Why Electric Ships

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Setting the Scene

“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

Big differences from DDG 51:
• 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
Cruise Ship

Regal Princess (Photo by Norbert Doerry)
Platform Supply Vessel

Siem Symphony
(photo by DXR: https://creativecommons.org/licenses/by-sa/4.0/)

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USS Makin Island
LHD 8

Thomas Dalton, Abe Boughner, C. David Mako, and CDR Norbert Doerry, "LHD 8: A step Toward the All Electric Warship", presented at ASNE Day 2002.
Integrated Power System (IPS)

IPS consists of an architecture and a set of modules which together provide the basis for designing, procuring, and supporting marine power systems applicable over a broad range of ship types:

- Power Generation Module (PGM)
- Propulsion Motor Module (PMM)
- Power Distribution Module (PDM)
- Power Conversion Module (PCM)
- Power Control (PCON)
- Energy Storage Module (ESM)
- Load (PLM)
IPS Architecture

• Integrated Power
  • Propulsion and Ship Service Loads provided power from same prime movers

• Zonal Distribution
  • Longitudinal Distribution buses connect prime movers to loads via zonal distribution nodes (switchboards or load centers).
IPS Design Opportunities

• Support High Power Mission Systems
• Reduce Number of Prime Movers
• Improve System Efficiency
• Provide General Arrangements Flexibility
• Improve Ship Producibility
• Support Zonal Survivability
• Facilitate Fuel Cell Integration
Support High Power Mission Systems

- Electromagnetic Gun
  - More than 10 MJ on Target
  - Megawatt Range

- High Energy Laser
  - Enhanced Self Defense
  - Precision Engagement
  - No Collateral Damage
  - Megawatt Class Laser

- Organic Surveillance Drone
  - High Altitude
  - Beam Power to Aircraft
  - Minimal Handling - No Refueling

- Integrated Power System
  - Affordable Power for Weapons and Propulsion
  - Power Dense, Fuel Efficient Propulsion
  - Reduced Signatures
  - Power Conversion Flexibility

- All Electric Auxiliaries
  - No Hydraulics
  - No HP Gas Systems
  - Reduced Sailor Workload
Reduce Number of Prime Movers

**Ship's Power**

**Propulsion**

**Traditional**

- Prime Mover
- GEN
- Prime Mover
- GEN
- Prime Mover
- GEN

**Power Conversion and Distribution**

**Electric Drive with Integrated Power**

- Prime Mover
- GEN
- Prime Mover
- GEN
- Prime Mover
- GEN
- Prime Mover
- GEN

**Reduction Gear**

**MD**

**Mtr**

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A generator, motor drive and motor will generally be less efficient than a reduction gear . . . .

But electric drive enables the prime mover and propulsor to be more efficient, as well as reducing drag.

<table>
<thead>
<tr>
<th></th>
<th>Mechanical Drive</th>
<th>Electric Drive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas Turbine</td>
<td>30%</td>
<td>35%</td>
</tr>
<tr>
<td>Reduction Gear</td>
<td>99%</td>
<td></td>
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<tr>
<td>Generator</td>
<td></td>
<td>96%</td>
</tr>
<tr>
<td>Drive</td>
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<td>95%</td>
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<tr>
<td>Motor</td>
<td>70%</td>
<td>75%</td>
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<tr>
<td>Propeller</td>
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<tr>
<td>Relative Drag Coefficient</td>
<td>100%</td>
<td>97%</td>
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<tr>
<td>Total</td>
<td>21%</td>
<td>24%</td>
</tr>
<tr>
<td>Ratio</td>
<td>116%</td>
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</table>

Representative values: not universally true

TRADE TRANSMISSION EFFICIENCY TO REDUCE DRAG AND IMPROVE PRIME MOVER AND PROPELLER EFFICIENCY
Improve System Efficiency: Contra-Rotating Propellers

- Increased Efficiency
  - Recover Swirl Flow
  - 10 – 15% improvement

- Requires special bearings for inner shaft if using common shaft line

- Recent examples feature Pod for aft propeller

[Anders Backlund and Jukka Kuuskoski, “The Contra Rotating Propeller (CRP) Concept with a Poded Drive”]

http://www.mhi.co.jp/ship/english/htm/crp01.htm
General Arrangements Flexibility
Improve Ship Producibility

• Vertical Stacking of Propulsion Components
• Pods
• Athwart ship Engine Mounting
• Horizontal Engine Foundation
• Engines in Superstructure
• Distributed Propulsion
• Small Engineering Spaces
Support Zonal Survivability

- Zonal Survivability is the ability of a distributed system, when experiencing internal faults, to ensure loads in undamaged zones do not experience a service interruption.
  - Sometimes applied to only Vital Loads.
  - Usually requires one longitudinal bus to survive damage.
- Limits damage propagation to the fewest number of zones.
  - Enables concentration of Damage Control / Recoverability Efforts.
Facilitate Fuel Cell Integration

• Many Advantages
  • Highly Efficient (35-60%)
  • No Dedicated intakes-uptakes; use ventilation

• Challenges
  • Reforming Fuel into Hydrogen – Onboard Chemical Plant.
  • Eliminating Sulfur from fuels.
  • Slow Dynamic Response – Requires Energy storage to balance generation and load
  • Slow Startup – Best used for base-loads
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