Application Center Governmental Naval

Propulsion System Choices for modern Naval Vessels

Washington, November 8, 2012

Hubert F. Ohmayer
# Major Brands Under One Umbrella

<table>
<thead>
<tr>
<th>Business Units</th>
<th>Engines</th>
<th>Onsite Energy</th>
<th>Components</th>
</tr>
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<tbody>
<tr>
<td><strong>Brands</strong></td>
<td></td>
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<tr>
<td><img src="image" alt="mtu" /></td>
<td><img src="image" alt="DETOIT DIESEL" /></td>
<td><img src="image" alt="mtu" /></td>
<td><img src="image" alt="L'orange" /></td>
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<tr>
<td><strong>Products</strong></td>
<td></td>
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</table>
Propulsion System Choices for modern Naval Vessels
MTU: Partner of Navies (Example German Navy)

<table>
<thead>
<tr>
<th>Year</th>
<th>Ship Type</th>
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<tbody>
<tr>
<td>1980</td>
<td>F122</td>
</tr>
<tr>
<td>1985</td>
<td>F123</td>
</tr>
<tr>
<td>1990</td>
<td>F124</td>
</tr>
<tr>
<td>1995</td>
<td>F125</td>
</tr>
<tr>
<td>2000</td>
<td></td>
</tr>
<tr>
<td>2005</td>
<td></td>
</tr>
<tr>
<td>2010</td>
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</table>
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Mission

Load Profile

Acoustics

Emission

Shock

Vessel Specific Requirements

Technical Requirement

Nationalization

Optimized Propulsion System

Commercial Requirements

---------?
Speed Profile Comparison

DDG-51 Operating Profiles Top Level Requirements vs. Actual

- DDG-51 Peacetime TLR
- DDG-51 Wartime TLR
- DDG-51 1998 Actual

Percent of Total Time Underway

Speed (Kts)

1 DE 2 DE GT CODAG
Propulsion System Choices for modern Naval Vessels

Changes in selection criteria

**Traditional criteria**

- ship speed requirements
- shock capability
- noise reduction
- infrared signature

**Additional criteria**

- change in operation requirements
- greater range of speed
- added mission flexibility
- longer periods away from base with smaller crews
- cleaner emissions
CODAD Propulsion System

DELTA Frigates – DCNS – Singapore Navy
LEKIU Class Frigates – BAE – Malaysia Navy
Padilla Class Frigates – HDW – Colombian Navy

CODAD – U-Arrangement
CODAD – T-Arrangement
CODOG Propulsion System

ANZAC Frigates – New Zealand
FFX – Republic of Korea Navy
F123 – German Navy

CODOG
CODAG Propulsion System

F124 – German Navy

MILGEM Corvette – Turkish Navy

NSC Deepwater – US Coast Guard

CODAG
CODELAG Propulsion System

FREMM Frigate

FREMM 16V4000N43 Genset

F125 – German Navy
2 engines – direct drive

father-son - CODOD

Hybrid - CODOE

4-engines - CODAD
## Propulsion Systems for smaller Vessels

Engines in operation according to speed profile of ship

<table>
<thead>
<tr>
<th>V (kn)</th>
<th>Time (%)</th>
<th>Power (kW)</th>
<th>Direct drive (2-engines)</th>
<th>CODOE (Hybrid)</th>
<th>CODOD (Father- Son)</th>
<th>CODAD (4-engines)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>25</td>
<td>350</td>
<td>1 x 20V4000M73L</td>
<td>1 x 12V2000M51B</td>
<td>2 x 12V2000M61</td>
<td>2 x 16V4000M53</td>
</tr>
<tr>
<td>12</td>
<td>50</td>
<td>1000</td>
<td>1 x 20V4000M73L</td>
<td>2 x 12V2000M51B</td>
<td>2 x 12V2000M61</td>
<td>2 x 16V4000M53</td>
</tr>
<tr>
<td>15</td>
<td>20</td>
<td>2000</td>
<td>2 x 20V4000M73L</td>
<td>2 x 20V4000M73L</td>
<td>2 x 20V4000M73L</td>
<td>2 x 16V4000M53</td>
</tr>
<tr>
<td>20</td>
<td>5</td>
<td>7200</td>
<td>2 x 20V4000M73L</td>
<td>2 x 20V4000M73L</td>
<td>2 x 20V4000M73L</td>
<td>4 x 16V4000M53</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Task</th>
<th>Speed</th>
<th>Time</th>
<th>Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transit, Interception, SAR</td>
<td>15 - 20 kn</td>
<td>5 %</td>
<td>30 - 100% of MCR*</td>
</tr>
<tr>
<td>Patrolling in operational zone</td>
<td>12 - 15 kn</td>
<td>20 %</td>
<td>15 - 30 % of MCR*</td>
</tr>
<tr>
<td>Loitering in operational zone</td>
<td>0 - 12 kn</td>
<td>75 %</td>
<td>&lt;15 % of MCR*</td>
</tr>
</tbody>
</table>

* MCR – Maximum Continuous Rating
Electrical Systems have losses:
- Generator
- Frequency converter
- E-motor

\[ \eta_{CODOE} = \eta_{\text{Generator}} \cdot \eta_{\text{Freq.}} \cdot \eta_{E-Motor} \approx 90\% \]

Electrical propulsion systems need more power to achieve same ship speed compared to mechanical systems
**Propulsion Systems**

**Comparison Investment and LCC**

**LCC include:**
- Fuel consumption
- LO consumption

**Investment cost include:**
- engines
- Gearboxes
- Shafts
- Propellers
- Gensets
- Electrical motors
- Frequency conv.

**Assumption:** 2,000 hrs operation per year

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<table>
<thead>
<tr>
<th>Investment</th>
<th>LCC</th>
</tr>
</thead>
<tbody>
<tr>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>95</td>
<td>100</td>
</tr>
<tr>
<td>100</td>
<td>105</td>
</tr>
<tr>
<td>105</td>
<td>110</td>
</tr>
<tr>
<td>110</td>
<td>115</td>
</tr>
<tr>
<td>115</td>
<td>120</td>
</tr>
</tbody>
</table>

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| Application Center Governmental Naval | 08.11.2012 |
Comparison CODAG / CODELAG
6000 ton ship

<table>
<thead>
<tr>
<th>Component</th>
<th>Volume (m$^3$)</th>
<th>Weight (t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CODAG</td>
<td>CODELAG</td>
<td>CODAG</td>
</tr>
<tr>
<td>Main Switch-Board 6,6 kV</td>
<td>0</td>
<td>240</td>
</tr>
<tr>
<td>Xfrmr &amp; Converter 6,6 kV</td>
<td>0</td>
<td>675</td>
</tr>
<tr>
<td>Gearbox</td>
<td>630</td>
<td>630</td>
</tr>
<tr>
<td>Shaft + Propeller</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Main Diesel Engines</td>
<td>378</td>
<td>0</td>
</tr>
<tr>
<td>Electrical Motors</td>
<td>0</td>
<td>540</td>
</tr>
<tr>
<td>Gas Turbine</td>
<td>300</td>
<td>300</td>
</tr>
<tr>
<td>Generator Sets</td>
<td>648</td>
<td>1200</td>
</tr>
<tr>
<td>Summary</td>
<td>1956</td>
<td>3585</td>
</tr>
</tbody>
</table>
German Frigate F125
7000 tons

- „Stabilization frigate“ for operation of about 2 years abroad
- 21 days of endurance
- About 5,000 operating hours per year
- Built acc. to actual naval design rules
- No. of sailors reduced by 50%
- Ships speed electrical mode >20 kts
- 4 vessels under contract
Fregatte F125 CODELAG Concept
max. 20 kts in electrical mode

**Gensets:**
4 Gensets with Diesel engine 20V 4000 M53B, each 3.015 kW @ 1.800 rpm

**Gas Turbine:**
1 Package MTU LM2500, 20.000 kW @ 3.600 rpm

→ full military qualification: shock, acoustics, ABC, Load acceptance
FREMM Frigates
CODELAG Propulsion System

L = 142 m
Displacement approx. 6000 tons
ASW Capability
27 kts max speed
15 kts max. electr. mode
FREMM
Propulsion plant max. 15 kts in electrical mode

CODLAG propulsion
Combined Diesel-Electric And Gas Turbine

- Gas turbine
- Gensets (4x)
- Gearbox
- El. motor
FREMM Gensets

4 x 16V 4000 Genset
2240 kW

- base frame filled with Polymeric concrete
- Sound enclosure
- Sliding door access
Turkish Corvette MILGEM

**ASW**

**Turkish Corvette MILGEM**

Length 99 m / 90.55 m WL
Width 14.4 m / 12.63 m WL
Draft 3.58 m
Tonnage 2100 t

Vessel speed 29+ kn
1 engine mode: 15 kn
Endurance 3500 nm (10 days/15 kn)
### MILGEM Corvette

**Scope of Supply**

**Scope per Shipset:**
- 2 x MTU 16V 595 TE 90, Enclosed Module
- 1 x Gasturbine LM2500
- 1 x Renk „CODAG/CC“ Gearbox
- 2 x Escher Wyss Props and Shafts
- 1 x Propulsion System Automation

**Service Support:**
- System Integration
- Support for Installation, STW and Trials
- Project Management

Extensive Integrated Logistic Support (ILS)-Package
MTU was awarded the contract to act as the Propulsion Plant Single Source Vendor (PPSSV) for the NSC.
| USCG Projects  
| NSC Design Basis |

<table>
<thead>
<tr>
<th>SAN Corvette</th>
<th>F124 Frigate</th>
</tr>
</thead>
<tbody>
<tr>
<td>WARP Drive</td>
<td>CODAG Drive</td>
</tr>
<tr>
<td>Waterjet And Refined Propeller</td>
<td>Combination Of Diesel And Gas</td>
</tr>
</tbody>
</table>

Total Power: 31,840 kW  

Total Power: 37,000 kW
USCG Projects
NSC Design Basis

Diesel Engine
20V 1163 TB93
7,400 kW
Mounting Systems
according to application
USCG Projects
NSC - Equipment

1 each Ő RENK AS 2/250-AS 198F Cross Connect / Reduction Gear
USCG NSC – Equipment Monitoring and Control System
Large Vessels
Propulsion System Combination

SISO (Single in / Single out) Direct Drive

SISO + E-PTI (Single in / Single out + Electrical PTI)
Large Vessels
Propulsion System Combination

CODAD (Combined Diesel and Diesel)

CODAD + EPTI (Combined Diesel and Diesel and EPTI)
Large Patrol Vessel **Hybrid Propulsion CODOE**

Reference: Royal Navy of Oman

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
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<tbody>
<tr>
<td>Length x Width x draft</td>
<td>98 m x 14.6 m x 4.1 m</td>
</tr>
<tr>
<td>Displacement</td>
<td>2700 tons</td>
</tr>
<tr>
<td>Total Power</td>
<td>18200 kW</td>
</tr>
<tr>
<td>Max speed</td>
<td>26 Kts</td>
</tr>
<tr>
<td>2x 20V8000M91</td>
<td>18200 kW</td>
</tr>
<tr>
<td>2x E-Motor</td>
<td>560 kW (280 kW each)</td>
</tr>
</tbody>
</table>
Oman Patrol Vessel **Hybrid Propulsion CODOE** Propulsion Arrangement
MTU Flexible Propulsion
Direct drive propulsion plant with loiter drives or conventional diesel arrangement

3 x 20V4000M73L
- 3600 kW; 2050 rpm
Loiter Drives
- Power up to 800kw

AUSTAL MRV 80
L = 80 m
Displacement 400 tons
max speed 25 kts
MTU Flexible Propulsion Concepts

Conventional Propulsion

Conventional
- 3 x 20V4000M73L (3600kW)
- Diesel engine with low load operation capability

Hybrid or Diesel Electric Propulsion

Hybrid Loitering, up to 10kn on e-mode
- Main diesels: 20V4000M73L
- Gensets: 2 x 12V2000M41A (541 kW)
- Integrated Electric Motors

Hybrid Patrolling, up to 17kn on e-mode
- Main diesels: 20V4000M73L
- Gensets: 3 x 16V2000M41A (725 kW)
- Integrated Electric Motors
Advantage 1 - Flexibility

Hybrid Propulsion at lower speed
- E-Motors power the vessel at loitering or patrolling speeds (10 or 17kts) depending on gensets installed
- E-Power for Hotel Load generated by Gensets
- Plant acceleration improved, since electric motors produce higher torque at lower speed

Hybrid Propulsion at higher speed
- Vessel powered by main diesel engines
- E-Power for Hotel Load generated by main diesel engines (E-Propulsion motor switched to alternator mode)
- Gensets disconnected from ship electric power distribution net
Advantage 2 - Fuel Oil Consumption

Reduction of Fuel Oil Consumption

Diesel engines running at low load have higher specific fuel oil consumption compared with higher loads. Hybrid propulsion avoids main engines running at very low load by using gensets for vessel propulsion and hotel load power generation.

Hybrid Plant for Loitering (up to 10kn)
9% Reduction of fuel consumption compared with conventional plant

Hybrid Plant for Patrolling (up to 17kn)
13% Reduction of fuel consumption compared with conventional plant
Emission Legislation Marine EPA, EU & North American ECA\(^1\) for IMO Tier III

**EPA Area**

**EU Area**

**ECA:**
- Coasts of Canada, USA & Hawaii (effective 08/2012).
- Puerto Rico, the US Virgin Islands (effective 01/2014).
- Range 200 nm, NO\(_x\), SO\(_x\) & PM\(^2\) emission control.

**Existing SECAs:**
- North Sea (SO\(_x\)\(^2\) only).
- Baltic Sea (SO\(_x\)\(^2\), and also proposed for NO\(_x\)\(^2\)).

**Discussed ECAs:**
- Coasts of Mexico, Alaska and Great Lakes, Australia, Singapore, Hong Kong, Tokyo Bay, Norway, Northern Mediterranean Sea, Black Sea.

\(^1\) IMO III applies only within ECAs (elsewhere IMO II): IMO III does not apply to a marine diesel engine installed on a ship with a length less than 24 metres when it has been specifically designed, and is used solely, for recreational purposes.

\(^2\) NO\(_x\)=Nitrogen Oxides; SO\(_x\)=Sulfur Oxides; PM=Particulate Matter
Advanced technologies are required to meet future emission legislation.
The basics of the catalytic exhaust purification are to use the following methods:

- **Selective Catalytic NOx Reduction (SCR)**: NOx reduction
- **Diesel Particulate Filter (DPF)**: Particulate matter (PM) reduction
- **Diesel Oxidation Catalyst (DOC)**: CO and HC reduction

Exhaust aftertreatment

**Exhaust Gas Aftertreatment (EGA)** can yield significantly lower emission levels than engine internal means.

There is potential to substitute muffler sound attenuation by EGA components.
Thank You.