The University of Texas at Austin
Center for Electromechanics

2016 ADVISORY PANEL
SUPERCONDUCTING & OTHER ROTATING MACHINES

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Rotating Machine's Niche

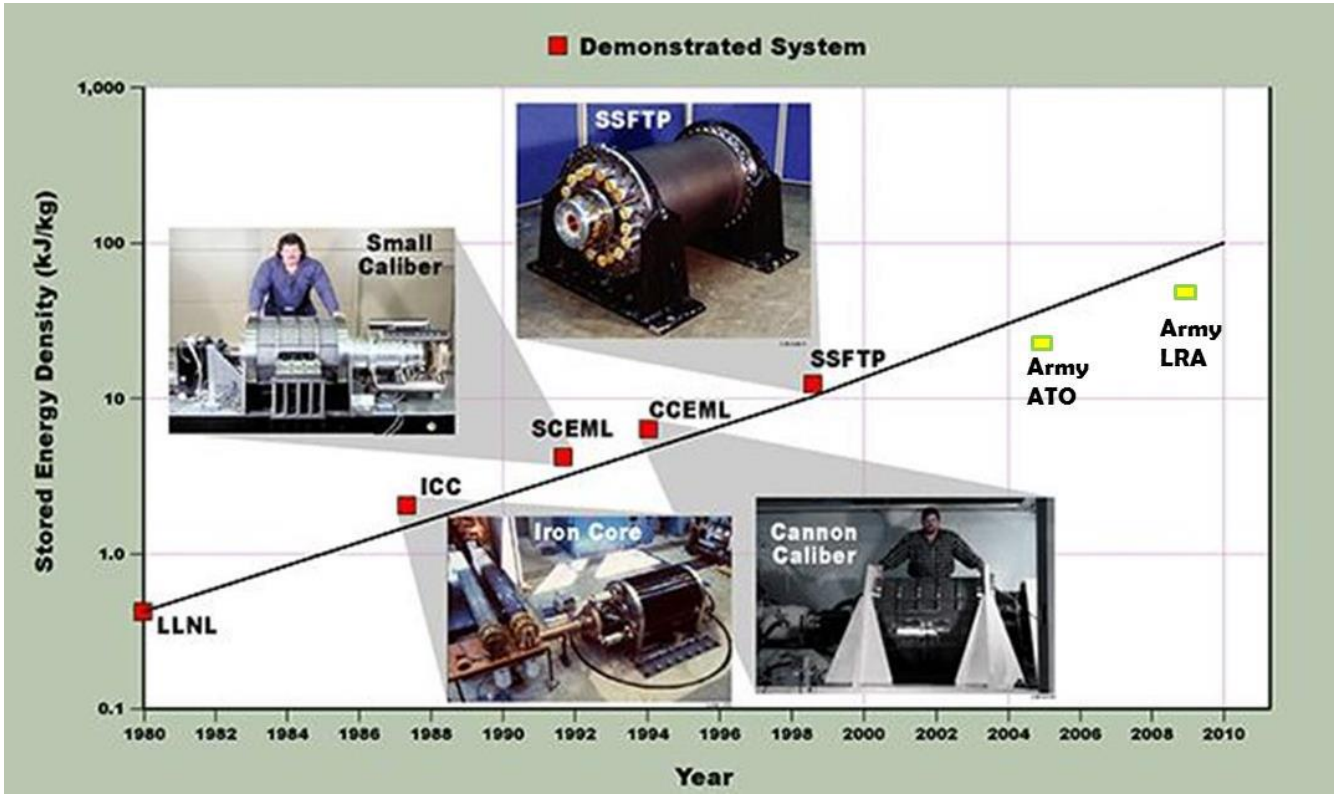
- **Offer balanced and efficient energy storage and power conversion capabilities**
- **Conducive for compact, light weight designs**
- **Provide multi-mode operational capabilities**
- **Pulse and continuous duty operation**
- **More thermal design "friendly" ?**

- **Over the past several decades, CEM has utilized the advantages of rotating machines to provide solutions for a broad range unique applications**

Pulsed Alternators

- Pulsed alternators designed for specific applications (pulse loads)
- 6+ generations designed, manufactured and tested
- 20x increase in demonstrated energy density

- Key enabling technologies developed
  - High performance composites
  - Innovative rotor assembly techniques
  - Advanced high strain insulation systems
- Modeling/Simulation development and validation



Electromagnetic Aircraft Launch System (EMALS)

- Energy storage and pulsed power for US Navy's new electromagnetic aircraft launch system
  - Multi-megawatt pulse
- Supported sled testing at Lakehurst demonstration and test facility
- Successful technology transferred to industrial partners

1999 state of the art technology metrics critical to the success of EMALS:

Motor Shear Stress	*= 7-15 psi*
PCS Power Density	*= 5kW/kg*
ESS Power or Energy Density	*= 3-5 kW/kg or 2-5 KJ/kg*

Navy's required metrics, all 2-5 times 1999 state-of-the-art:

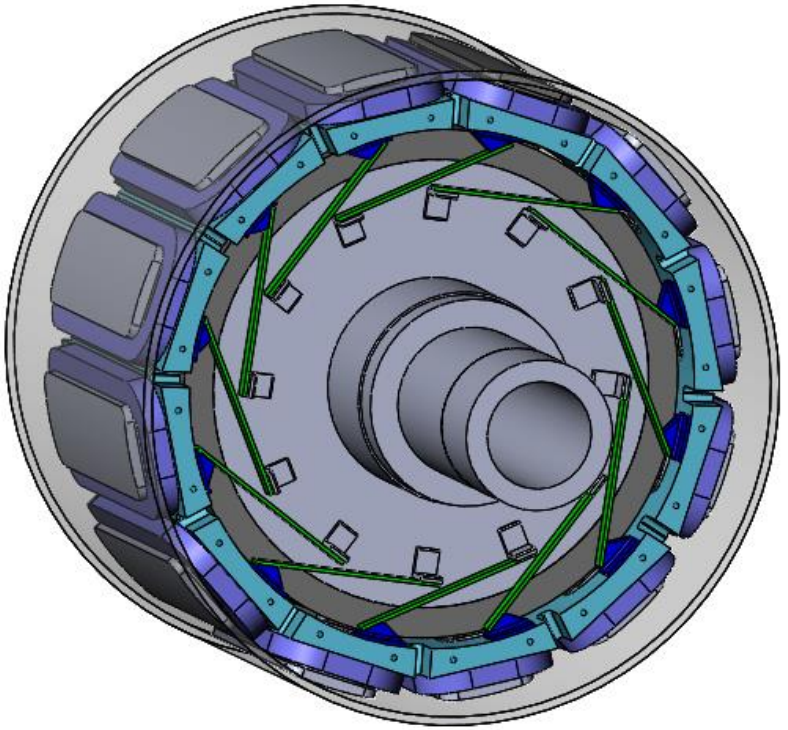
Motor Shear Stress	*≥ 30 psi shear stress*
PCS Power Density	*≥ 10 kW/kg*
ESS Power and Energy Density	*≥ 3 kW/kg and 5.0 kJ/kg*

Demonstrated metrics:

Motor Shear Stress	*= 33-37 psi*
PCS Power Density	*= 16 kW/kg*
ESS Power and Energy density	*= 3.1 kW/kg and 5.8 kJ/kg*

Current Projects – Superconducting Wind Generator (Rotor Design)

- System parameters:
  - 2 MW power generation
  - 20 rpm peak speed – direct drive
  - High torque requirement
  - 12 pole design
  - Wound superconducting coils
  - Approx. 2 m x 1.5 m long (rotor body)
  - Evacuated rotor structure
- UT-CEM tasks:
  - Rotor thermal insulation design
  - Integrated cryogenic hardware mechanical support design
  - Mockup testing and validation of rotor design (thermal & mechanical)

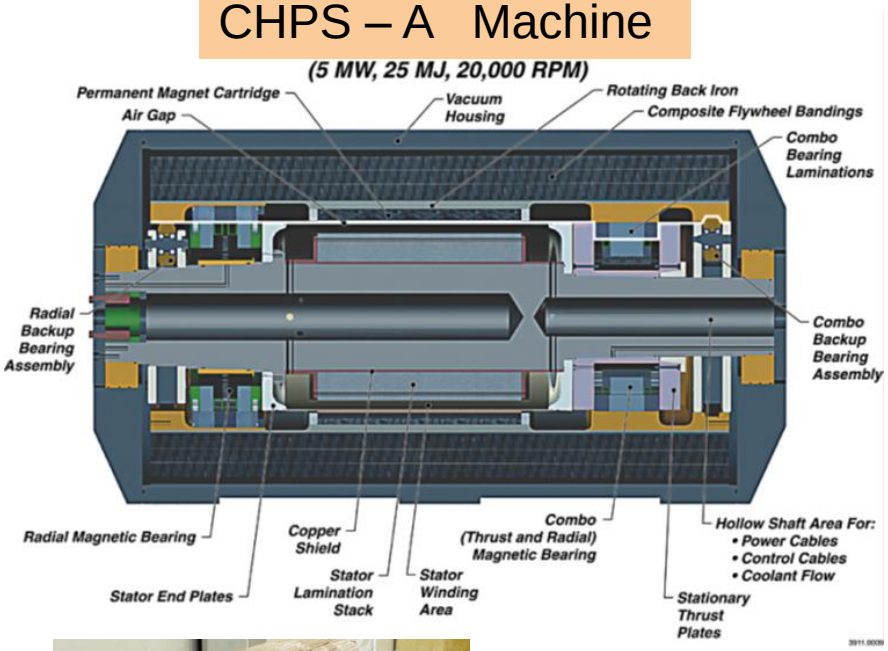


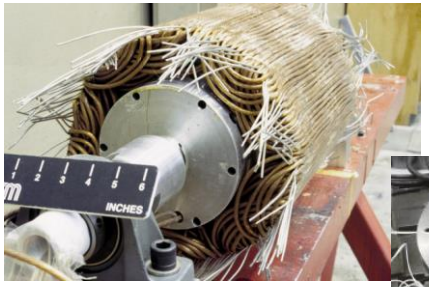
- Cryogenic components – illustrated blue
- Vacuum shell shown transparent

Current Projects – CHPS-N (Combat Hybrid Power System – Navy)

- CHPS-Navy design derived from CHPS-Army program
- CHPS – Army parameters:
  - 5 MW, 25 MJ -- 20,000 rpm
  - “inside –out” arbor-less design
  - Continuous or pulse duty
- Demonstrated:
  - Assembly of multi-pole magnetic rotor
  - Assembly of full scale liquid cooled stator
  - Static torque, voltage, & cooling
  - Full scale magnetic bearing loading

CHPS – A Machine





CHPS Component Verification Hardware

Current Projects – CHPS-N (cont)

Technical Objectives

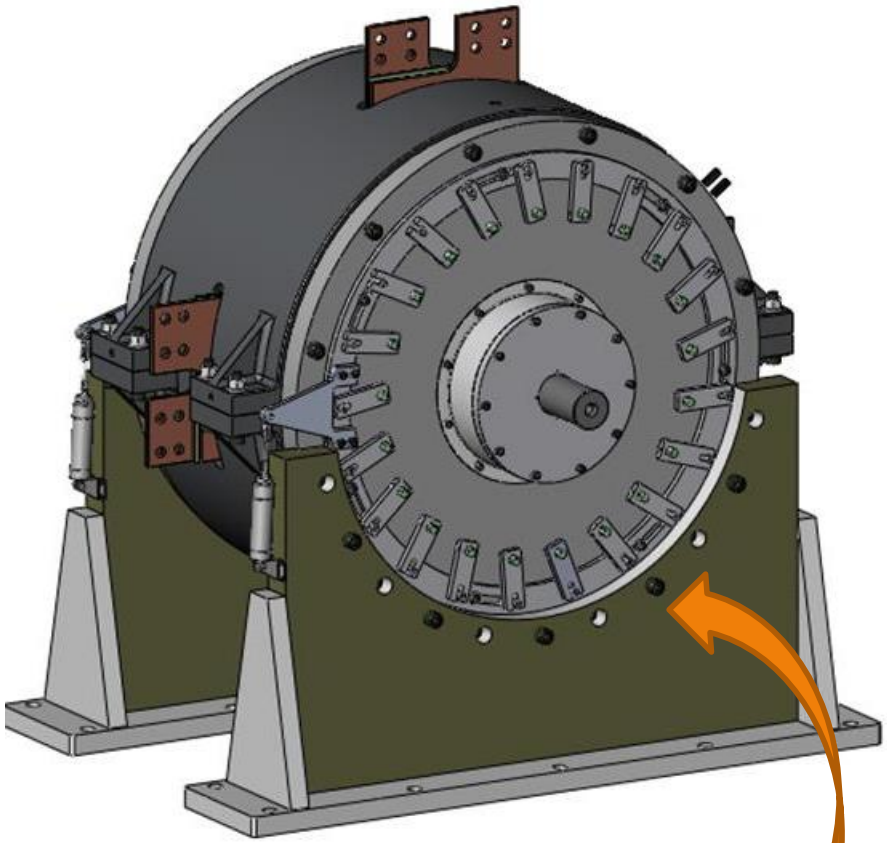
- **Adapt CHPS-A design and optimize for ship powertrain (60 Hz, shipboard 1800 RPM generator or high speed, 7,000 RPM generator).**
- **Emphasizes safety, focused on significant and credible risks**
- **Bring the CHPS-N design to advanced state, supported by appropriate risk mitigation experiments**
- **Status: Spin test May 2016**

Features

- **Smallest mass and volume topology – fits through 26" hatch**
- **Flexible mission support – pulse power, power quality and load leveling**
- **Design can be scaled down or up**
- **Very long cycle life – can minimize cycling of chemical energy storage components**
- **Exploits recent advances in composite materials to enable high tip speeds – *key enabler for very high power density generators.***
- **Exploits the CHPS-A permanent magnet (PM) cartridge technology to allow survival at high tip speeds – *another key enabler for very high power density generators.***
- **Exploits the CHPS-A inside-out magnetic bearing technology to allow high rotor rotational speeds, even for large rotors – *a third key enabler for very high power density generators.***
- **Potentially can exploit CEM composite arbor technology developed under NASA funding, Army pulse power funding, and Federal Railroad Administration funding.**
- ***Represents significant advancement in state-of-the-art that can benefit other Navy applications.***

Current Projects – Homopolar Generator (Bridge Steel Welding)

- D.O.T. Phase II SBIR (KAI Inc. prime)
- Power supply for homopolar pulsed welding of steel bridge beams
- Full scale system designed to weld 90 sq-in (3” x 30” girders)
- Subscale “demo” system will validate HPG design and provide weld samples
- “Reduced manufacturing cost” design has spurred new interest in commercial HPG pulsed power applications
- Subscale HPG manufacturing nearing completion
- Assembly and Testing – summer 2016



Subscale demo HPG
- 23” x 39” x 48”
- 1.2 MA peak current
- Up to 12 sq-in welds

Current Projects – Missile Defense Agency (Airborne power supply)

- M.D.A. SBIR (Mohawk prime)
- Solicitation requirements
  - Power supply for high energy laser
  - High altitude, airborne platform
  - Include power generation, storage, power conditioning
  - Compact lightweight design
  - Megawatts of power for 10's of seconds
  - < 1 min between discharges
  - Scalable
  - Prime power – 5 to 10 KVA, 3 phase, 115-200 VAC line-neutral
  - NON – BATTERY concepts preferred
- MDA design traceable to previously demonstrated CEM high speed flywheels
- Hardware manufacturing underway

- World record tip speed rotor
- Tested Sept. 2003
- 16.7 inch dia. rim
- Peak speed 60,070 rpm
- Tip speed – 1337 m/sec

Looking to the Future

- Pulsed Alternators
  - Pursue unique pulsed load applications (lasers, railgun, etc..)
  - Advance and promote multi-mode capabilities
- Compact energy storage and power generation
  - Outreach to potential industrial and D.O.D. applications
  - Continue development of performance enabling technologies
- Homopolar Generators
  - Pursue and develop other industrial applications (sintering, billet heating, etc..)
  - Continue cost reduction activities
- Airborne applications
  - Pursue other compact airborne applications
  - Investigate growing interest in all-electric aircraft
- Superconducting wind power generation
  - Continue development of large scale superconducting generation technology