DOD & DOE Operational Energy Workshop

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Dr. John Pazik
ONR, Code 331
703.696.4404
john.pazik@navy.mil

Revolutionary Research . . . Relevant Results

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SECNAV "Five Energy Targets"

The lifecycle energy cost of platforms, weapons systems, and buildings, the fully-burdened cost of fuel in powering these, and contractor energy footprint will be mandatory evaluation factors used when awarding contracts.

The Navy will demonstrate a Green strike group of nuclear vessels and ships using biofuel in local operations by 2012. By 2016, the Navy will sail a "Great Green Fleet" composed of nuclear ships, surface combatants with hybrid electric power systems using biofuel, and aircraft flying only on biofuels.

By 2015, the Department of the Navy (DoN) will reduce petroleum use in the commercial fleet of 50,000 vehicles by 50 percent by phasing in a composite fleet of flex fuel, hybrid electric, and neighborhood electric vehicles.

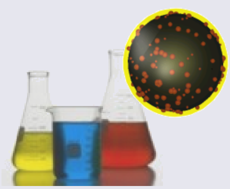
By 2020, at least half of the DoN's shore-based energy requirements will come from alternative sources.

By 2020, half of total DoN energy consumption will come from alternative sources.

Navy Energy Systems S&T

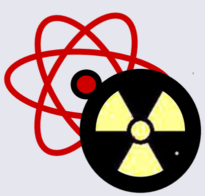
Fuel → **Power Generation** → **Energy Storage** → **Distribution & Control** ←[Thermal]→ **Power Loads[1]**

Fuel



Fuels Chemistry

Alternative Fuels

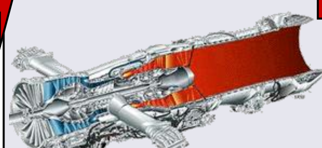


Nuclear

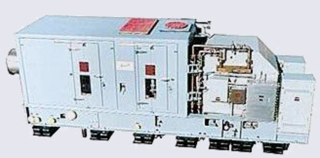
Power Generation

"Ion Tiger" UAV Fuel Cell

Fuel Cells



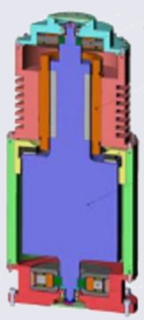
Aircraft Engines



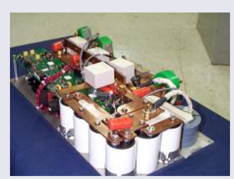
Gas Turbine Generators

Energy Storage

Batteries

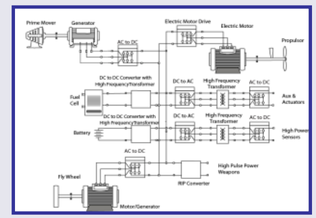


Flywheels

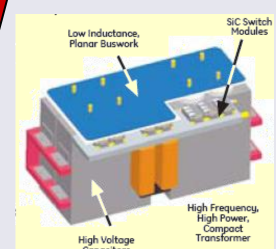


Capacitors

Distribution & Control



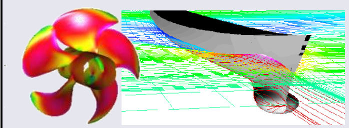
Electrical Architectures & Pulse Forming Networks



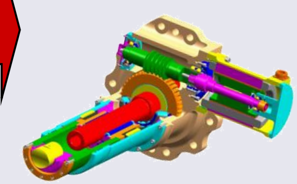
High Voltage Silicon Carbide (SiC) Switches

Power Loads[1]

Electric Weapons

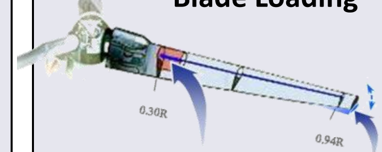


Powering & Resistance



Electric Acuators

Reconfigurable Blades / Blade Loading



[1]includes Electromechanical Conversion

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Navy Alternative Fuels S&T

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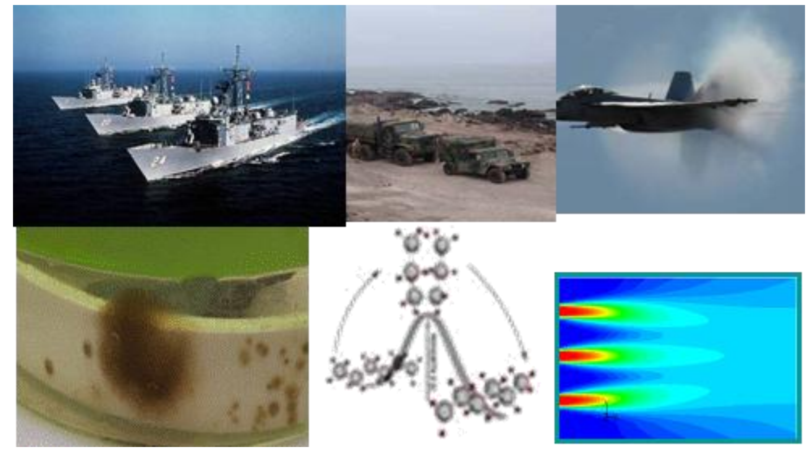
OBJECTIVES:
- Investigate/establish the science to understand any Navy-specific impacts from alternative fuels and how these impacts may be mitigated
- Explore combustion process of current Navy engines with alternative fuels
- Increase engine efficiency; reduce fuel costs, emissions
- Explore science leading to efficient, safe processes converting sea-based, Navy sources to alternative fuels

TECHNICAL CHALLENGES:
- Maintain engine performance/durability under Navy operational environments
- Synthetic fuels chemistries maintain energy density, and physical/combustion properties of Navy petro-based fuels
- Synthetic fuels and synthetic fuel blends maintain stability during storage and fuel logistics

APPROACH:
- Concentrate on Naval-specific issues – sea salt ingestion, seawater biocontamination, materials, and synthetic fuel operational effects on engines
- Leverage research from DOE, DOD and other services, academia and industry
- Explore synthesis of alternative fuels from Naval sources



TECHNICAL ACCOMPLISHMENTS:
- Alternate fuels and fuel combinations are more amenable to anaerobic decay and associated consequences. BD formulations degrade relatively rapidly, regardless of prior exposure of the inoculum to HC, BD, or even oxygen.
- Colorimetric procedure developed to quickly assay presence of BD in fuel formulations and for detecting corrosive metabolites.
- A new two-phase opposed-flow flame model developed
  - Ideal flow config facilitates modeling chem. Complexity
  - Models couple droplet dynamics with detailed kinetics
  - Model validated with published heptane experiments

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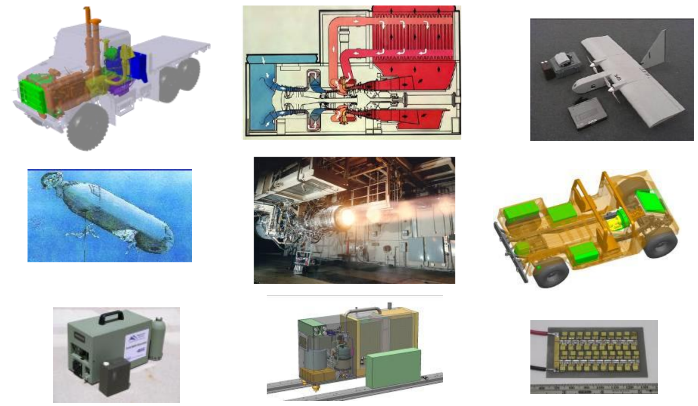
Navy Power Generation S&T



OBJECTIVES:

- Develop fuel efficient, affordable Naval air, littoral, shipboard, and subsurface power generation technologies for individuals, autonomous vehicles, aircraft, ship service, & main propulsion power
- Investigate/establish the science to understand any Navy- unique operational and environmental impacts on power generation technologies and how these impacts may be mitigated
- Increase efficiency; reduce fuel costs, emissions

TECHNICAL CHALLENGES:

- System & subsystem performance/durability under Naval operational environments
- Materials capability/durability/reliability
- Increased power density to operate in Naval platforms

APPROACH:

- Leverage research from DOE, DoD (VAATE, etc), academia, and industry.
- Explore & develop S&T with focus on Naval-unique issues
- Validate performance and durability for power dense & efficient power generation technology through system/subsystem demonstrations

TECHNICAL ACCOMPLISHMENTS:

- Demonstrated fuel cell equipped Ion Tiger UAV for high endurance missions
- Demonstrated & transitioned series electric drive 100kW MTVR OBVP with equivalent power quality to TQG.
- Completed turbine section hardware development for F135-based performance demonstrator engine (testing begins in 2011); completed planning and initiated contractual efforts for F135-based durability demonstrator engine (testing begins in 2014)
- Demonstrated 50% efficient 600kW Ship Service Fuel Cell operating on Navy logistics fuel

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Navy Energy Storage

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OBJECTIVES:

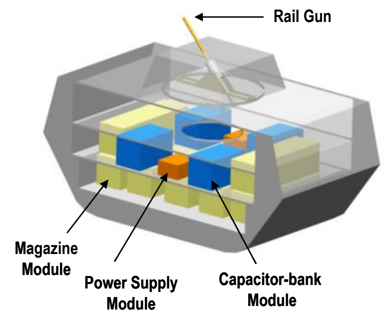
- Capacitors: storage capability of >30 J/cc at the materials level and 5-10 J/cc at the packaged capacitor level
- Batteries: enhanced energy and power densities in safer cell and system designs

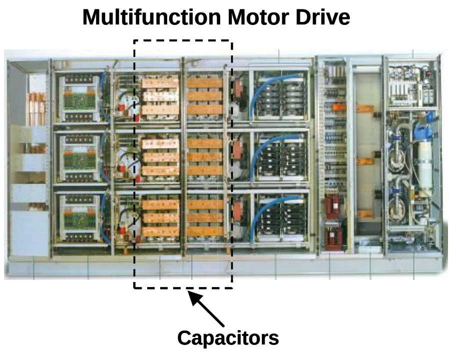
TECHNICAL CHALLENGES:

- Increasing energy storage density (breakdown threshold and permittivity) and maximizing charge/ discharge rates.
- Understanding and controlling dielectric break-down mechanisms; identifying/enabling benign failure modes.
- Scaling up promising materials, processing and packaging technologies for consistent, predictable properties.
- Reproducible fabrication approaches for 3D architectures

APPROACH:

- Fundamental understanding of dielectric charge storage and transfer at the materials level.
- Enhanced polymer-based dielectric films and processing technologies for very high pulse power rates and/or high temperature (>200˚C) capability.
- Hybrid polymer/ceramic dielectric materials, films and devices.
- Novel materials and battery architectures that significantly increase electrochemical storage and charge rates





TECHNICAL ACCOMPLISHMENTS:

- Dielectric materials-level energy densities >20 J/cc for PVDF copolymer and >30 J/cc for thin glass
- Demonstrated 3D cells with a discharge energy density of 50 Wh/kg and a charge-discharge efficiency of 75%.

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Navy
Power Distribution and Control

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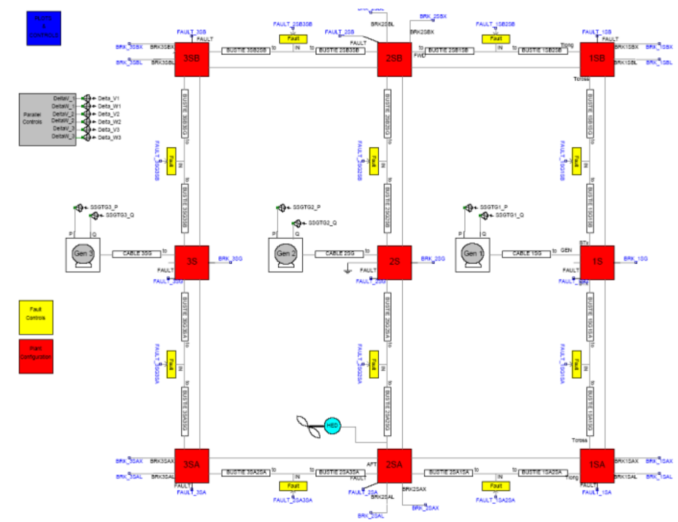
OBJECTIVES:

- Develop Next-Generation electrical architectures & associated control & protection systems that support future mission loads and increase overall efficiency.
- Develop high density power conversion equipment.
- Develop real-time & non-real-time modeling & simulation (M&S) techniques, including hardware-in-the-loop.
- Undergraduate curriculum for Power Systems, Drives, and Power Electronics



TECHNICAL CHALLENGES:

- Achieving/Managing bi-directional power control, at power densities suitable for platform implementation
- Maintaining electrical system stability while slewing power at rates needed to support mission loads
- Affordably bridging power requirements delta between commercial and navy

TECHNICAL ACCOMPLISHMENTS:

- System Models Developed for notional Hybrid Electric Drive and MVDC architectures
- Compact Power Conversion EC Phase 1 product development initiated (TRL 6 demos planned for FY12)

APPROACH:

- Develop physics-based component models & M&S design & evaluation techniques
- Understand thermal control physics & chemistry
- Identify & investigate new materials & techniques
- Employ SiC-based switching elements
- Develop alternative converter topologies

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Navy
Thermal Transport and Control

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<u>OBJECTIVES</u>:

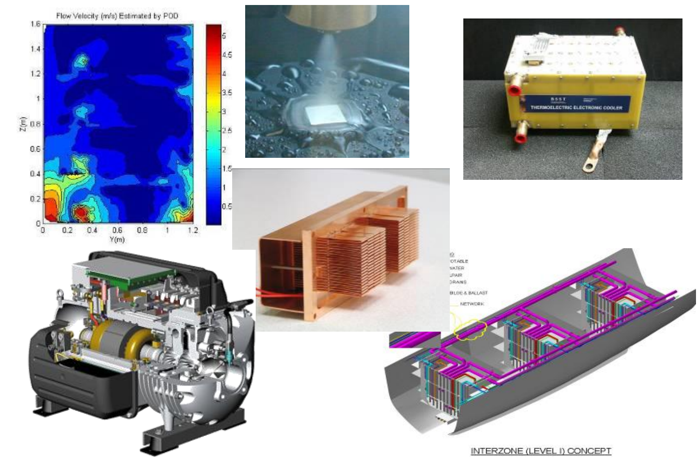
- **Advance thermal science and technology in order to efficiently acquire, transport, and reject heat and enable higher power density electronic systems.**

<u>TECHNICAL CHALLENGES</u>:

- **Limited understanding of evaporative heat transfer.**
- **Two-phase systems often limited by hydrodynamic instabilities and critical heat flux.**
- **Limited materials and fluids available.**
- **Efficient and environmentally friendly cooling techniques are required to minimize additional HVAC systems.**

<u>APPROACH</u>:

- **Fundamental studies and physics-based models of evaporative cooling, including heat transfer and CHF.**
- **Understanding and control of two phase flow in complex geometries, including pressure drops and flow instabilities.**
- **Enhancement of heat transfer through interfacial engineering.**
- **Multi-scale, thermal models of electronic systems and ship-level thermal simulations.**



<u>TECHNICAL ACCOMPLISHMENTS</u>:

- **4Q/07: Demonstrated use of microchannel heat sink as an evaporator in a compact refrigeration system cooling capable of dissipating high fluxes (~1000 W/cm2) with device temperatures below 125 °C. 3Q/08: Developed 21st Century HVAC system architecture for naval combatants.**
- **2Q/09: Developed solid-state, high heat rejection computing chassis.**
- **3Q/09:Developed enhanced evaporator for CVN-72 AC plant modernization effort.**

Navy Electromechanical Conversion

OBJECTIVES:

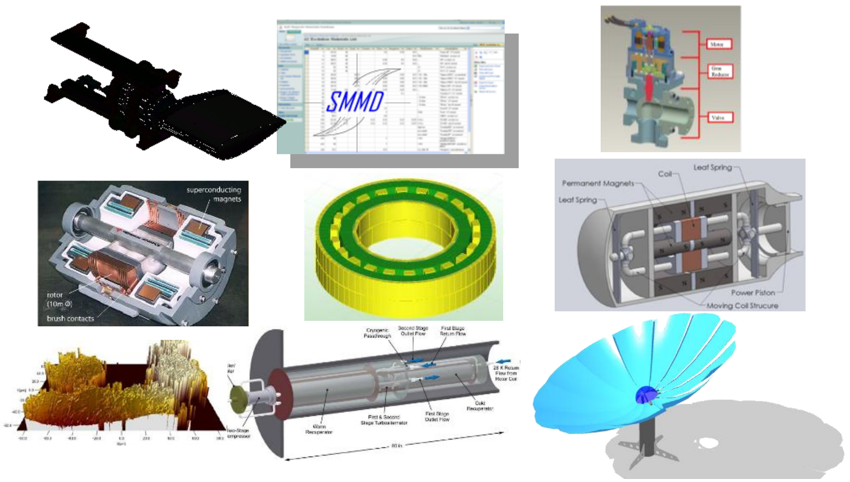
- Rare earth-free magnetics
- Developing tactical renewable technologies
- < 10-11 m/m wear for sliding electrical contacts

TECHNICAL CHALLENGES:

- Efficient waste heat recovery
- Materials having desired properties (magnetic strength, temperature compatibility,
- Defect-free materials

APPROACH:

- Studying novel concepts in energy conversion – fundamental research
- Experimental, computational, analytical investigations



TECHNICAL ACCOMPLISHMENTS:

- 4Q/09: Established link between fatigue life and wear for sliding electrical contacts. Good wear results achieved for Be-Cu brushes
- 2Q/09: Established web-based, soft magnetic materials database

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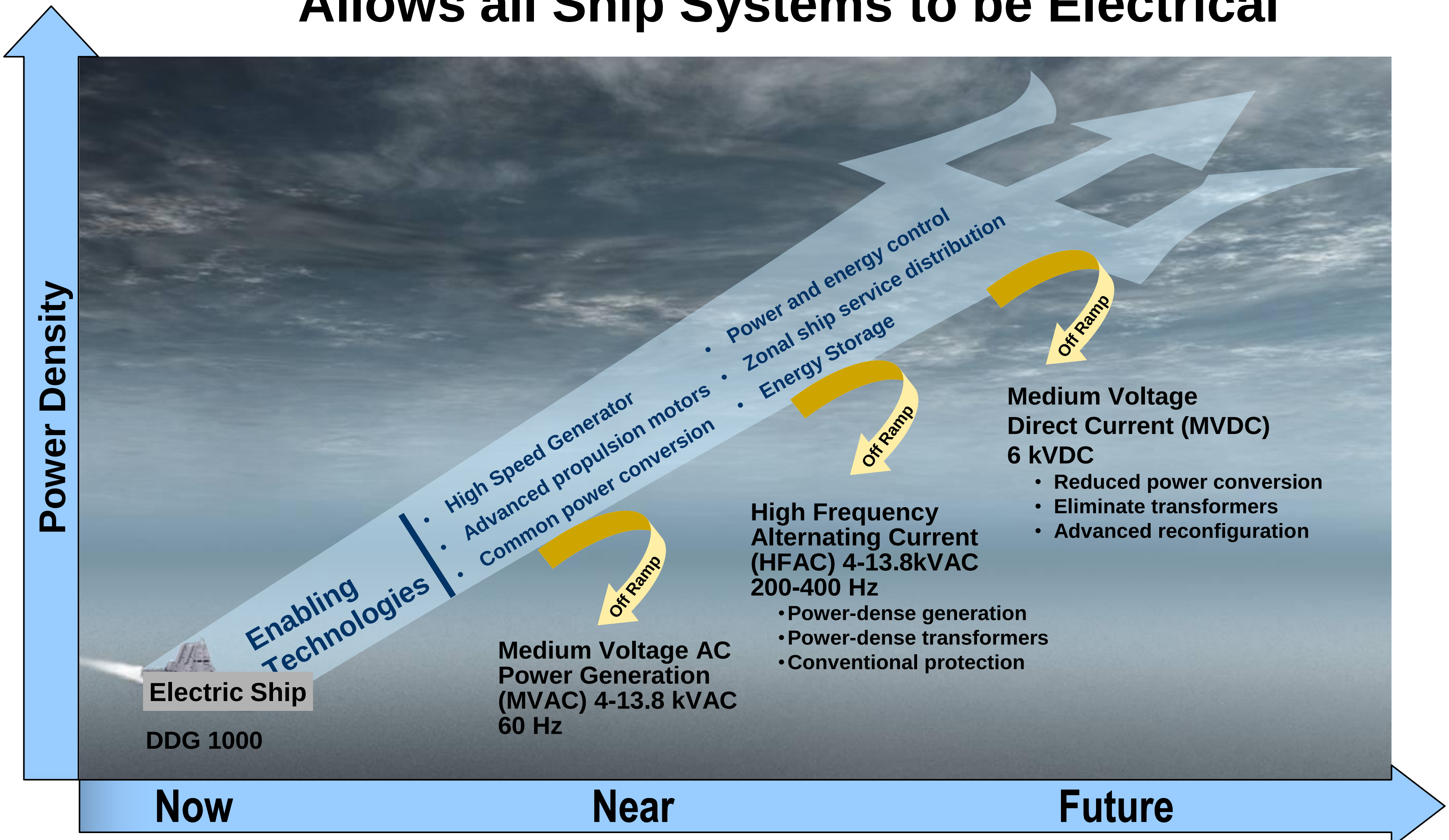
Next Generation Integrated Power Systems

Allows all Ship Systems to be Electrical



"Directing the Future of Ship's Power"

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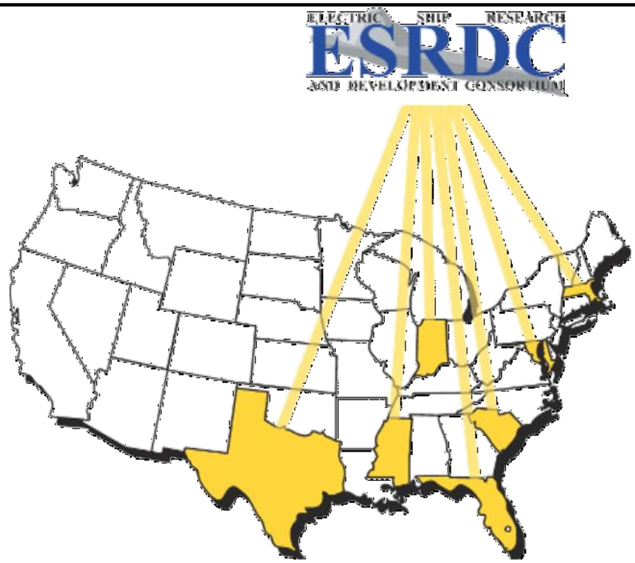
Electric Ship Research and Development Consortium



Florida State University
Massachusetts Institute of Technology
Mississippi State University
Purdue University
University of South Carolina
University of Texas at Austin
U.S. Naval Academy

- **ESRDC completed development of a first in the world 5MW Power-In-the-Loop addition to the CAPS facility.**
- **The system has a programmable 5MW interface which can emulate any electrical system.**
- **For example, a real 5MW motor can be operated as if it was installed in a real ship system. The motor experiences the real current, voltage, and frequency as if it were connected and operating in the real system.**
- **The motor can also be mechanically loaded with real hydrodynamic propulsion codes. The real motor operates as if it were installed in a real ship propelling the ship through an ocean with various sea states.**
- **The load management research focused on power system stability under various load conditions, efforts will continue to establish guidelines for assessing the influence of synchronization in possible AC power grids on ships.**

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E&P CoI Five Challenges

1. Tactical Energy Independence

2. Autonomous Platform Power

3. Grid Power Distribution & Control

4. Platform Efficiency & Environmental Impact

5. Electric Weapons & High Power Sensors

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Interagency Advanced Power Group

"The Interagency Advanced Power Group (IAPG) is a Federal membership organization that fosters the exchange of information to avoid duplication of effort and the advancement of technology among researchers and developers in Advanced Power fields, <u>with the objective of increasing the effectiveness of the total interagency Power program</u>.

- ***<u>Power</u>*** **= encompassing energy sources, conversion techniques and devices, thermal management of such power conversion, and transmission systems or components.**

Army **Air Force** **Navy** **DOE** **NASA**

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CoI Motivation & Purpose

- DoD S&T *Communities of Interest* are groups of scientists, engineers, technology executives, Acquisition staff, and operators with common technology interests

They are intended to

- Foster technical discussion, discovery, debate, coordination, planning, and assessments by subject matter experts
- Provide a forum for sharing new ideas, technical directions and technology opportunities, jointly planning programs, influencing DSTAG budget plans, measuring technical progress, and reporting on technology state of health
- Serve as visible and enduring structures to integrate technology efforts throughout the large, widely dispersed, sometimes fragmented DoD S&T enterprise
- Facilitate rapid, technically accurate, broadly-vetted responses to queries from DoD leadership and Congress
- Provide DoD S&T corporate understanding and memory, and a place for new staff to get up to speed quickly
- Timely identify critical areas and opportunities

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