Electric Ships Office
PMS 320
Directing the Future of Ships Power

Surface Navy Electrical Leap Forward
Sea-Air-Space Exposition
03 April 2017

Mr. Stephen P. Markle, PE
Director & Program Manager

NAVSEA Naval Sea Systems Command
Office of Naval Research
PEO SHIPS
PEO IWS
SEA 21

NEXT SURFACE COMBATANT EVOLVED CAPABILITY

"In FY2030, the DON plans to start building an affordable follow-on, multi-mission, mid-sized future surface combatant to replace the Flight IIA DDG 51s that will begin reaching their ESLs [Estimated Service Life] in FY2040."

Report to Congress on the Annual Long-Range Plan for Construction of Naval Vessels for FY2015

Update:

"…next Large Surface Combatant will begin in FY2030."

Report to Congress on the Annual Long-Range Plan for Construction of Naval Vessels for FY2017

Big Differences:

- High Energy Weapons and Sensors
- Flexibility for affordable capability updates

Photo by CAPT Robert Lang, USN (Ret), from site
http://www.public.navy.mil/surfor/swmag/Pages/2014-SNA-Photo-Contest-Winners.aspx

CURRENT MISSION SYSTEM INTEGRATION APPROACH

Each mission load brings a unique point solution-based intermediate power system

Advanced Sensors

AMDR
Air and Missile Defense Radar

Electronic Warfare

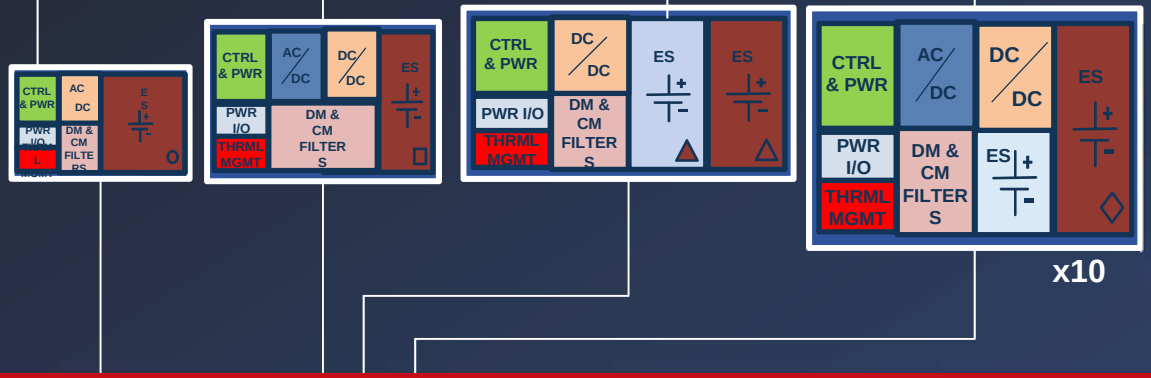
SEWIP Block III
Surface EW Improvement Program

Directed Energy

SSL-TM
Solid State Laser Technology Maturation

Future Weapons

TBD



INTERMEDIATE POWER SYSTEMS:
30-40% OF MISSION LOAD EQUIPMENT

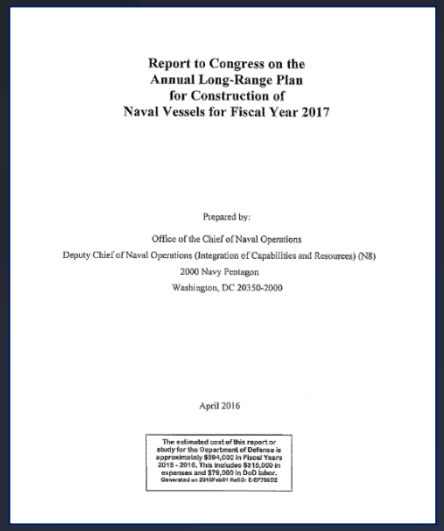
CURRENT INTERFACE: MIL-STD 1399

Federated Systems:

- High Maintenance
- Difficult Logistics
- Not Easily Integrated
- Not Common
- Cost More
- Waste Space & Weight

Today's Navy Pays a SWAP-C and Support Penalty

NAVAL POWER AND ENERGY SYSTEMS TECHNOLOGY DEVELOPMENT ROADMAP (NPES TDR)



Report to Congress on the Annual Long-Range Plan for Construction of Naval Vessels for Fiscal Year 2017

Prepared by:

Office of the Chief of Naval Operations
Deputy Chief of Naval Operations (Integration of Capabilities and Resources) (N8)
2000 Navy Pentagon
Washington, DC 20350-2000

April 2016

The estimated cost of this report or study for the Department of Defense is approximately $184,000 in Fiscal Years 2015 - 2016. This includes $115,000 in expenses and $79,000 in DoD labor.
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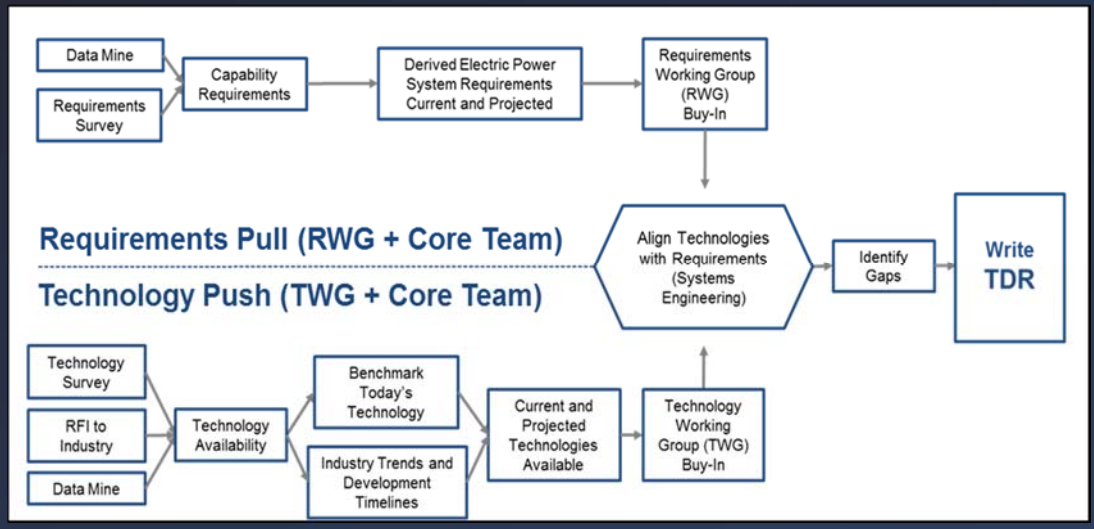


Product Areas

Controls

Distribution

Energy Storage

Generators

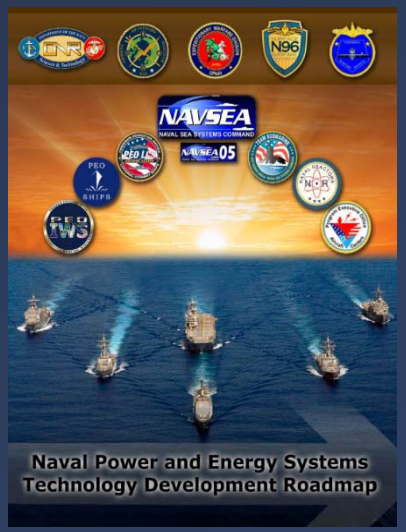
Motors

Prime Movers

Power Converters

Metrics

Efficiency
Power Density
Operating range
Cooling Requirements
Current Capacity
Cost
Operating temperature
Maintenance
Fault management
System response
System Reconfiguration



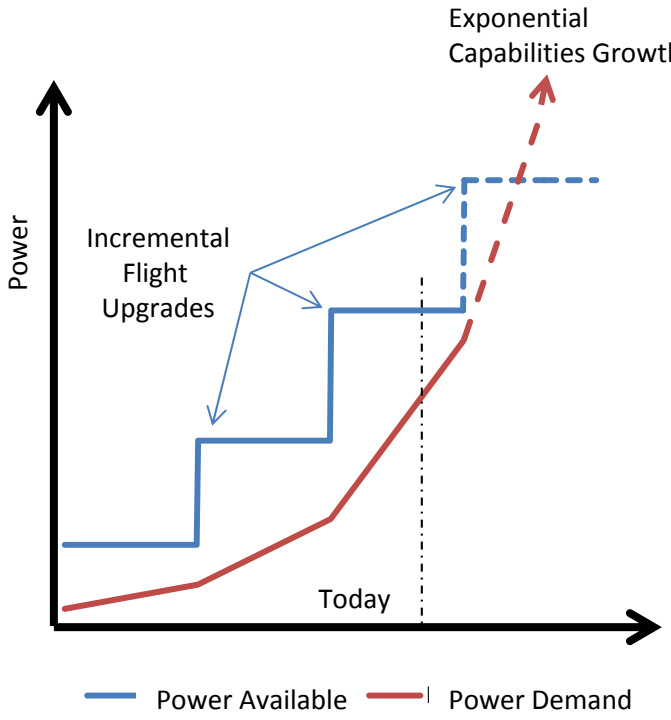
http://www.navsea.navy.mil/Resources/NPESTechDevelopmentRoadmap.aspx

Future Power Demand Increases in the Fleet

Increases in Power Requirement Aboard Ships

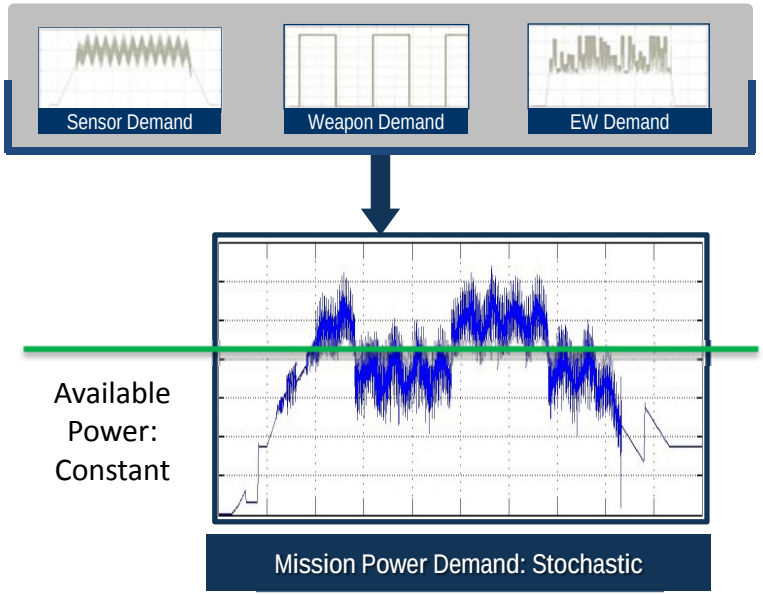
More Power

Step Change Incremental Development of Power Generation vs. Increase In Power Requirement Over Time



Different Demand

New Capabilities Demand Pulse and Stochastic Power

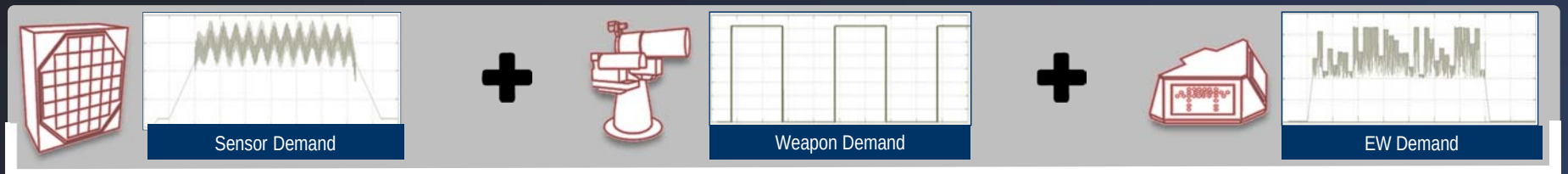


Current Available Power Aboard Ships Cannot Support Dynamic Loads

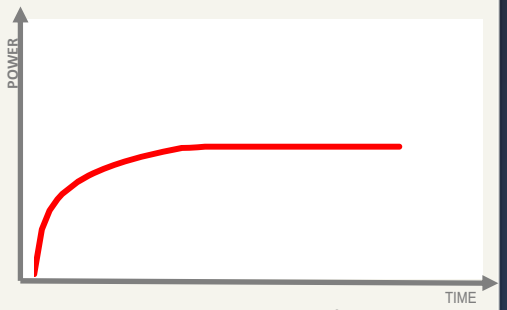
Increased Warfighting Capability to Overmatch the Threat Demands Power

Challenges of Integrating High Power Mission Systems:

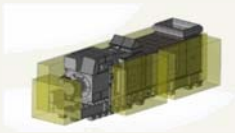
Directed Energy Systems Require Pulse Power & Increased Power



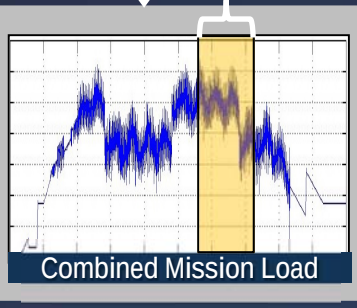
Generator Response to Load

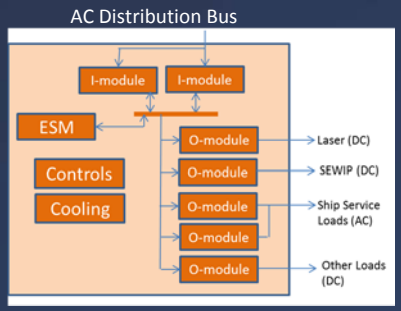


Generators operate at continuous loading for efficiency & reliability

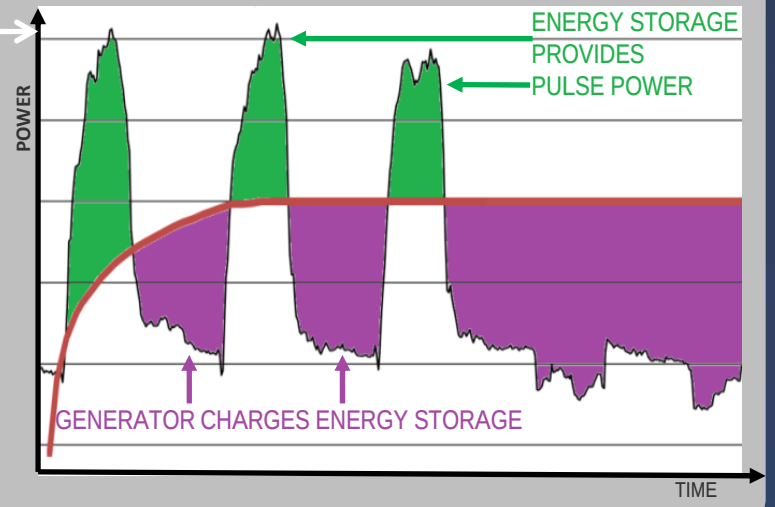


Current generators cannot respond quickly and dynamically for new demands





Energy Storage Response to Load



Energy Magazine provides pulse power and load leveling when generators cannot meet demand

Solution: Energy Magazine = Energy Storage + Controls

ENERGY MAGAZINE

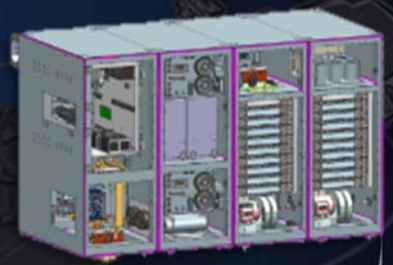
Energy Storage Module (ESM) **Proof of Concept:** Prime - RCT under ONR Swampworks Program

2011

- **Energy Storage** Media: Lead acid batteries installed in a 28' ISO container
- **Functionality:** Stored energy of 100 kW-hr (360 MJ)
- **Status:** Modifications to support ONR laser projects in process

Energy Magazine (EM) **Prototype:** Prime - DRS under PMS 320, Electric Ships Office

2018



- **Energy Storage Media:** Lithium ion batteries installed in a 78x48x100 inch military designed cabinet
- **Functionality:** Stored energy of 71 kW-hr (256 MJ), between the ship's electric plant and mission load
- **Status:**
  - Build and subassembly testing in process
  - System testing on track for 1Q//FY18

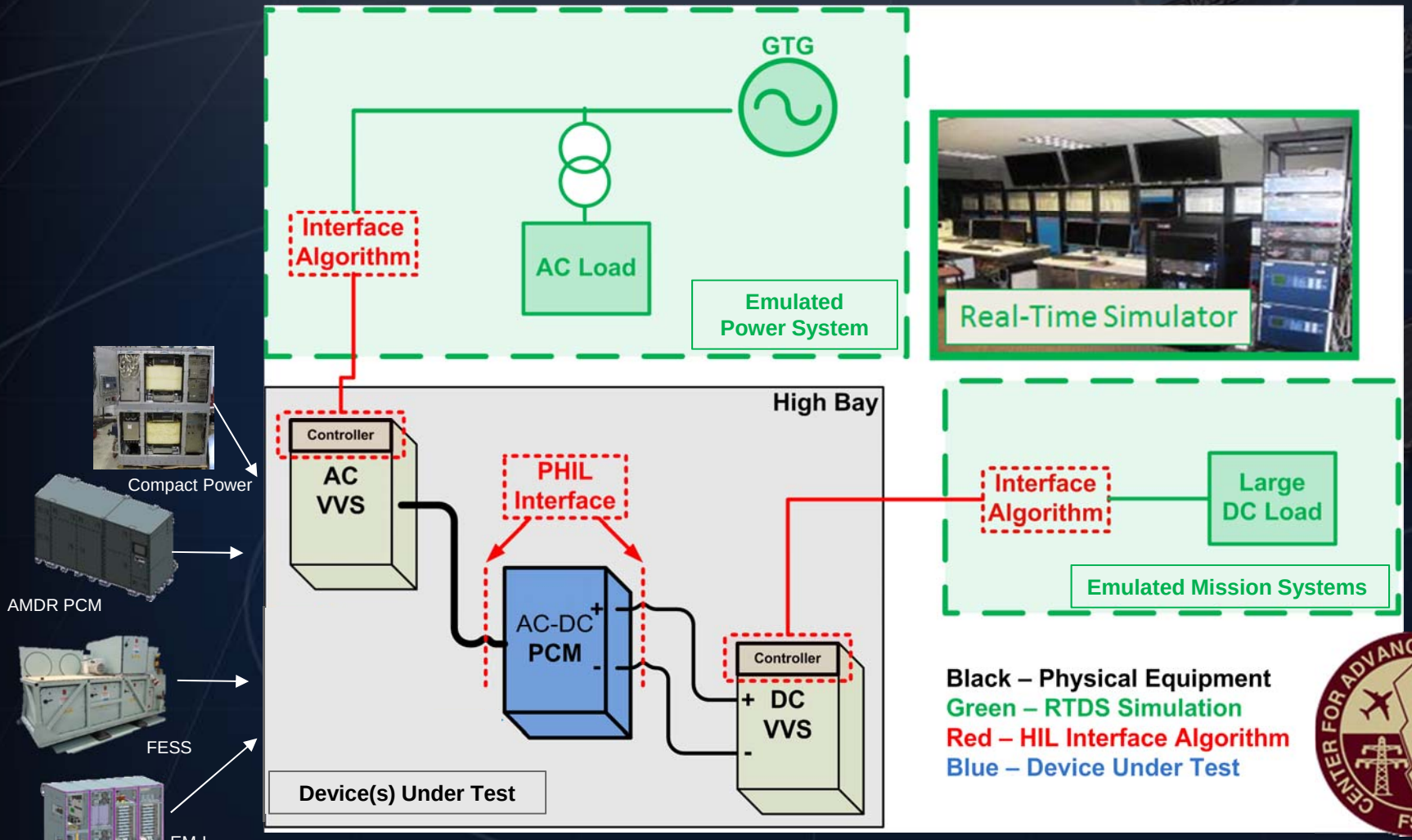
Energy Magazine Mk II: Prime - DRS under PMS 320, Electric Ships Office

2020

- **Energy Storage Media:** Lithium ion batteries installed in military designed cabinets
- **Functionality:**
  - Stored energy of 153 kW-hr (550 MJ), augments ship's electric plant by peak shaving
  - Allows energy storage media to be installed separate from power electronics
- **Status:**
  - Evolved EM Prototype Design
  - Ship Production Ready in FY2020

Power Hardware in the Loop Testing

Florida State University Center for Advanced Power Systems



Real Time Simulation: Technical and Programmatic Risk Reduction

Energy Magazine Demonstration

EM INTERFACE IPES

Electric Ships Office 320

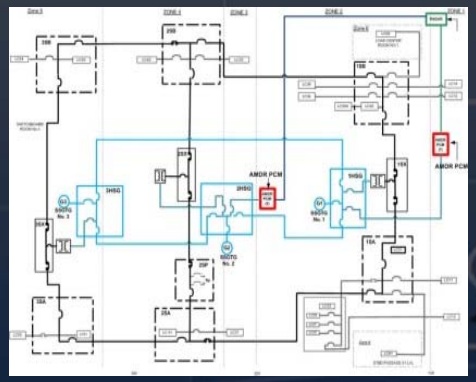
Modeling & Simulation

- *DDG 51 Flt IIA & III VV&A'd Electrical System*
- *Detailed Mission System*

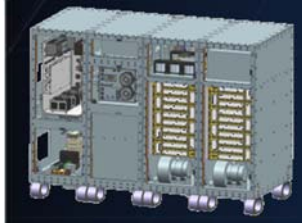

SEWIP


SSL


AMDR



+ Energy Storage Models & Hardware


EM-L (DRS)


FESS (GKN/UK)

Real Time Dynamic Simulation
FSU CAPS

Knowledge

Control Hardware in the loop (CHIL)
Power Hardware in the loop (PHIL)

+ Power & Energy Management

- *Sandia NL Distributed Energy Management*

Demonstrations Validate Interfaces for Pulsed High Energy Systems

FUTURE MISSION INTEGRATION SOLUTION

Common Shared Energy Storage and Services with an Integrated Management System to Support Load Demands and Lower Ownership Costs

Advanced Sensors

AMDR
Air and Missile
Defense Radar

Electronic Warfare

SEWIP Block III
Surface EW
Improvement
Program

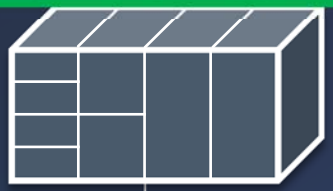
Directed Energy

SSL-TM
Solid State Laser
Technology
Maturation

Future Weapons

TBD

FUTURE INTERFACE: MIL-STD 1399 LVDC/MVDC *(draft)*



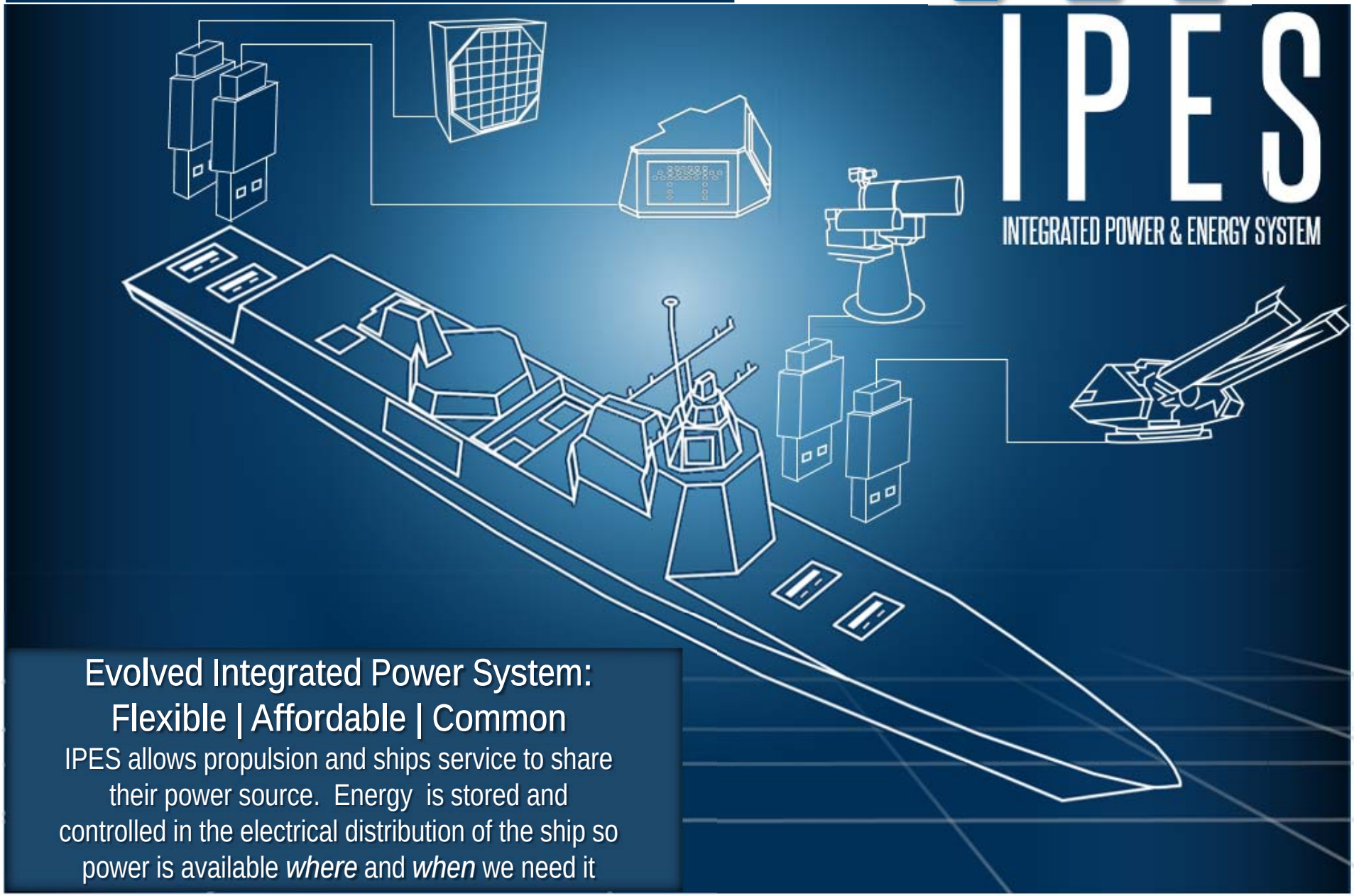
Energy Magazine

Common Architecture

- Shifts the Interface
- Flexible for Growth
- Adds Functionality
- Affordable
- Saves Space & Weight

Shifts the interface towards the loads for affordability and commonality

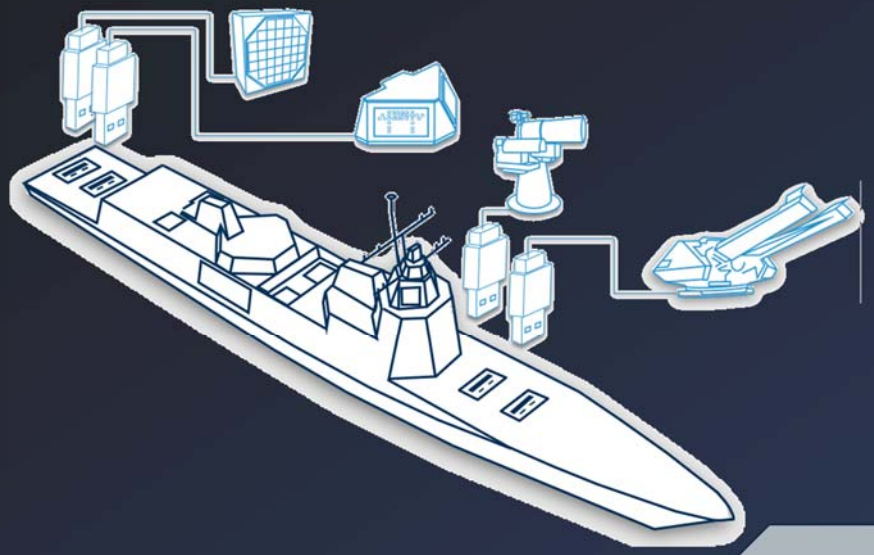
INTEGRATED POWER AND ENERGY SYSTEM (IPES)



Evolved Integrated Power System: Flexible | Affordable | Common

IPES allows propulsion and ships service to share their power source. Energy is stored and controlled in the electrical distribution of the ship so power is available *where* and *when* we need it

IPES: Advanced Cyber Safe Control System

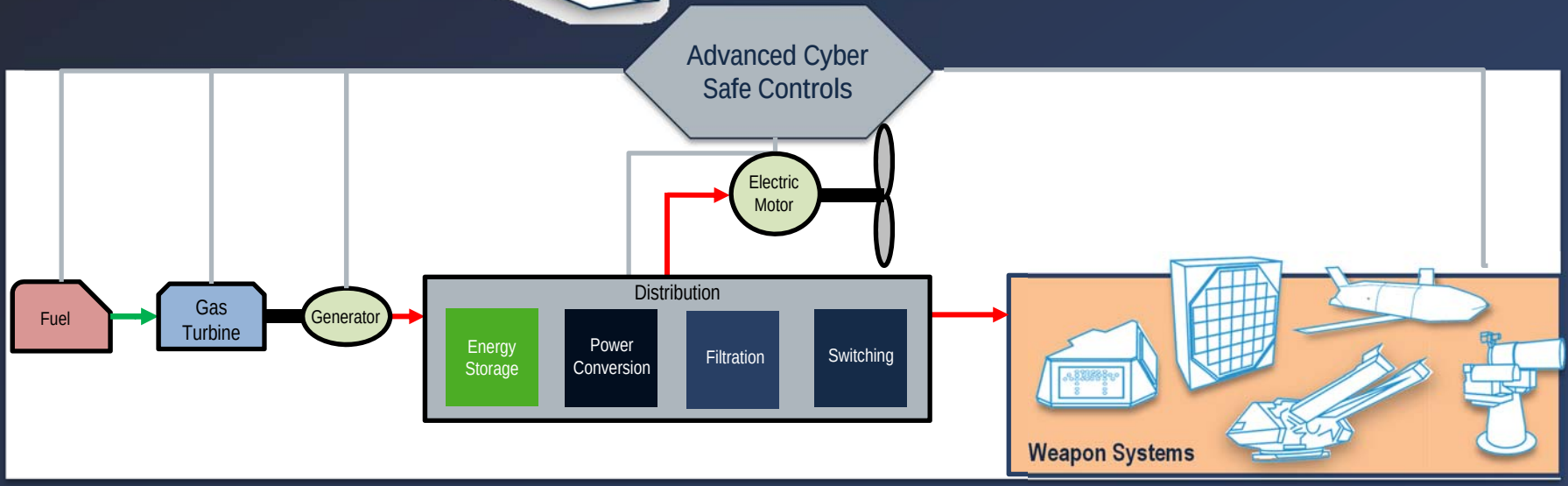


Integrated Power & Energy System

Flexible | Common | Modular | Scalable

Shared Power and Energy is controlled and distributed so power is available *where* and *when* needed.

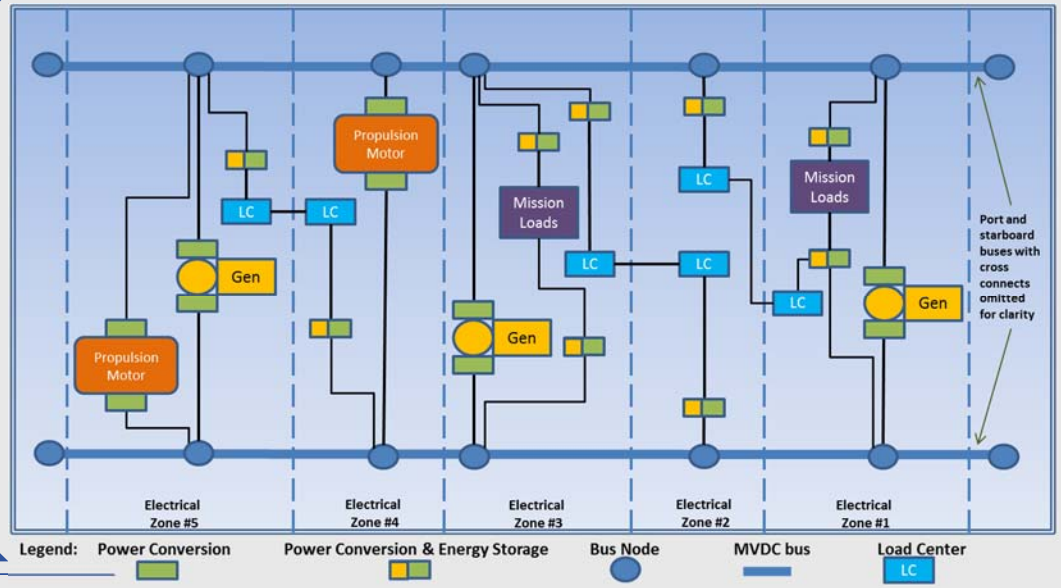
IPES = IPS + Shared Energy + Advanced Controls



The Right Power in the Right Place at the Right Time

IPES: Power Architecture

INTEGRATED POWER & ENERGY SYSTEMS (IPES)



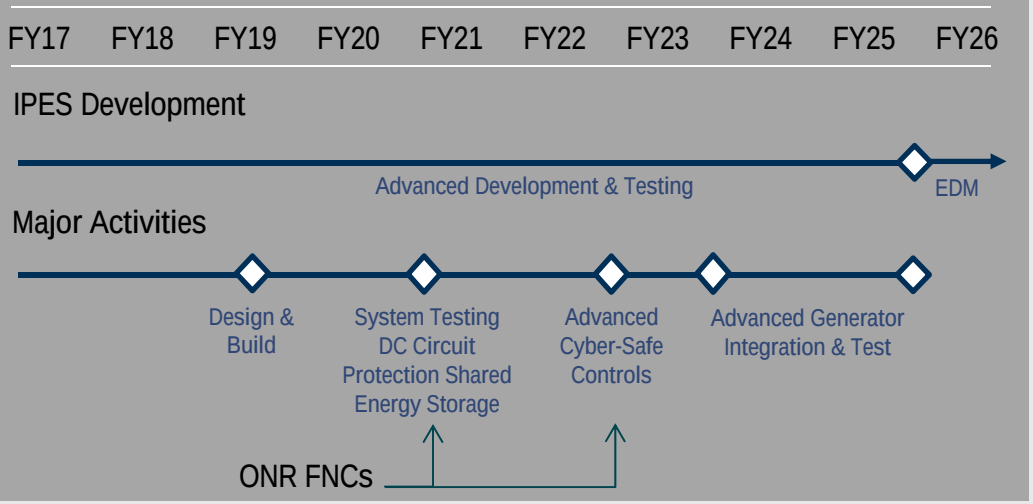
Is:

- Evolutionary from DDG1000 IPS
- Shared energy storage
- Advanced controls with combat systems interface
- Affordable, Scalable, and Flexible
- Zonal 12KVDC integrated power and energy
- MVDC IPES ADM White Paper of 08 April 2016 contains a full description

WARFIGHTING BENEFITS:

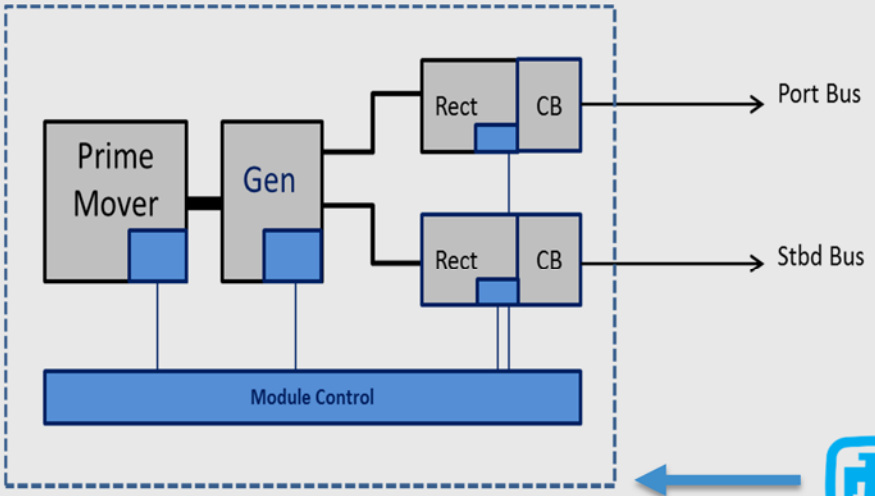
- Decouples mission system pulse loads from power generation
- Seamlessly transitions power and energy to high power pulsed weapons and sensors as required while maintaining system stability
- Matures and tests control system Active Power Management and Cybersecurity
- De-risks integration of modular energy storage at the main distribution and/or zonal levels

NOTIONAL SCHEDULE:



ADVANCED POWER GENERATION MODULE (APGM)

25MW 12KVDC GTG



Key Attributes:

- High Power Density
  - Fits in a warship less than10,000 tons
- DC permits use of variable speed to optimize efficiency
- Dual windings for independent buses
- Independent rectifiers convert AC → DC
- Module level controls
- Isolation from pulsed and/or stochastic load profiles
- Accommodation of high energy weapons (DC loads)

Sandia National Laboratories → Building Scale Generator and Testing to Inform interface

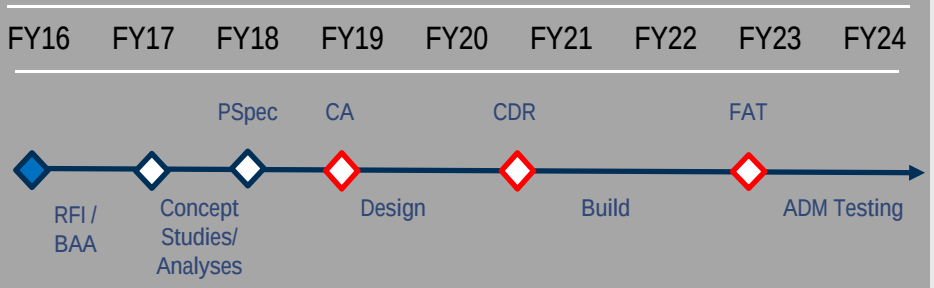
WARFIGHTING BENEFITS:

- Provides power dense and fuel efficient electrical generation capability
- Supports ships with future high power pulsed weapons and sensor systems in an IPES configuration
- Will be incorporated into IPES ADM upon delivery

PLANNING:

- ✓ FY16: Industry RFI and Industry Day
- FY17/18: Industry/Government Studies
  - Sandia: Building scale APGM emulator, test in 300 VDC microgrid lab to inform system performance requirements.
  - Study contracts being prepared

NOTIONAL SCHEDULE:



IPES PLANNING UPDATE

- Industry Day Held 3 August 2016
  - 156 people from Industry, Academia, and Government Stakeholder Organizations
- BAA White Papers Received for 25 MW GTG at 12KVDC
- Continuing to Develop supporting M&S and power hardware in the loop test capabilities
- Functional / Component Deep Dives in progress
- See BAA N0002410R4215

2017 Industry Day being planned for Mid-August

Electric Ships Office

PMS 320

Directing the Future of Ships Power

OVERVIEW

In 2007, ASN(RDA) established PMS 320, the Electric Ships Office (ESO) within PEO SHIPS to facilitate the high degree of technical integration with ship platforms and power systems, scope future technology development, and support critical concept decisions.

OUR MISSION

The mission of PMS 320 is to develop and provide affordable, capable Naval power and energy system integration solutions to meet evolving customer demands by:

- Defining common open architectures and interface standards,
- Developing common solutions,
- and Focusing Navy and informing Industry investments

OUR VISION

PMS 320 will work across the Navy's Research & Development Enterprise in partnership with industry to develop and introduce innovative technologies to enable the Navy's distributed lethality principles through efficient power & energy management.

PMS 320…

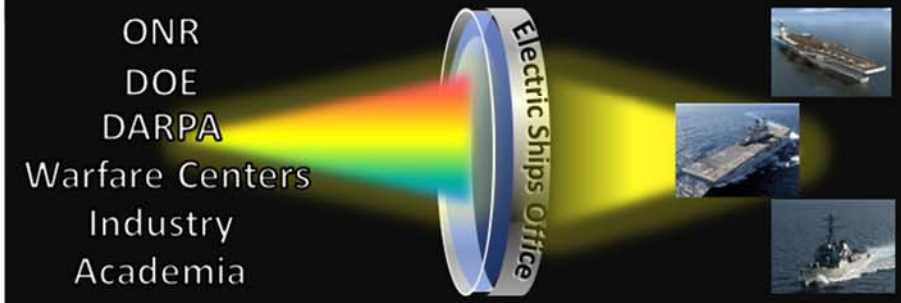
- Manages the Combat Power and Energy Systems OIPT
- Works with the S&T community to apply new technologies to solve fleet problems
- Works in conjunction with ONR, DARPA, Academia, Industry Professionals, and Warfare Centers
- Aligns developments with warfighter need
- Supports SECNAV and CNO initiatives to reduce energy use

WHAT WE PRODUCE

- Smaller, simpler, and more affordable ship power systems
- Power for pulsed high energy weapons and sensor systems
- Future Naval Power Systems and transition appropriate Science & Technology to the fleet
- Naval Power and Energy Systems Technology Development Roadmap (TDR)

NPES TDR: http://www.navsea.navy.mil/teamships/PEOS_ElectricShips/default.aspx

Providing Affordable, Integrated Power and Energy Solutions



- Provide fuel efficient and affordable power to meet power requirements for advanced sensors and future weapons
- Reduction in weight and lower life cycle costs
- DDG 51 Flight III AG9160RF rating is 4MW with 3.3% fuel efficiency improvement from DDG 1000 RR4500 3.85MW ATG

- Provides power conversion from DDG 51 Flight III 4160 VAC distribution system to 1000VDC at 1.42 MW/unit output power
- The two PCM cabinets can be paralleled via auctioneering diodes (in AMDR) and will share the AMDR load

- 12 kVDC Architecture
- IPS + Shared Energy Storage + Advanced Controls
- Enables multiple pulsed, high power mission systems

- De-risks SSL for all ships; creates modular building block for flexible commonality
- Facilitates integration of future weapon/sensor systems

- Fit into a DDG-51 size ship
- 25 MW
- Variable speed DC output

- Reduce DDG 51 FLT IIA Class in-service fuel consumption and increase on station time
- Provides propulsion at low ship speeds without the need for LM 2500 main engines
- Output Power: 2550 HP (1.9MW) - port shaft only