



# **2016 Advisory Panel Electric Ship Technologies**

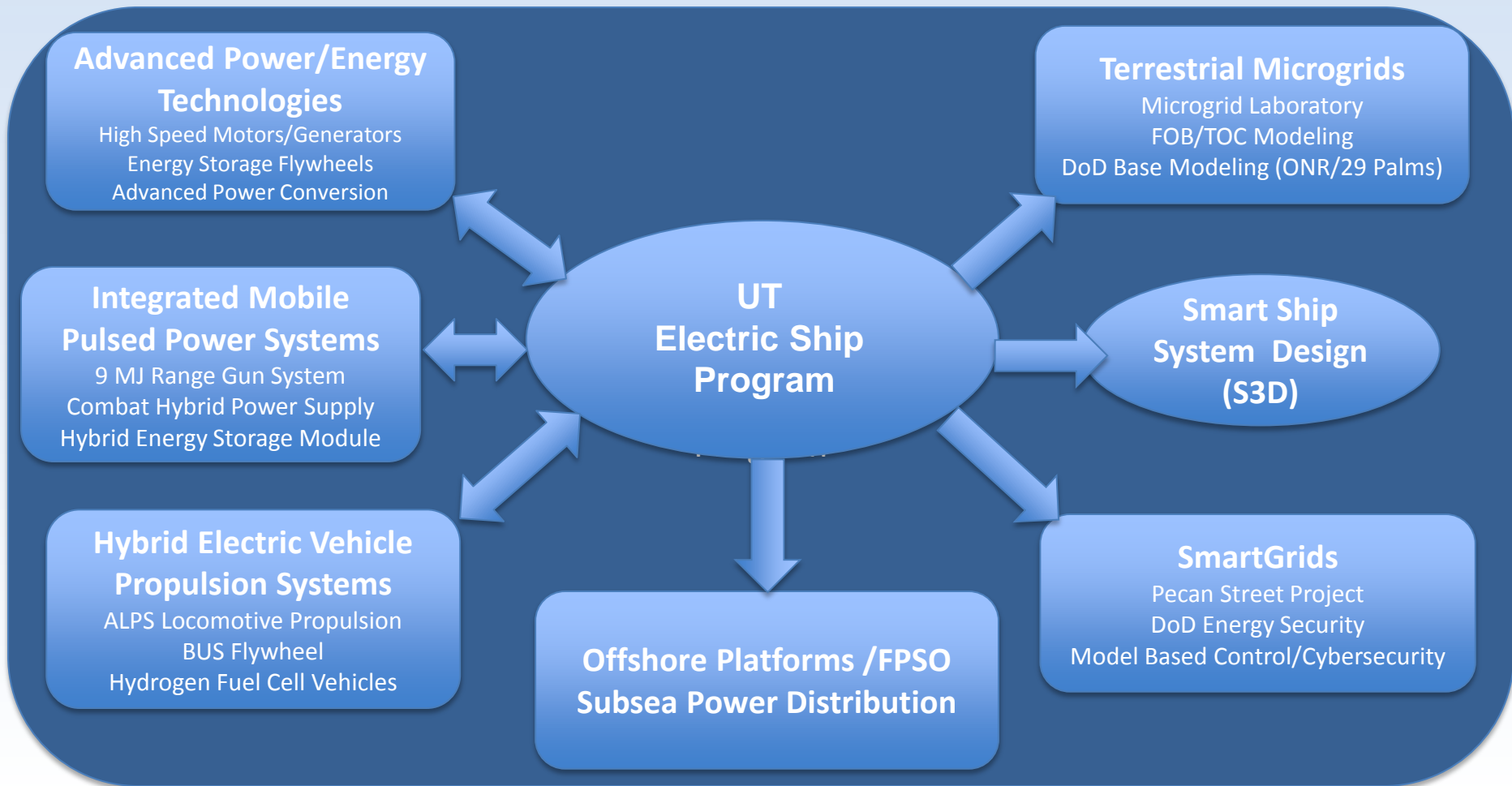
**John Herbst**

**Center for Electromechanics  
The University of Texas at Austin  
5/10/2016**

# Research Significance

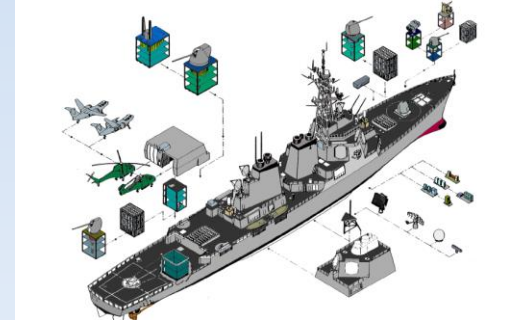
- **Commercial – efficiency driven**
  - **80-90% of world trade goods travel by sea**
  - **Cargo ships represent major source of GHG emissions**
    - Lower quality bunker fuel w/ substantial Sulphur content
- **Naval – capability driven**
  - **Reliability, Resilience, Efficiency**
  - **Ability to rapidly transfer power from propulsion to emerging high power electric weapons/sensors**
    - EM Railguns, AMDR, FEL, Solid State Laser, Active Denial

# Technology Relationships



# CEM Electric Ship Research Overview

- **Abisso Program**
- **ONR Megawatt Power Module**
- **ONR Hybrid Energy Storage Module**
- **Electromagnetic Aircraft Launch System (EMALS)**
- **Laser Integration Study with Naval Postgraduate School (NPS)**
- **Electric Ship Research and Development Consortium (ESRDC)**
  - **Power System Architecture Modeling**
  - **T-Craft Innovative Naval Prototype**
  - **Swampworks IPS Architectures & Demonstrations**
  - **Combat Power and Energy Systems – Design Tools and Methods (CPES-DTM)**
  - **10 kTon Ship Design using Smart Ship Systems Design (S3D)**
  - **EMRG Microgrid Integration**



# ABISSO Program

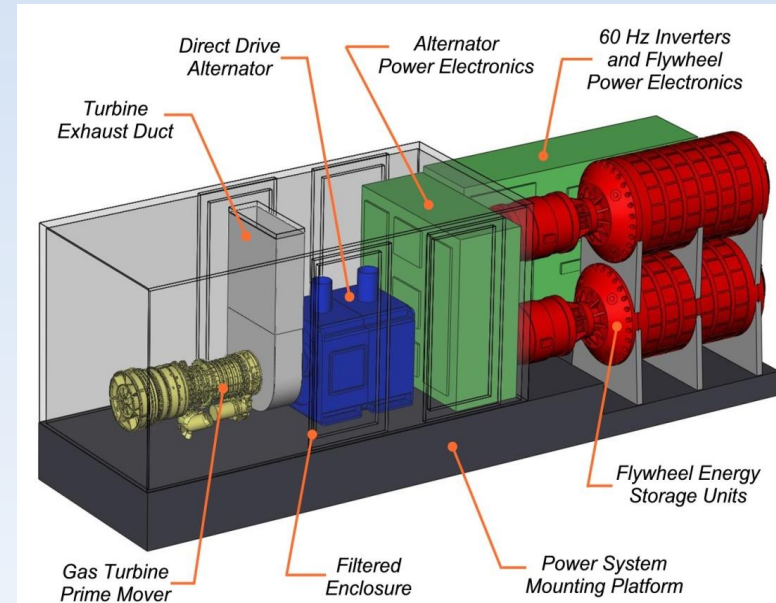
- Explore “green-ship” technologies for The Abisso
  - Privately funded research vessel
- Research Topics
  - Electric load distribution
  - High efficiency lighting
  - Hull air cavity and coatings
  - Wind power
  - Roll stability
  - HTS machines for propulsion
  - High efficiency HVAC plants
  - Diesel generator set optimization
  - Biodiesel for marine diesel engines
  - Large scale energy storage with sodium/sulphur batteries





# Megawatt Power Module Program

- Explore the use of high speed generation and flywheel energy storage to improve the efficiency of the DDG 51 ship service electric power system
- UT-CEM partnered with Rolls-Royce North American Technologies, Inc.
  - **Rolls-Royce**
    - Gas turbine performance models
    - DDG 51 integration plan
    - Technology development program plan
  - **UT-CEM**
    - System modeling and simulation
    - Energy storage flywheel design/analysis
    - Motor/generator design/analysis
    - Technology development program plan

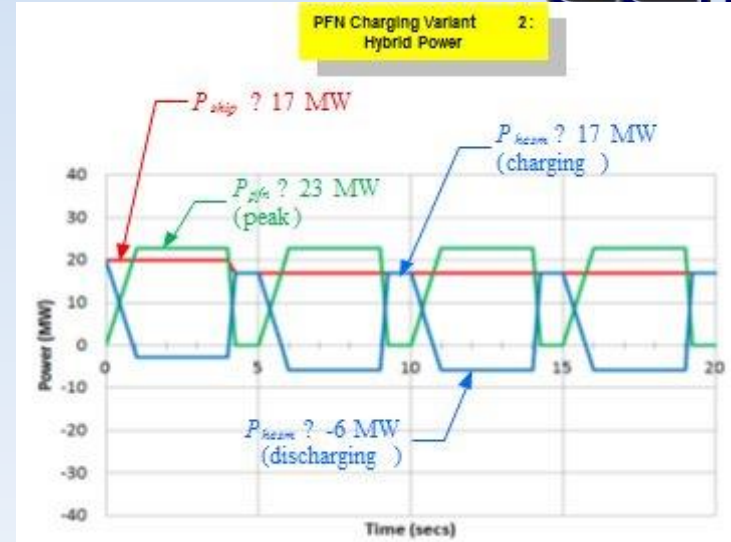


DDG 51 Fuel Saving Projections	
Case Description	Projected Fuel Savings*
AG9140 Genset	25.0%
Single Shaft Turbine + HSG	27.5%
Twin Shaft Turbine + HSG	34.8%

\* Relative to baseline operation including 10 minute UPS.

# ONR Hybrid Energy Storage Module

- High power energy storage to buffer repetitive charging of Pulse Forming Network (PFN)
  - Hybrid constant current/constant power charging profile
- Combat Hybrid Power Supply for Navy applications
  - Leverages prior research program for Marines
  - High energy/power density rotating machine
    - 8.5 MW peak power and 4 MW continuous power
  - Risk mitigation experiments underway



# EMALS Program Objectives

**Deploy an advanced technology launch system which provides:**



- *Better Control of Applied Forces*
- *Improved Reliability and Maintainability*
- *Reduced Manning Workload*
- *Increased Operational Availability*



# EMALS Program

- Energy Storage System (ESS) Prototype Design
- Prototype Fabrication & Test
- System Modeling & Simulation
- Technology Transfer to ESS Manufacturer



Prototype Shipboard ESS



Kato COTS Generator

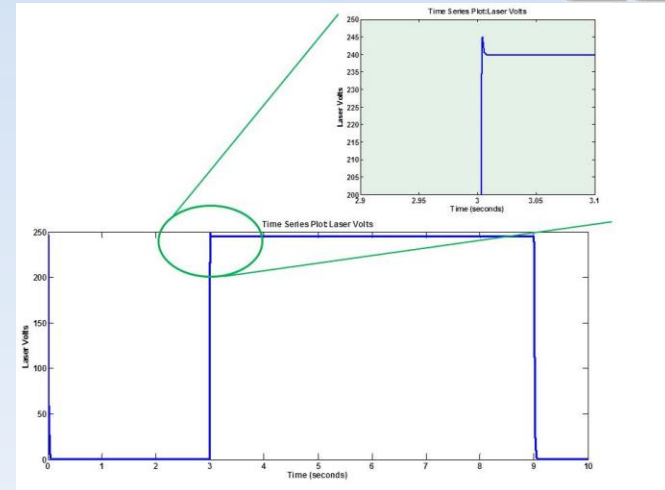
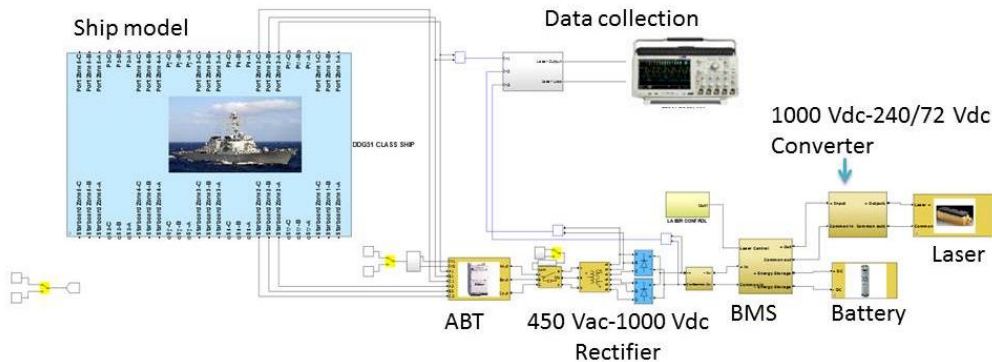
# NPS-UT Laser Integration Study



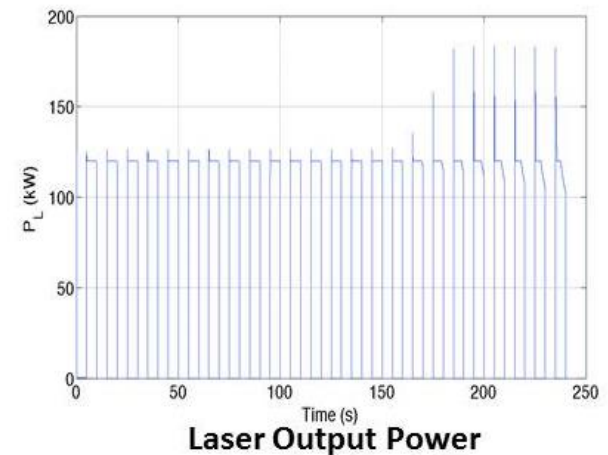
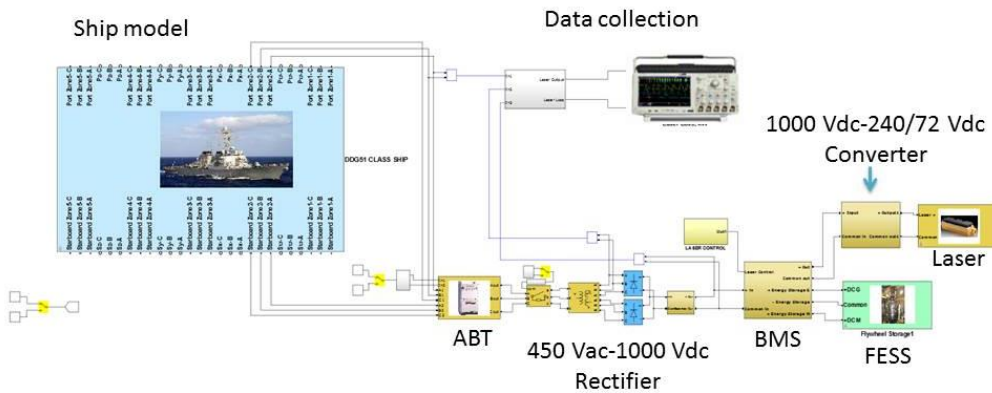
- **Dynamic thermal/electrical modeling of notional first generation Solid State Lasers (SSL) with a variety of power system topologies**
- **Developed modular low fidelity electrical models of SSL weapon systems onboard a DDG-51 Flight IIA and Freedom Class Littoral Combat Ship (LCS)**
  - **30kW SSL (LaWS) + notional 60kW and 125kW SSLs**
  - **Diesel and gas turbine generators**
  - **Lead acid and lithium ion batteries**
  - **Capacitors**
  - **Flywheels**

# Simulation Models

## Destroyer with Laser Load and Lithium-Ion Battery Storage



## Destroyer with Laser Load and Flywheel Energy Storage System (FESS)



# **ELECTRIC SHIP RESEARCH AND DEVELOPMENT CONSORTIUM**

40 YEARS OF INNOVATION FOR TEXAS AND THE NATION

# Founding Member of the ESRDC

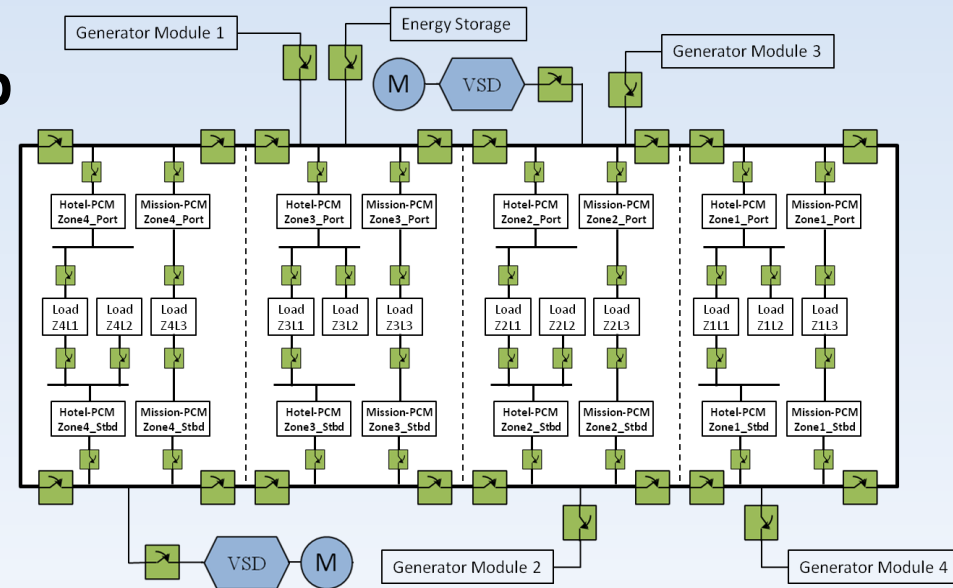


- **UT is a founding member of the ONR-sponsored Electric Ship Research and Development Consortium, eight universities focused on electric ship technologies**
  - **UT, FSU, MIT, USC, MSU, Purdue, NPS, Naval Academy**
  - **Thirteen year program**
    - 5-year continuation proposal in process
- **UT ESRDC Activities**
  - **Electric Ship Architecture Modeling (MVAC, HFAC, MVDC)**
  - **T-Craft Technical and Source-selection support**
  - **Combat Power and Energy Systems – Design Tools and Methods**
  - **NPS Laser Integration Studies**
  - **10kTon Ship Design Program**
  - **Swampworks Architectures & Demonstrations**
  - **EMRG Microgrid Integration**



# Ship Architecture Modeling

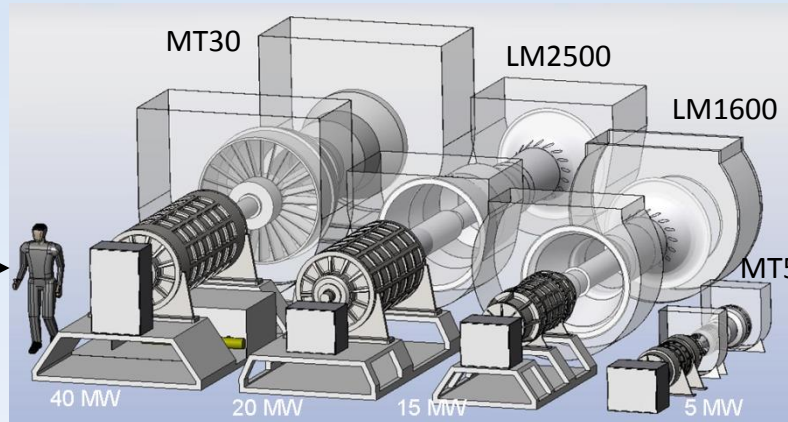
- High fidelity and average-value time-domain simulations of ship power system architectures
  - **MVAC, HFAC, MVDC**
- Developed enhanced capability to model ship power systems
  - CEMSolver
  - Hardware in the loop testing
- Protection modeling in DC ships
  - Series faults



# Fuel Consumption Analysis

24 Hour-mission  
(DDG-51)

40 + 20 + 15 + 5 = 80 MW Genset

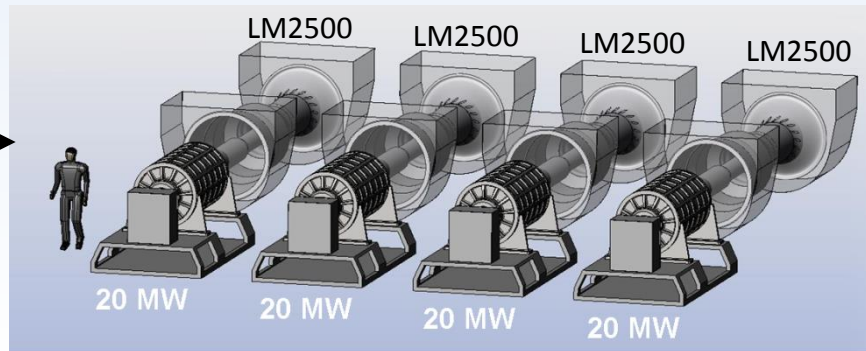


Fuel Consumption

→ 101 m<sup>3</sup>

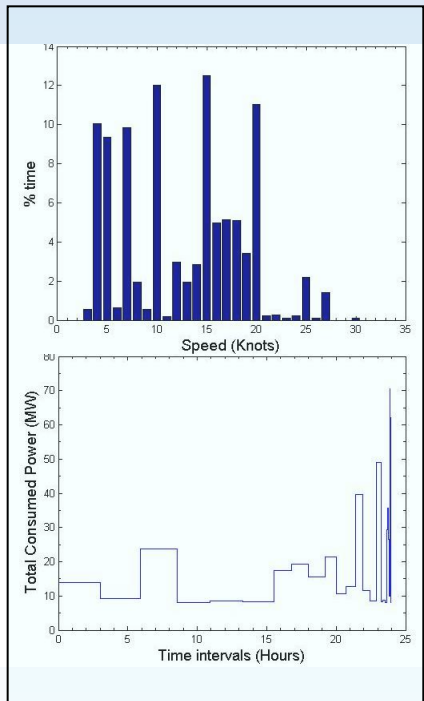
Combination (MW)				Fuel Volume (m <sup>3</sup> )
5	15	20	40	101
20	20	20	20	112
4	4	36	36	117

20 + 20 + 20 + 20 = 80 MW Genset



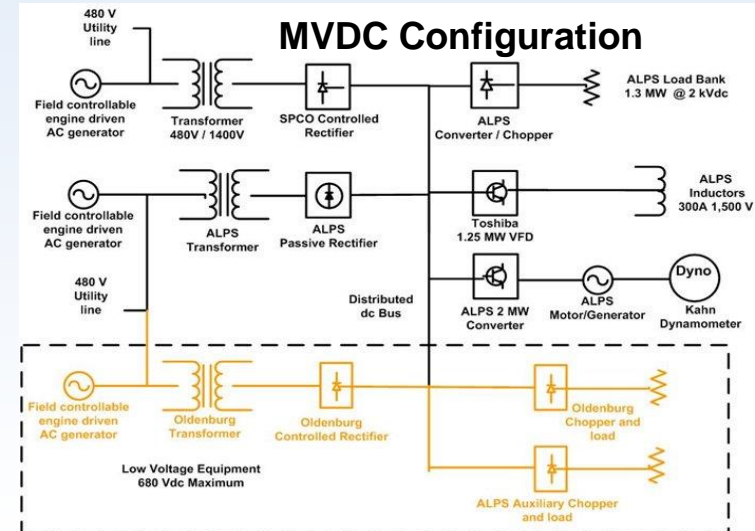
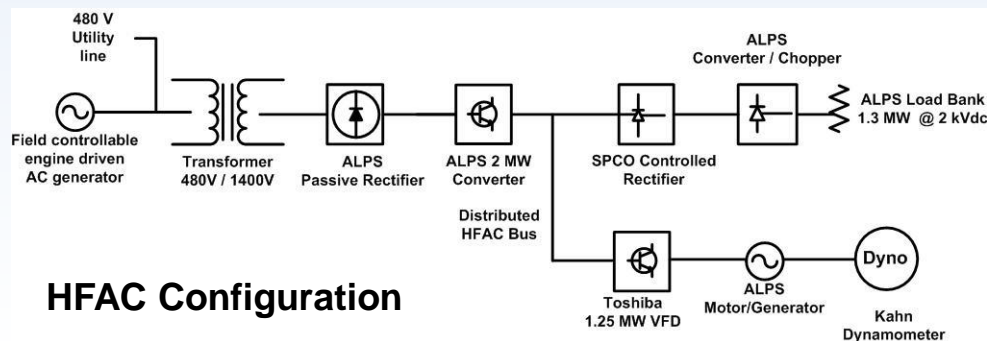
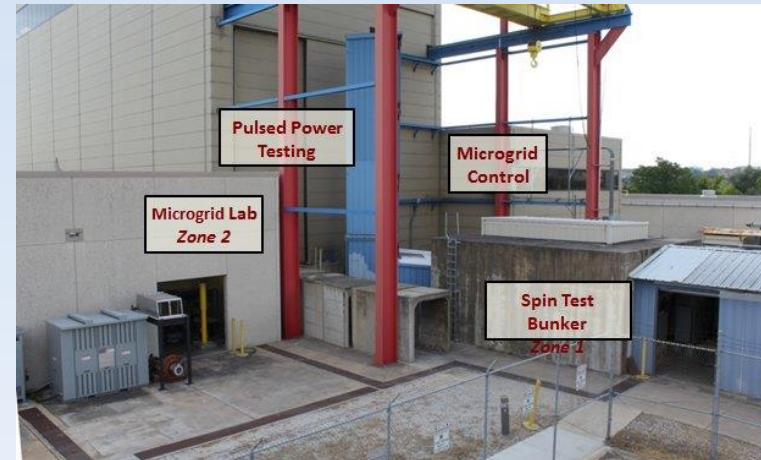
Fuel Consumption

→ 112 m<sup>3</sup>

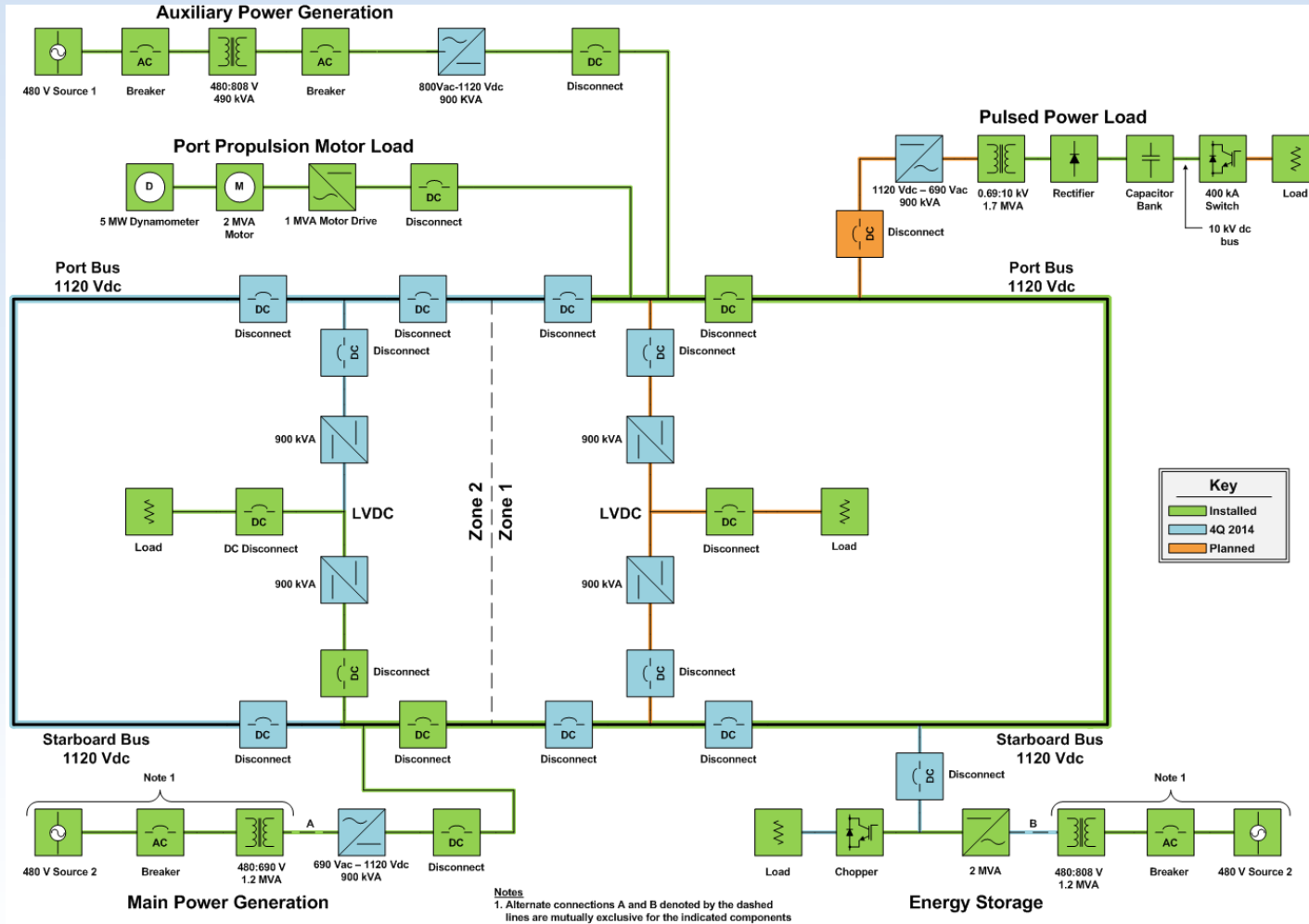


# UT Microgrid Laboratory

- Flexible, MW-scale microgrid
  - Configured for MVDC bus; HFAC architectures also possible
- Multiple functionalities:
  - Component & subsystem testing
  - System level interactions
  - Controls development



# Swampworks Demonstrations



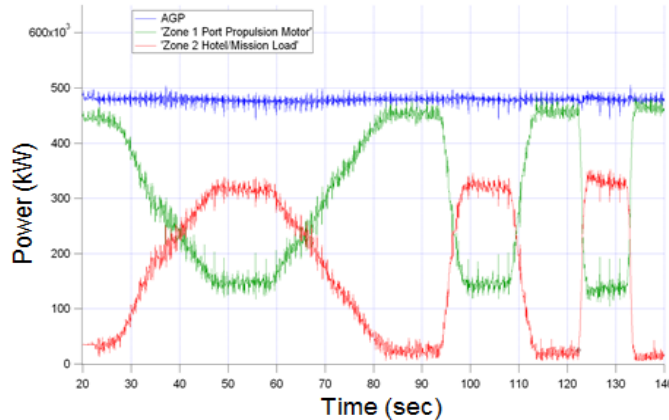
(Emulation)



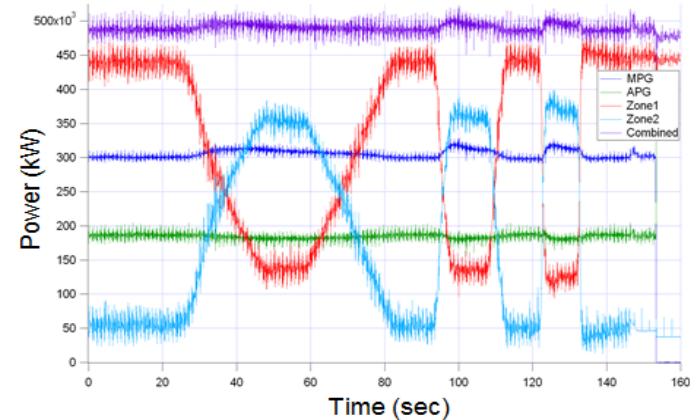
# Swampworks Experiments



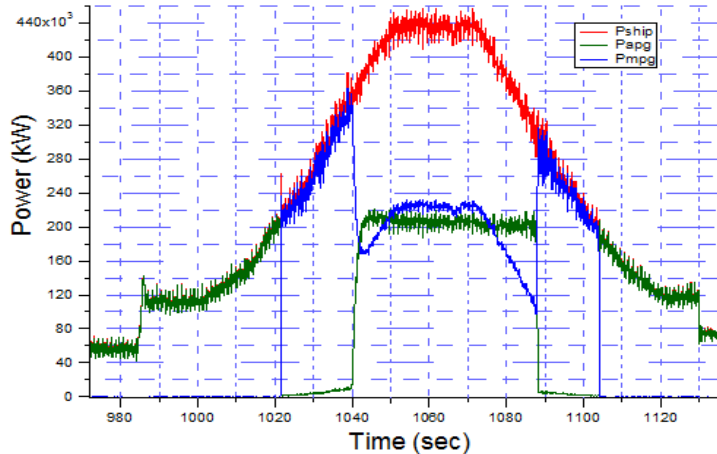
### Load Transfer - Single Source



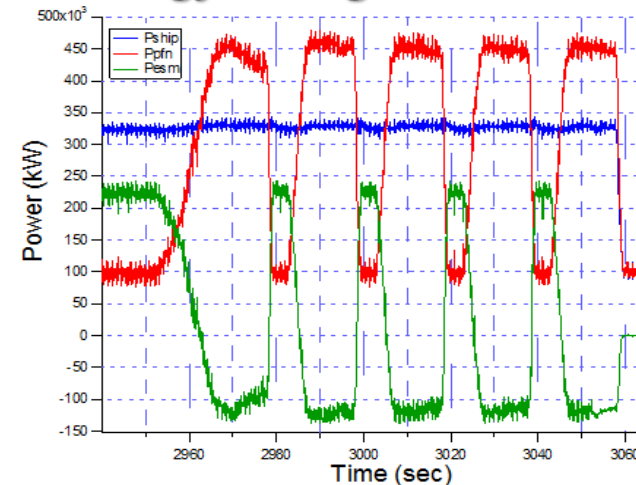
### Load Transfer - Two Sources



### Source Transfer - Variable Load

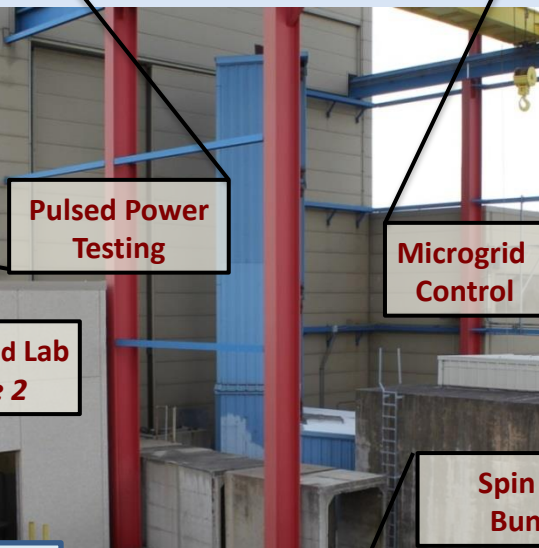
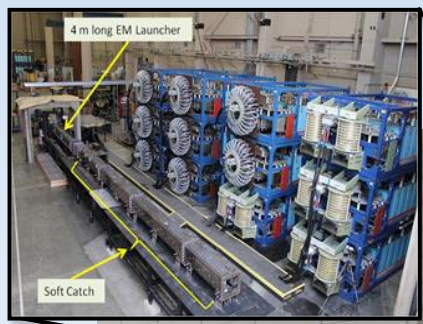


### Energy Storage Emulation



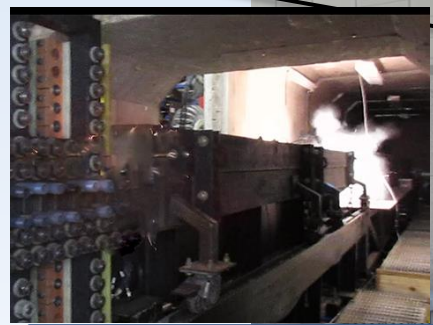


# Microgrid – EM Launcher Integration

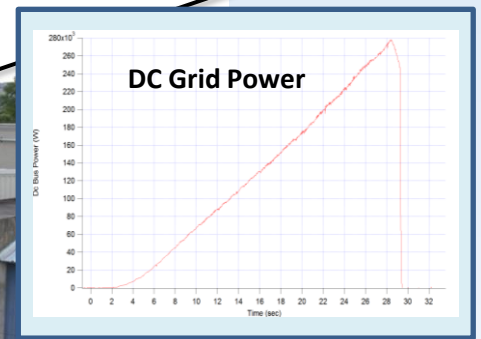


**Pulsed Power Testing**

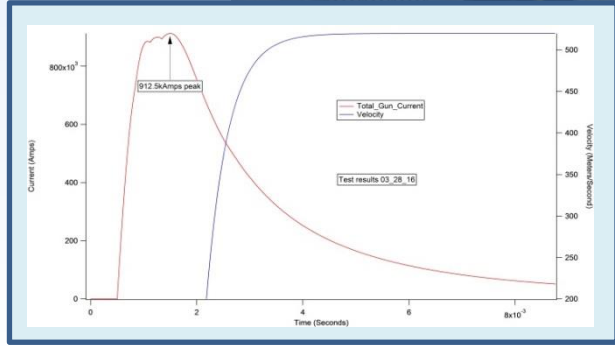
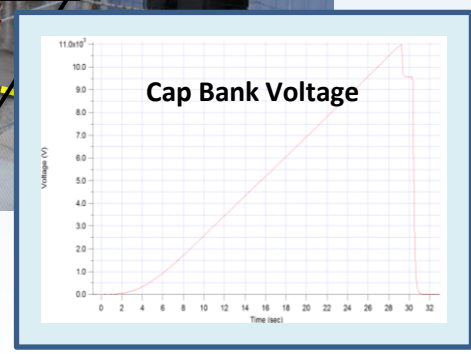
**Microgrid Control**



**Spin Test Bunker Zone 1**



**2 MW, 12 krpm Motor Generator**



# Future Opportunities



- **The near future will likely focus on**
  - **Technology transfer**
  - **Technology for size reduction**
    - **Likely combining emerging thermal and electrical opportunities augmented by nanotechnology**
  - **Enhanced design capabilities**

**for the next generation surface combatant**
- **Longer term opportunities**
  - **Powering autonomous underwater vehicles**
  - **Power and energy logistics for Pacific engagements**

# Summary



- **UT has a strong Electric Ship Technology program building on 40+ years of research expertise**
  - **13+ years of focused ESRDC research**
  - **New 5 year grant proposal in progress**
- **UT has demonstrated experience with high power density components and systems**
  - **EMALS energy storage generators**
  - **High speed motors/generators**
  - **Pulsed alternators**
- **UT has unique capabilities in this domain**
  - **MW-scale microgrid configured for dc distribution**
  - **EM Railgun and soft-catch system**
  - **Demonstrated experience with high power density components and systems**

# Questions?

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