Hyperlaminar Flow Engine for Combined Heat and Power

ARPA-E
GENSETS Kickoff Meeting

October 21-22, 2015

Chicago, IL

Center for Electromechanics
The University of Texas at Austin

Mohawk Innovative Technology, Inc.®

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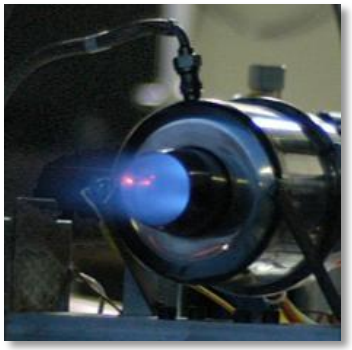
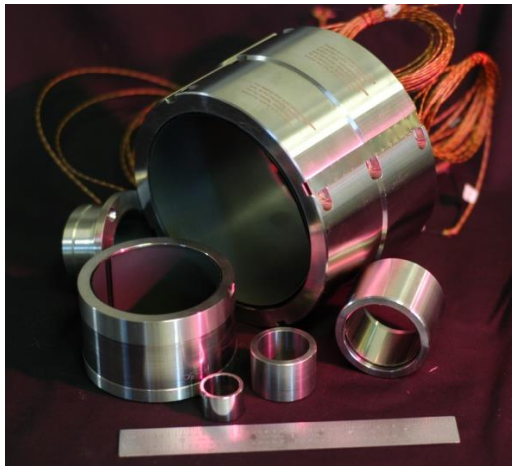
MiTi's Team

- Lead: Mohawk Innovative Technology, Inc.
  - Hooshang Heshmat, PhD;
  - James F. Walton II
  - Jose L. Cordova, PhD;
  - Andrew Z. Hunsberger
- Power Conversion: University of Texas – CEM
  - Michael Lewis;
  - Raymond Zowarka, PhD
- Recuperated Combustion: Mitis
  - Michel Delanaye, PhD

Technology Investments at MiTi

- Founded 1994
- $50 Million and over 500,000 Highly Dedicated Professional Man Hours of Continuous R&D Have Made Possible
- Advanced Foil Bearing Capabilities and Applications in High-Speed Oil-Free Rotating Machinery

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Oil-Free Turbomachinery

ORC Turbogenerator

65 kWe @ 30,000 rpm

Air Cycle Machine

120,000 rpm

Turbogenerator

8 kWe @ 180,000 rpm

Hydrogen Blower

1.5 kWe @ 360,000 rpm

Hydrogen Pipeline Compressor

200 kWe @ 60,000 rpm

Composite Flywheel Energy Storage

60 kWe @ 60,000 rpm

Micro Machining

500,000 rpm

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Key Technical Challenges

- Multi-Company R&D Integration
- Miniaturization Including Manufacturing Tooling
- Integration & Thermal Management
- Component Efficiencies
- Rotating Group & Bearings
  - High Tip Speed, High Temperature/Strength Materials
  - Self Generating Counterfaces for Enhanced Flow
  - Rotor-Bearing System Dynamics & Balancing
- Flameless Combustion
- High Frequency Power Conversion Electronics

Miniaturization Technology & Design Methodology

Scale Factor Reduced by 3 Orders of Magnitude (kW to W)

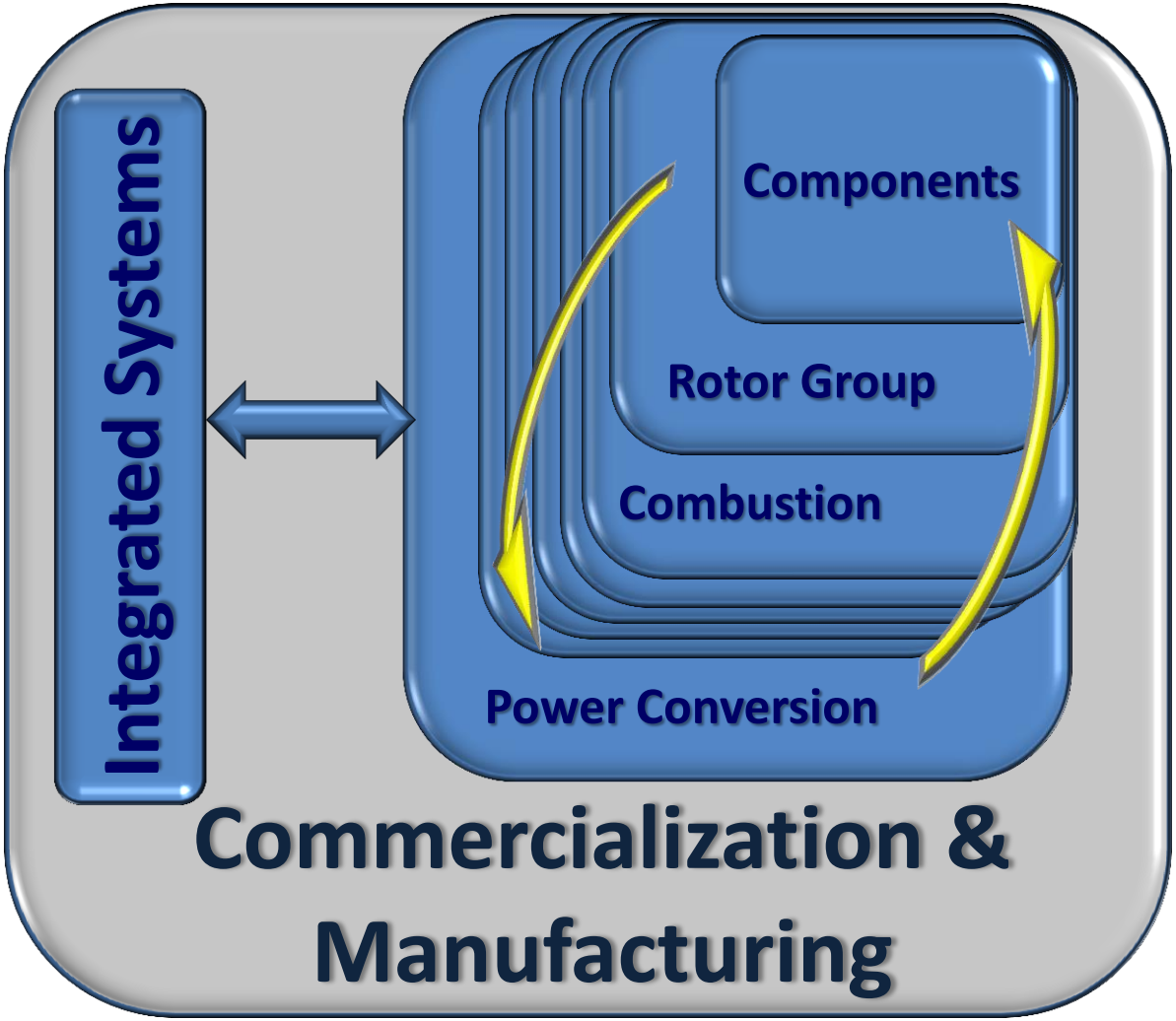
Key Technology Miniaturization

- ► Design Rule (t•P)
- ► Parametricalization
- ► Time + 3D Modeling
- ► Process-Technology

Miniaturization Factor

$\mathcal{M}_f \leq 1$

New Field of Machinery



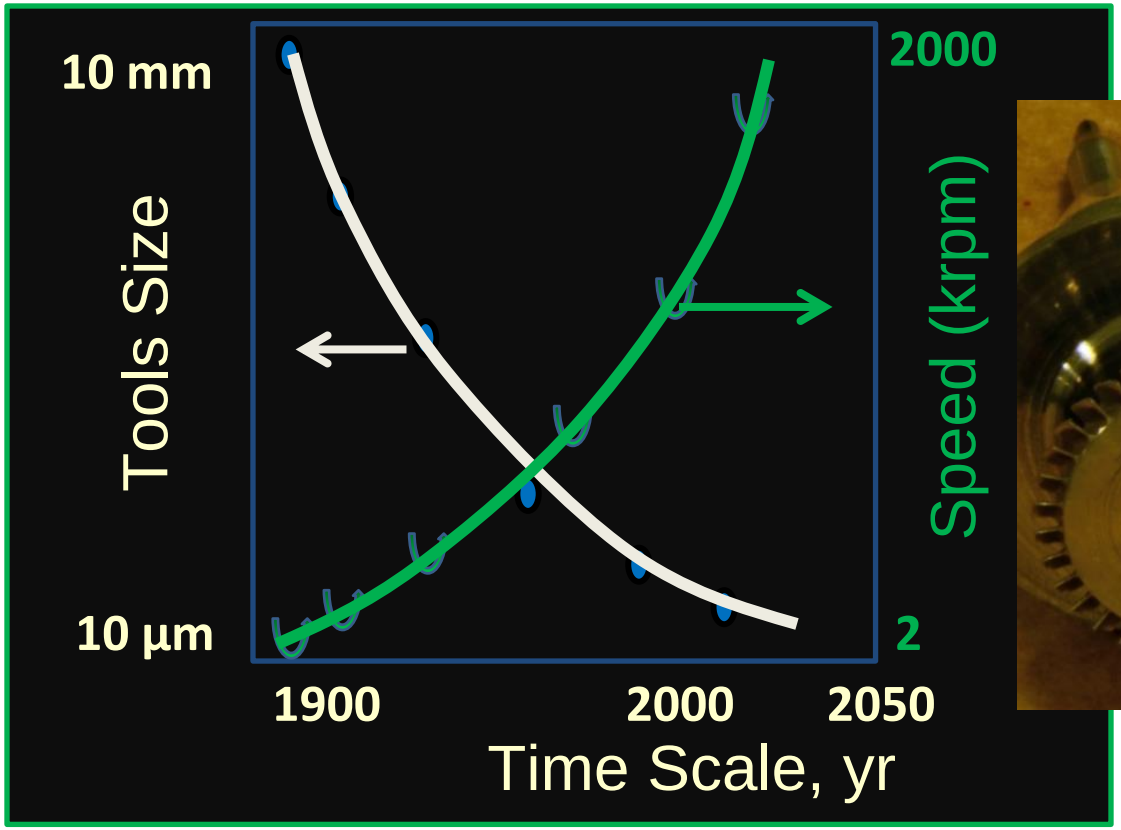
Miniaturization Technology Development

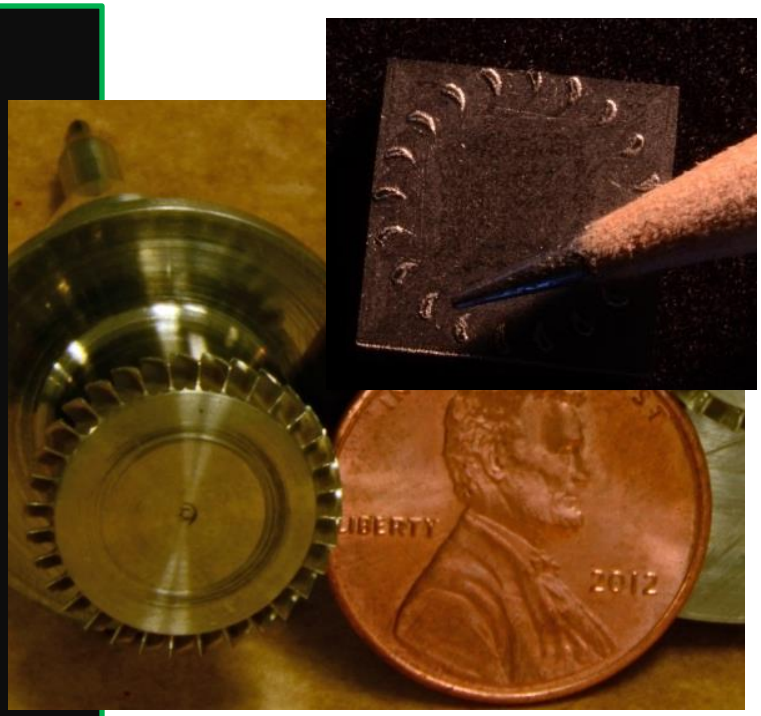
Miniaturized manufacturing tools are key to development and fabrication of miniaturized system components.

MiTi Miniaturized CHP System:

$0.25 < \mathcal{M}_f < 0.3$

High-speed spindle development lags tool developments:
10 µm range requires 1 Mrpm spindle, which HYTBD





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Miniaturization Technology Development

In Order to Properly Miniaturize Critical System and its Components:

- Design & Parametricalization method is essential for 4-D miniaturized system

- Miniaturized manufacturing tools are key to the economical development and fabrication of miniaturized system components

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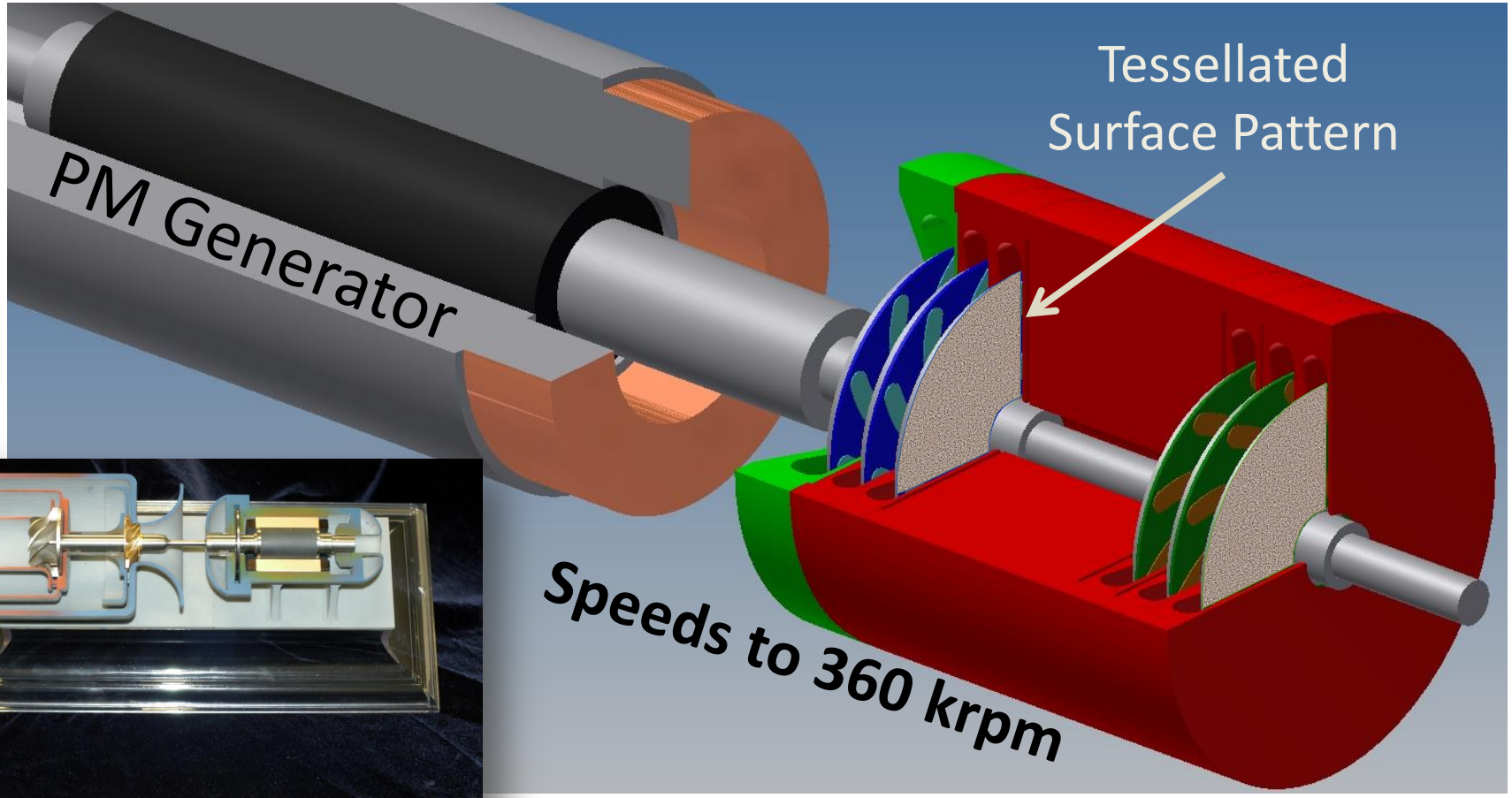
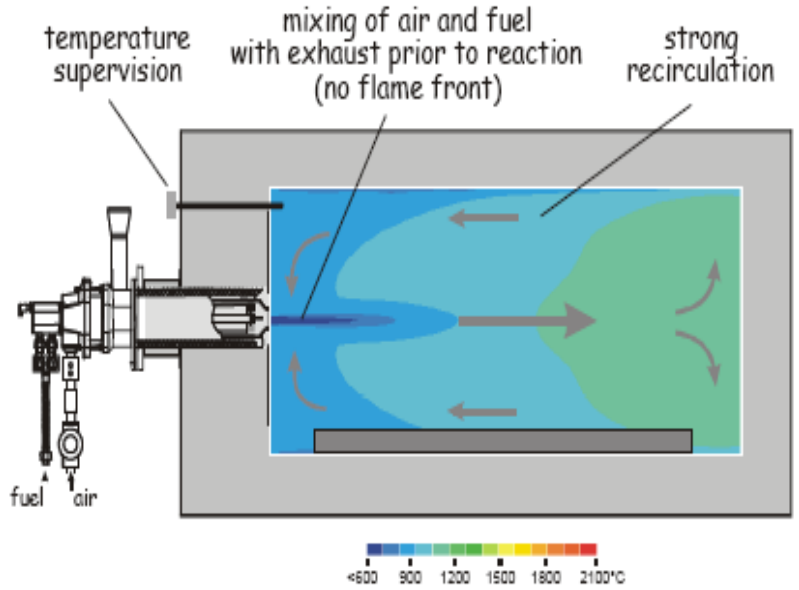
Multi-Stage Hyperlaminar/Viscous Shear Aero-Components (Compressor & Turbine)



Novel Meso-Flameless Combustion

- Lean Mix System With Recirculation For High Combustion Efficiency.
- Increased Chemical Time Scale & Intensified Turbulence
- Low Pollutant Emissions (Low NOx & CO).
- Large Fuel Flexibility.
- Stable And Noiseless.
- Integrated Recuperator



3 kW Flameless Combustor Demonstrator

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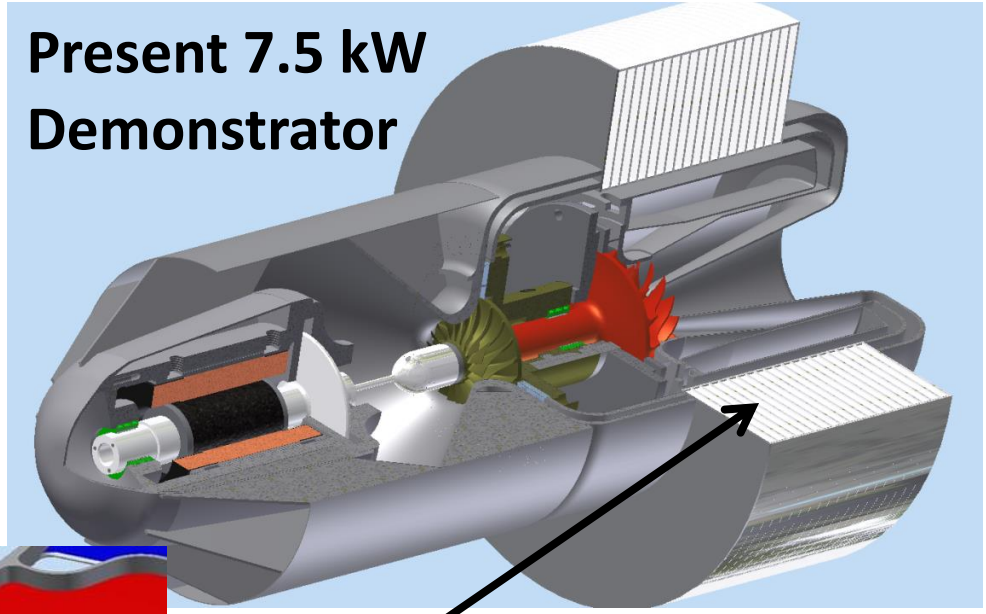
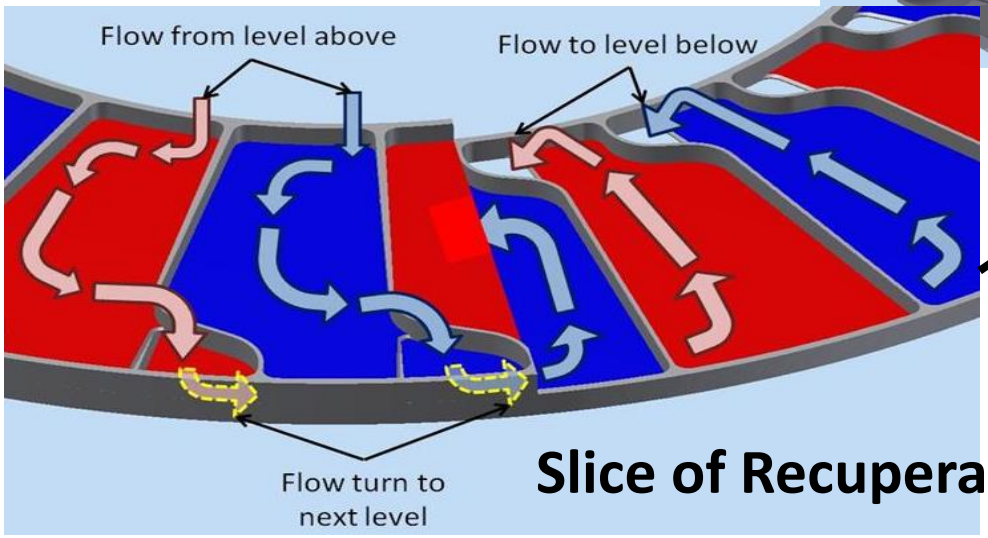
MiTi® Meso-Recuperator Design

Features

- Compact Annular Geometry (92% Effectiveness)
- Heat Exchange Counter/Cross/Co-Flow

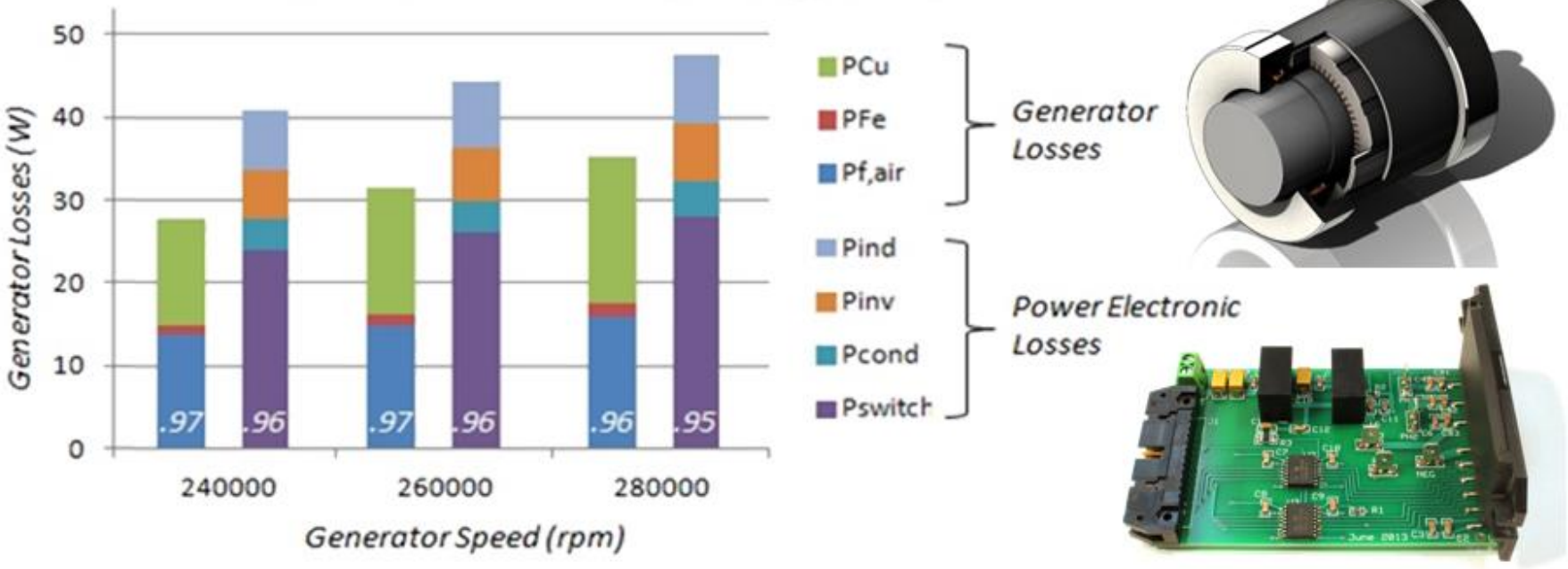




Slice of Recuperator

Electrical Energy Conversion

- UT-CEM Will Lead Generator And Power Conversion Design
- 1 Kw High Speed PM Generator – DxL = 40 X 50 Mm^2
- Overall Electrical Energy Conversion Goal Of 90%



Expected Program Impact & Outcomes

- Novel Miniaturized Modular CHP System
  - Commercial & Residential Applications
  - Portable Military Applications
  - Micro-UAV Power and Propulsion
  - Portable Consumer Power
    - Remote Medical & Research Facilities
    - Outdoor Adventurists
  - Remote Backup Power for Communications
  - Robotic Systems Motive Power
  - Combined Modules for Variable Power
- Foundation for Advanced Manufacturing Technologies Leading to Wide Array of Maintenance Free MEMS Class Machinery –(i.e., No Scheduled Oil Changes)

Thank you for your attention

MiTi is grateful to ARPA-E for the Opportunity

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