The future battlespace will be faster paced, more complex, and increasingly competitive...
“The prioritized shipbuilding plan assigns the highest priority to frontline combat platforms, affording the opportunity to quickly adopt new capabilities in response to emerging disruptive capabilities…”

- High energy weapons and sensors required to pace technology, outpace adversaries, and maintain maritime dominance
- Maintain flexibility to rapidly introduce new mission systems

**Disruptive Technology**

*The Key to Disruptive Technology is an Agile Power System*...
Where is Surface Navy Power & Energy Going?

Directed Energy
Pulsed, high powered weapons and sensors required to pace technology, outpace adversaries, and maintain maritime dominance
- These are elastic by nature
- Some are stochastic
- All are DC
- Limited response capability

Near Term: MVAC Distribution Systems
- Build in flexibility to rapidly introduce new mission systems/power gen & distribution
- Incorporate federated Energy Storage as Buffer
- Develop knowledge base for MVDC

Next: MVDC Distribution Systems
- Integrated & Distributed Energy Storage
- Increased Efficiency & System/Power Density

The Naval Power & Energy Systems Roadmap:
- Aligns electric power system developments with war fighter needs
- Enables Capability Based Budgeting

“Directing the Future of Ship’s Power”
**Power and Energy are the Foundation of the Kill Chain**

- Shared energy storage for new dynamic loads
- Minimize space, weight and cooling impacts
- Utilize all shipboard energy to produce useful power

**Path to the Future**

- **Shift the power interface**
- **Develop a common intermediate power and energy system**
- **Advance Fully Integrated Power and Energy Systems**

**Validation**

- New DC MIL-STD

**Back fit / Forward fit**

**New Ship Design**

- Near: MVAC with federated energy storage
- Next: MVDC with integrated & distributed energy storage

MVDC: MIL-STD-1399-300.3
LVDC: MIL-STD-1399-300.4

Distribution Statement A: Approved for Public Release; Distribution is unlimited.
Naval Power and Energy Systems Technology Development Roadmap

- Aligned to the Navy’s 30-year shipbuilding plan and Surface Capability Evolution Plan (SCEP)
- Originally issued in 2007 as part of the ESO stand-up; updated in 2013, 2015 and 2019.
- Includes all major product areas for Naval Power and Energy Systems
- Serves as a Guide for Future Investment by Navy, DoD, Industry, and Academia

**PRODUCT AREAS**

1. Energy Storage
2. Power Conversion
3. Prime Movers
4. Generators
5. Electric Motors
6. Distribution System
7. Controls
8. Thermal Management


- The case for a power and energy leap forward
- Future power and energy requirements
- Power and energy technology development
- Delivering capability through power and energy modernization
Established NPES Plan & Development Processes

Reference: Figure 6 page 38-39 NPES TDR

2019 NPES BAA: https://beta.sam.gov and Search the Solicitation Number N0002419R4145

Distribution Statement A: Approved for Public Release; Distribution is unlimited.
**Future Power and Energy Requirements**

Mission, power, and energy demands outpace ship capability without investment.

Current: Generator Response to Load

Future: Energy Storage Response to Load

**Power is Energy divided by time (P = E/t) or Energy equals Power times time (E = P * t)**

---

**Current: Generator Response to Load**

- **Kinetic Weapons**
  - Generators operate at continuous loading for efficiency and reliability
  - Current generators cannot respond quickly and dynamically to new demands

**Future: Energy Storage Response to Load**

- **Directed Energy Weapons and Sensors**
  - Pulses of a different nature require different ranges of pulse power technologies
  - Future directed energy demands need common large-scale energy storage

---

**Key to Success = Energy Storage and Advanced Controls**
Shifting the Electrical Interface Towards Mission Systems

Today's Navy pays a SWAP-C and support penalty.

Tomorrow's Navy shifts the interface for affordability and commonality.

Current Interface: MIL-STD 1399 (440VAC)

Future Interface: MIL-STD 1399 LVDC/MVDC (draft)

Common Architecture:
- Shifts the interface
- Flexible for growth
- Adds functionality
- Affordable
- SWAP-C

Distribution Statement A: Approved for Public Release: Distribution is unlimited.
**Shifting the Interface: Energy Magazine**

Energy Magazine Bridges the path to the Future with Back-fit Installations

**Intermediate Navy Uses Current and Future Naval Interfaces**

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

**CURRENT INTERFACE: MIL-STD 1399 (440VAC)**

Energy storage couples today's ships with tomorrow's technology

Distribution Statement A: Approved for Public Release: Distribution is unlimited.
Digital Engineering & Power Hardware in the Loop Testing

Real Time Simulation: Technical and Programmatic Risk Reduction

Distribution Statement A: Approved for Public Release: Distribution is unlimited.
Energy Magazine (EM)

Provides shipboard ready power system support for Pulsed High Power, High Energy Weapons and Sensors for Backfit and Forward Fit. The system is a modular, configurable, and scalable design with multiple input and output modules.

Energy Magazine: Power for Pulsed Mission Systems

Specifications

Input: 450VAC, 4160VAC, 12kVDC

Output: 375VDC, 650VDC, 1kVDC

Type IIkVDC Type II

Dimensions (Threshold)
- Power Control Cabinet (PCC): 75" (W) x 48"(D) x 78" (H)
- Energy Storage Cabinet (ESC): 75"(W) x 48"(D) x 78" (H)
- Total: 150"(W) x 48"(D) x 78"(H);

Weight (Threshold)
- PCC: 16000 lbs;
- ECC: 9000 lbs;
- Total: 25000 lbs; adjustable depending on application

Energy Storage:
- 153 KWhr (550 MJ) Battery, Capacitor, or Flywheel Stored energy, augments ship’s electric plant by peak shaving.
- Qualified, shipboard ready, 9310 characterized storage system

Provides shipboard ready power system support for Pulsed High Power, High Energy Weapons and Sensors for Backfit and Forward Fit. The system is a modular, configurable, and scalable design with multiple input and output modules.
**Energy Magazine: Leveraging 9 Years of Investment**

**2011: Energy Storage Module-Land (ESM-L):**
Proof of Concept for SSL-TM Land Demo Testing
Lead acid battery based technology in 28’ conex box

**2018: Energy Magazine Laser (EM-L):**
ESM Capability in 1/10 the size with lithium batteries (EaglePicher)
Supports Laser Engagement Profiles

**2019: Energy Storage Module-Ship (ESM-S):**
Second ESM Unit Modified for SSL-TM on LPD 27

**2019: Multi-function Energy Storage Module (MFESM):**
Power Electronics with Hybridized Energy Storage: Batteries + Capacitors

**2020: Energy Magazine Laser (EM-L) MK 2:**
Early Transition of MFESM; Batteries (SAFT) with Energy Magazine Laser Prototype

**2021: Energy Magazine Prototype (EM-P):**
Separate the interface between Power Electronics and Batteries, Faster Recharge

**2023: Multi-function Energy Magazine:**
Supports laser, SEWIP, AMDR UPS, & bus stability

---

**Distribution Statement A: Approved for Public Release: Distribution is unlimited.**
The introduction of agent-based, distributed, nonlinear control will be a revolutionary step to tackle pulsed load challenges.

Active state anticipation provides the ability to meet pulsed load challenges while reducing energy storage capacity and overall power requirements.

**Advanced Controls Provide Flexibility**

Configures system to operate at max efficiency when appropriate and switch to max performance through 3-way control between machinery system, mission planning, and directed energy mission requirements.

Controls/Methods take full advantage of power/energy resources within ships machinery the energy they require. Utilizes shared energy storage and higher bandwidth capabilities of power conversion equipment located within the distribution system.
Enable high power directed energy weapons and advanced sensors through automated control of distributed, shared power generation and energy storage resources.
MVDC Today – A Decade Down the Road

- Integrated Power and Energy System (IPES)
  - Integrated Power and Energy System (IPES) Background
  - MVDC Background: why MVDC?
  - IPES TDR Recommendations
  - Near term Task: Develop DC Interface
- Why IPES MVDC ADM?
  - Risk Reduction
  - ADM Results Support AoA

MVDC: highly integrated system from generator to loads

- Articulated MVDC reference architecture
- Modeling and simulation analyses/Subscale test beds
- Energy Magazine Demonstrations – Integrate Energy Storage
- Initiated procurement of MVDC test equipment at NSWC
- Various ESRDC, SBIR, and STTR projects
- Transition advanced controls (now a pre-FNC)
- Energy Magazine Installations and Demonstrations – Integrate Energy Storage
- Full scale hardware demonstration, validation of models

The Quest Continues
Increasing demand for high quality power to support a variety of loads
Successful shipboard integration of advanced weapons, sensors, and C2 will be directly dependent on the ability to effectively and efficiently distribute the right amount of power to the right place at the right time

Operational Energy Imperative
Increase the effective use, conversion, storage, distribution, and control of energy to enable the integration of future weapons and sensors onto platforms.

- Hon. Richard V. Spencer (27 June 2019)

Key Takeaways

Tactical Energy Management (Energy Storage & Advanced Controls) – provides the foundation for an affordable, scalable, and flexible power system

Power conversion – advances in SiC will enable affordable upgrades for high power, mission-critical applications

Integration testing – leading edge system models, test capabilities, and facilities required to fully characterize and de-risk NPES technology

Power is the Foundation of Disruptive Warfighting Capability
Electric Ships Office

OVERVIEW
In 2007, ASN(ROA) 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.

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.


Providing Affordable, Integrated Power and Energy Solutions

ONR
DOE
DARPA
Warfare Centers
Industry
Academia

Distribution Statement A: Approved for Public Release: Distribution is unlimited.