- Hybrid electric propulsion example
- Trade Study and Demonstration
- Conclusions

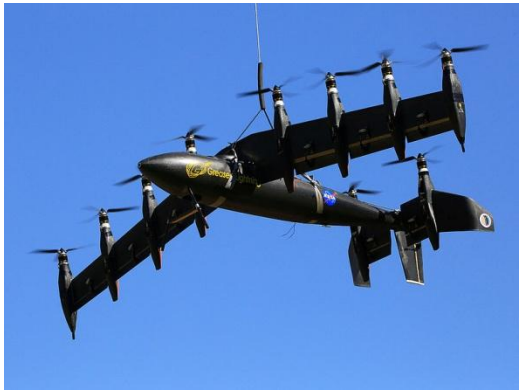
Why (Hybrid) Electric?

Starting in 1930s

From Wikimedia Commons, the free media repository

Present

Present and future



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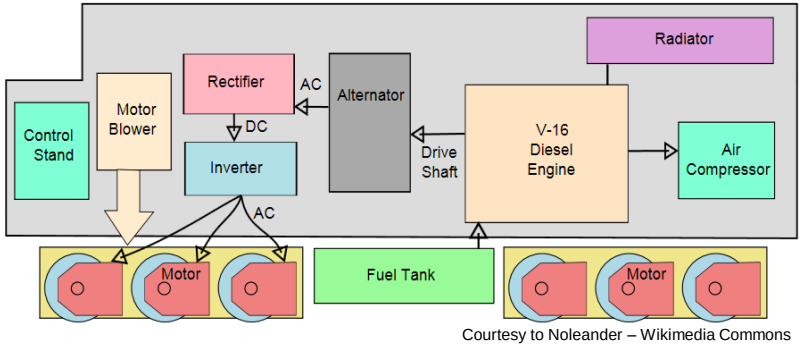
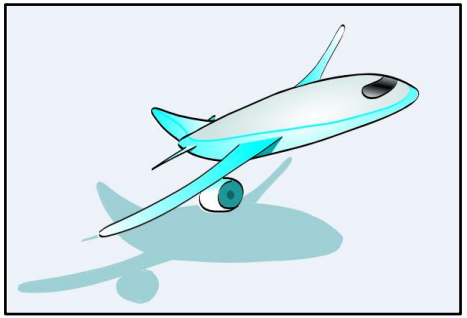
- Improved maneuverability due to the greater torque from electric motors
- Increased safety and reliability
- Easier maintenance
- Environmental and cost benefits

Environmental and operational benefits

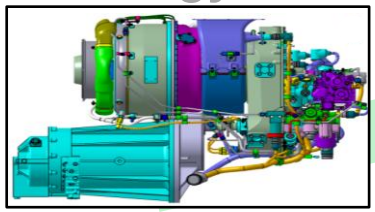
Enabling Technologies

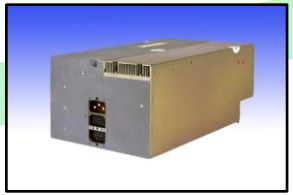


Courtesy to Noleander – Wikimedia Commons



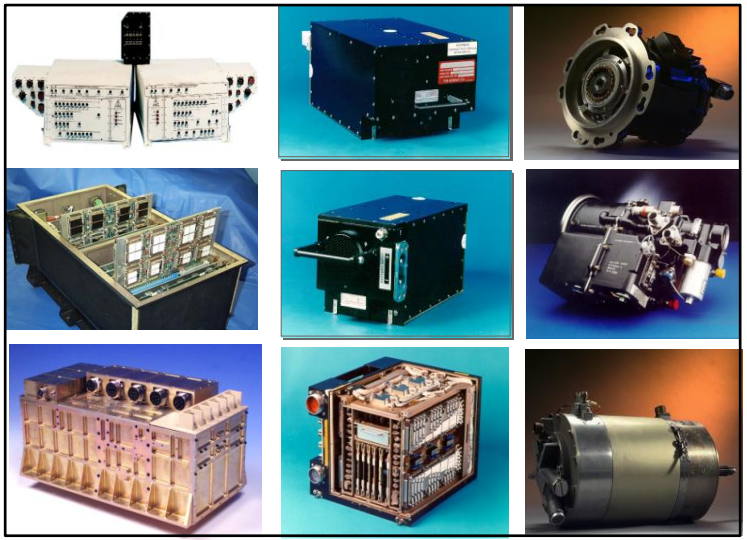
- **Engine (diesel or gas – turbine)**
- **Electric machinery (generators/motors)**
- **Power conversion and distribution**
- **Energy storage**





Aerospace requires high power density and efficiency

Electric Power Overview



All photos are From Wikimedia Commons, the free media repository

- Leading supplier of electric power systems and equipment since 1914
  - Bendix → AlliedSignal → Honeywell
  - Military and commercial aircraft
  - Military ground vehicles
  - Ground power
- Electric power generation, distribution, conversion and systems integration

Honeywell

Electric Power Products

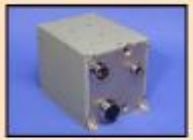
Generation + Conversion + Distribution + Control → Utilization

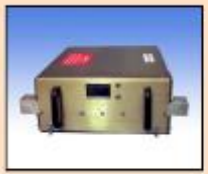

APU Starter Generator


Main Generator


Emergency Power


APU Start Control Unit / Start Power Unit


Motor Controller


Dual Use Main Engine Start / Motor Controller


Power Distribution Panel


Secondary Electric Power Distribution Centre (SSPC Technology)


Secondary Electric Power Distribution Box (SSPC Technology)


APU Generator Control Unit


Generator Control Unit


Electrical Power Control Unit


Motor


Actuator


Drive Systems

Honeywell

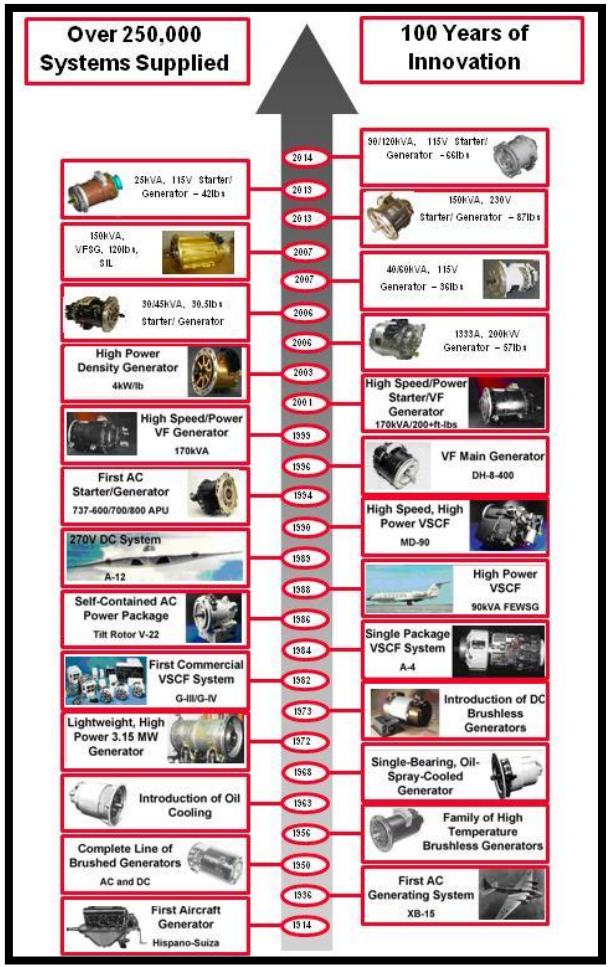
Example Platforms

All photos are From Wikimedia Commons, the free media repository

Honeywell

Power Generation Experience

- 100 years experience
- Industry leading product range of wound field generators:
  - Fixed and variable-frequency
    - AC and DC
    - Air and Oil Cooled
- Permanent magnet (PM) machines experience
- Speeds up to 200krpm
- Power levels to 1000kW
- SRM high speed technology developed and demonstrated
- High reactance PM machines



Honeywell

Power Conversion Products

Start Systems

Start Converter Unit (SCU)

737 APU
Start Power Unit (SPU)

Power Conversion Products

GIV
Converter Electronics Unit

MD90
Converter Electronics Assembly

E2C
Motor Controller

JSF
PTMSC

Future Products

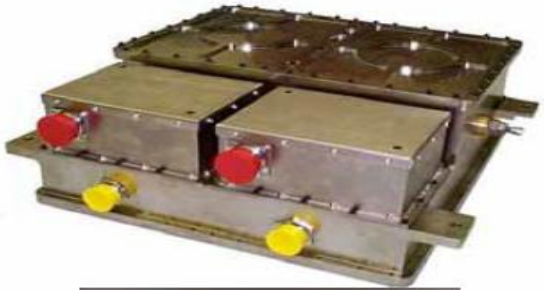
- Focus On Off-The-Shelf Components In New Designs
- Standardized Inverter Design
- Power Module Building Blocks
- High Density/Low Volume/Low Cost Power

Honeywell

Electric Drive Systems

For Servo Actuation

For Power Conditioning



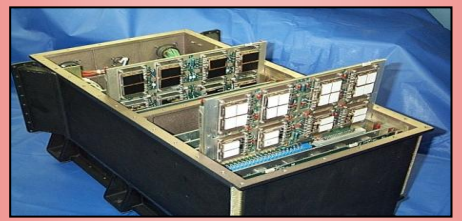
For Pumps & Fans

Honeywell

Power Distribution

Commercial Air Transport

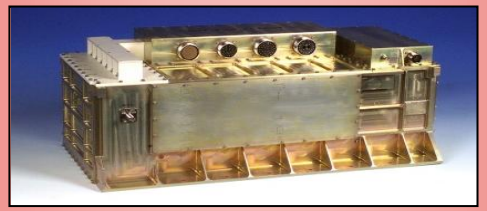
737 NG



A380 SSPC

Defense & Space

X33 LVPCA



X33 HVPCA

Business, Regional and General Aviation

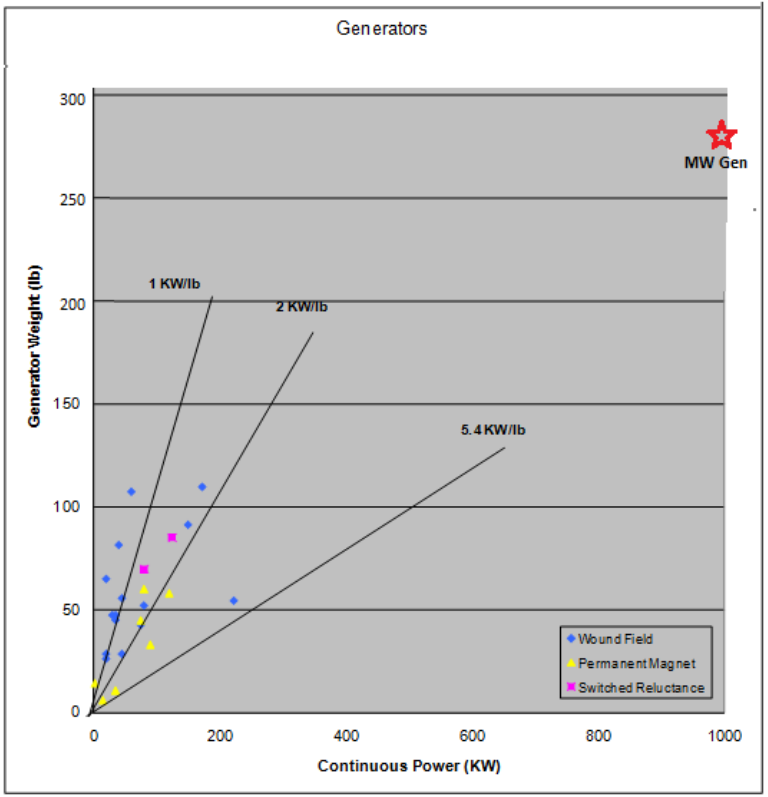
Agusta PDP

Dash 8

Honeywell

Improving Power Density and Efficiency

- Existing generators typically:
  - <2 kW/lb
  - <90% efficient
- Goal to achieve:
  - 5kW/lb
  - 98% efficiency
- Technologies:
  - Electromagnetic design
  - Thermal management
  - Bearing system
- MW class power for electric propulsion

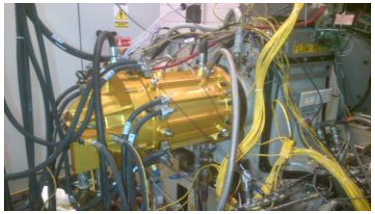


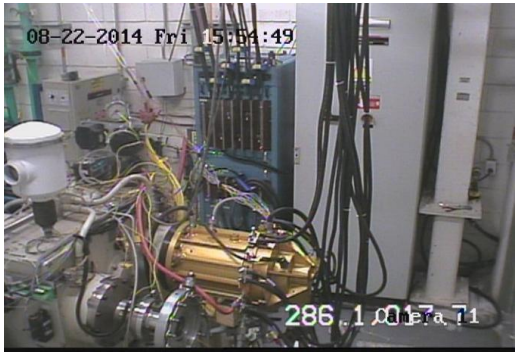
MW generator provides high power density and efficiency

1 MW Generator Summary

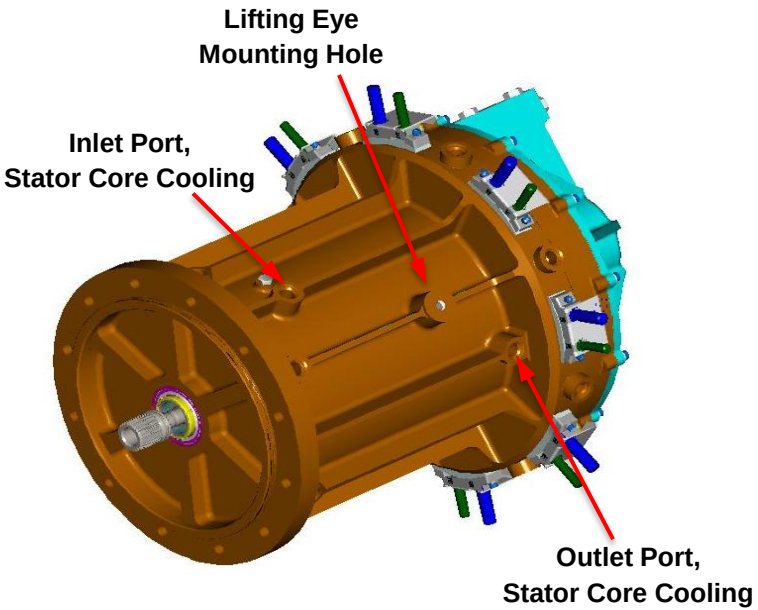
- High power, high efficiency generator for hybrid electric aircraft propulsion
- Tested to maximum drive stand capability, results as expected

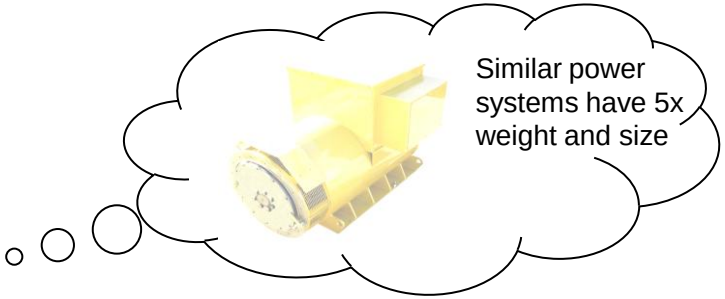
Rating	1MW continuous (after rectification)
Voltage	300VDC or 600VDC (±300V after rectification)
Speed	19,000rpm (20,000rpm over-speed)
Weight	126.5Kg (279lbs) (Generator Only)
Design efficiency	98% at rated load
Cooling	Oil conduction and spray
Type	Wound field synchronous with rotating rectifiers
Poles	8 (main machine)
Output winding	2 X 3-phase Y with 30° electrical shift
Rectification	Passive external

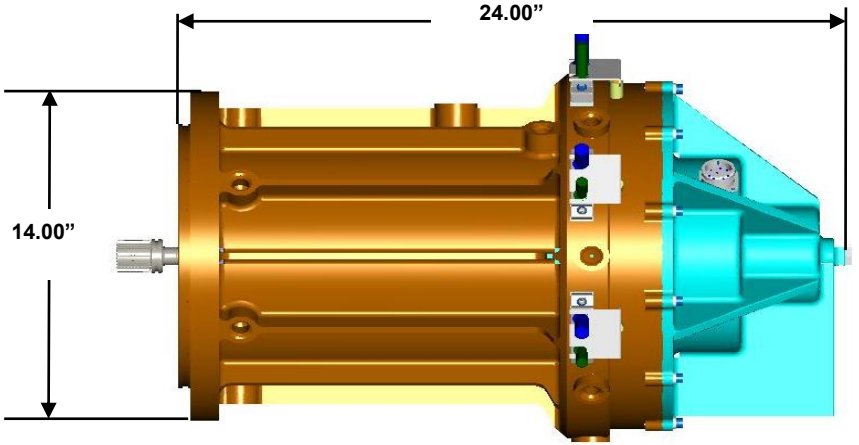




High Power/Efficiency Generator Outline







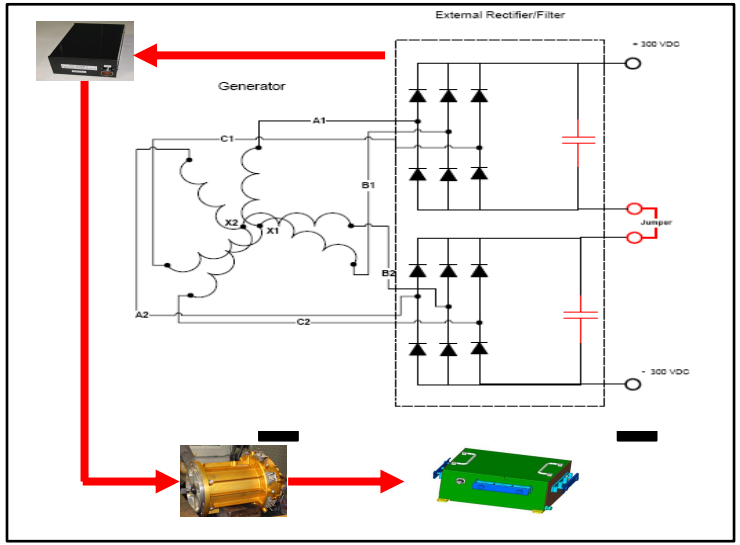
1MW of output power with a compact and lightweight unit

Power Generation System

- Generator (A)
- Generator control unit – GCU (B)
- Rectifier bridge and filter (C)

Benefits of wound–field generator:

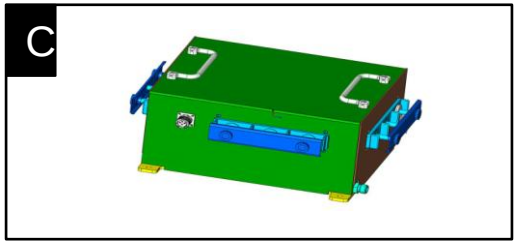
- Can be quickly de-excited (turned off)
- Performance is not temperature-dependent
- Increased system reliability



280 lbs

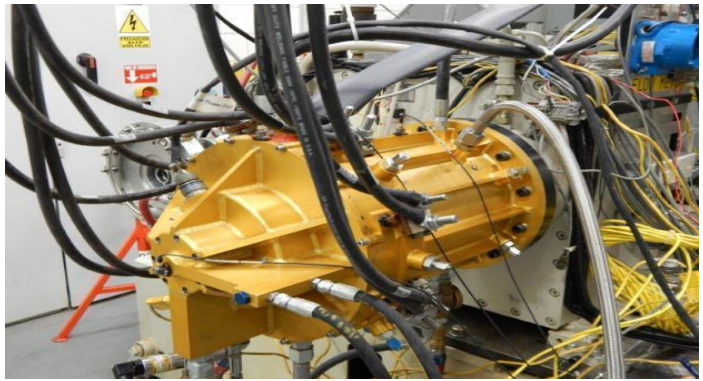
7 lbs

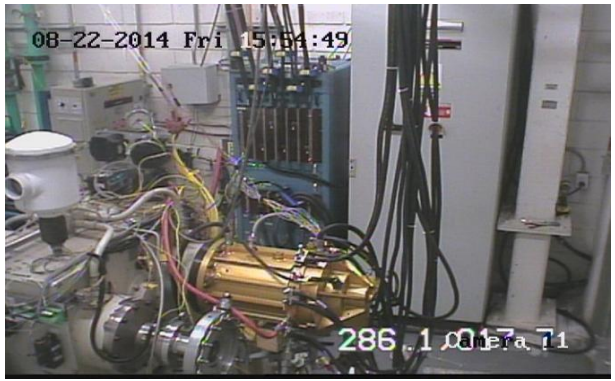
60 lbs

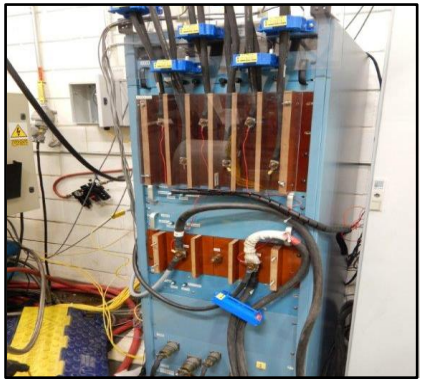


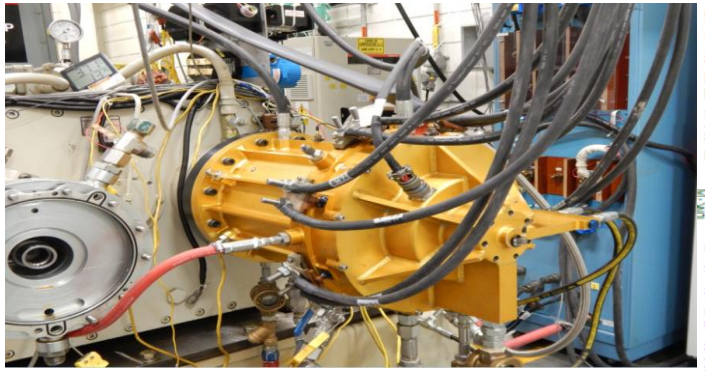
1MW at 97% efficiency with a ~350lbs generator system

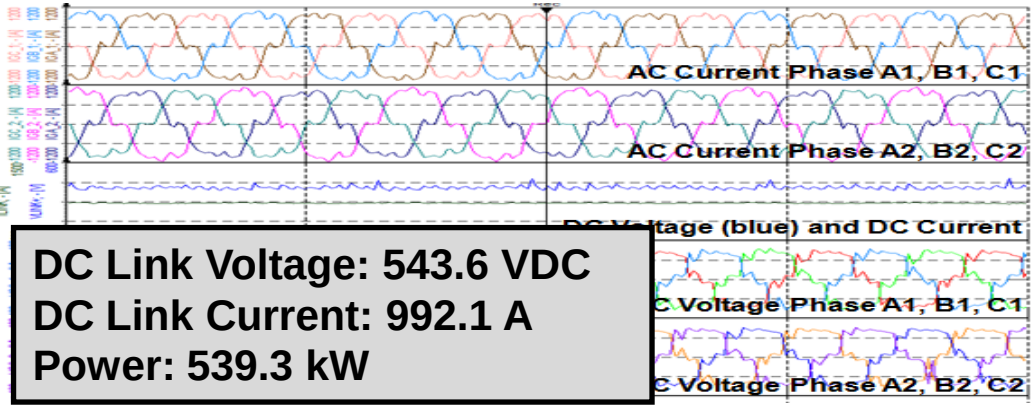
Generator Testing - 540kW











DC Link Voltage: 543.6 VDC
DC Link Current: 992.1 A
Power: 539.3 kW

Generator tested to maximum drive stand capability

200kW High Power Density Generator

- 200 kW output power
- Same power density as MW generator
- Prototypes built and tested

Wound-field generator provides:

- Operation without converter
- Superior fault accommodation
- Superior control flexibility

Honeywell

The Honeywell Turbine Engine Family

APUs

100 to 1700 hp for commercial and military aircraft

Turbofan Engines

3,000 to 10,000 lb thrust for commercial and military aircraft

Turboprop Engines

575 to 1,600 shp for commercial and military aircraft

Turboshaft Engines

500 to 5,000 shp for tanks, commercial and military rotorcraft

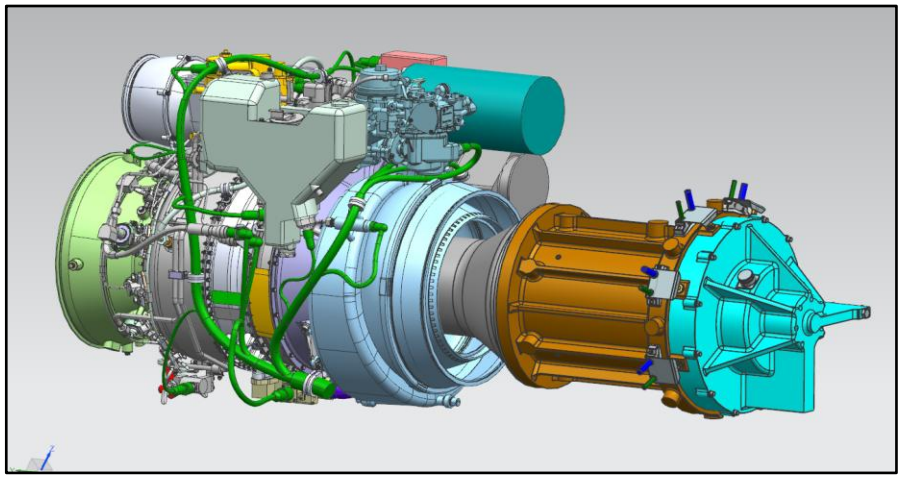
B08-147

More Than 135,000 Engines Delivered

Hybrid Electric Propulsion Example

Turbine → 1 MW Generator → Electric Motors

e.g. Induction Motors (IM)



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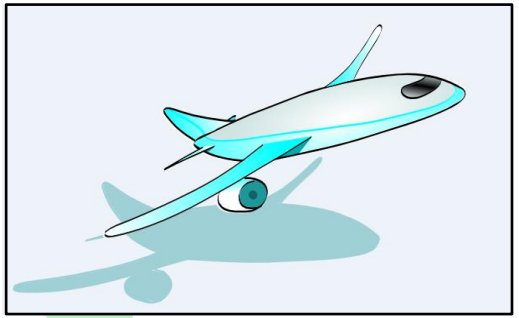
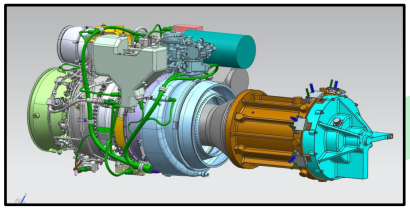
Proposed Study Objective

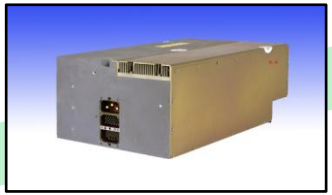
- Understand Turbine + MW + Motor Capabilities
- Cooling System Design (shared system)
- Concept packaging layout/models
- Determine fuel burn and system efficiency
- System Demonstration by Simulation and Test
- Deliverables
  - Power capability from ground to altitude conditions
  - Concept packaging layout/models
  - Cost, weight, volume
  - Efficiency

Conclusion

- Testing and analysis to date show that the current design is capable of 1MW
- High power density and efficiency together with the compact package makes this technology an ideal solution for hybrid electric aircraft propulsion
- Looking for Government and Industry partners to help mature and demonstrate this enabling hybrid-electric propulsion technology







Aircraft hybrid electric propulsion is here