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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Approved for Public Release
USS Makin Island  
LHD 8

US Navy photo by Brett A. Anderson

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.

NOTES:  
1) ALL LOAD CENTERS ARE 2000A  
2) "X", " *", "X" - INTERLOCKED  
3) ALL 4160V CABLE TO BB TYPE 55KV
USS Zumwalt
DDG 1000

Sposato, Bill, “DDG 1000 Class Destroyer” Presented to U.S. Navy Port Engineers, 31 August 2011

US Navy Photo by Zachery Bell
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

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

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

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

High Powered Sensor
- Combination Sensor and Weapon

High Powered Microwave
- Minimal Handling - No Refueling

High Powered Laser
- All Electric Auxiliaries
- No Hydraulics
- No HP Gas Systems
- Reduced Sailor Workload

Integrated Power System
- Affordable Power for Weapons and Propulsion
- Power Dense, Fuel Efficient Propulsion
- Reduced Signatures
- Power Conversion Flexibility
Reduce Number of Prime Movers

Ship’s Power

Traditional

Electric Drive with Integrated Power

Propulsion

Power Conversion and Distribution

Reduction Gear

MD

Mtr

MD

Mtr
Improve System Efficiency

• 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>
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<tbody>
<tr>
<td>Gas Turbine</td>
<td>30%</td>
<td>35%</td>
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<tr>
<td>Reduction Gear</td>
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<tr>
<td>Generator</td>
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<tr>
<td>Drive</td>
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<tr>
<td>Motor</td>
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<tr>
<td>Propeller</td>
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<tr>
<td>Relative Drag Coefficient</td>
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<tr>
<td>Total</td>
<td>21%</td>
<td>24%</td>
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<tr>
<td>Ratio</td>
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Representative values: not universally true
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 Podded 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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