Current Issues

- **More Data Being Captured**
- **Increased Environmental Regulations**
- **Need for Integrated Systems**
- **Centralized Knowledge**
- **Fuel Selection/Cost Considerations**
- **Costs and Regulations Are Key Drivers to Improve Performance**
- **Volume of Data Required to Satisfy Regulatory Reporting Is Increasing**
- **Operators Need Strategies to Manage in a Competitive Market**
Regulatory Landscape

<table>
<thead>
<tr>
<th>Year</th>
<th>2013</th>
<th>2015</th>
<th>2020</th>
<th>2025</th>
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<tbody>
<tr>
<td>NOx</td>
<td></td>
<td></td>
<td>Tier III NOx N America ECA</td>
<td>Tier III NOx Baltic/ North Sea</td>
</tr>
<tr>
<td>SOx</td>
<td></td>
<td>0.1% LSFO ECA</td>
<td>0.5% LSFO worldwide</td>
<td>Phase 3 EEDI ?</td>
</tr>
<tr>
<td>CO₂</td>
<td>Phase 0 EEDI</td>
<td>Phase 1 EEDI</td>
<td>Phase 2 EEDI</td>
<td>IMO DCS</td>
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<tr>
<td>Other Regulations</td>
<td>Revised IMO IGC Code</td>
<td>IMO IGF Code</td>
<td>EU IHM Existing &amp; Non-EU</td>
<td>Possible Future Regulations</td>
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<td></td>
<td>IACS CSR-H</td>
<td>IMO GBS</td>
<td>EU MRV</td>
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<td></td>
<td>USCG BWDS 1500-5000 m³</td>
<td>USCG BWDS &lt;1500 &gt;5000 m³</td>
<td>EU MRV</td>
<td></td>
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<td></td>
<td>US EPA VGP2</td>
<td>BWMC 08 Sept 2017</td>
<td>US EPA VGP3</td>
<td>VGP4</td>
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</tbody>
</table>

Tier III NOx N America ECA
Tier III NOx Baltic/ North Sea
0.1% LSFO ECA
0.5% LSFO worldwide
Phase 0 EEDI
Phase 1 EEDI
Phase 2 EEDI
IMO DCS
Revised IMO IGC Code
IMO IGF Code
New SOLAS Ch XIII: III Code
New SOLAS Ch XIV IMO Polar Code
IACS CSR-H
USCG BWDS 1500-5000 m³
USCG BWDS <1500 >5000 m³
EU MRV
US EPA VGP2
BWMC 08 Sept 2017
US EPA VGP3
VGP4

Possible Future Regulations:
- MBM
- Underwater Noise
- Bio-fouling
- Ship Recycling
- Black Carbon
Technical Measures to Reduce CO$_2$ Emissions

**Hull and Propeller**
- Hull optimization, bow and stern (operational profile)
- Efficient propeller
- Energy saving devices
  - Pre-swirl ducts
  - Rudder bulb; PBCF; ...
  - Twister rudder

**Machinery**
- Main engine, optimally tuned
- Optimized load on gen-sets
- Minimize electrical loads, VFD control
- Waste heat recovery, economizer
- Condition monitoring, maintenance

**New technologies**
- Air lubrication
- Wind: sail, Flettner rotor
- Solar
- Biofuel
- Hydrogen
- Fuel cells
Hull Optimization - 4400 TEU Container vessel

11.0 m draught and 19.0 kn speed
EEDI Containerships

Attained EEDI for Containerships

Based on IMO MEPC.70 INF14 published data August 19 2016
EEDI Bulk Carriers

Attained EEDI for Bulk Carriers

Based on IMO MEPC.70 INF14 published data August 19 2016
EEDI Bulk Carriers: < 40k dwt

Based on IMO MEPC.70 INF14 published data August 19 2016
Marine Engines: Higher Efficiency

- Specific fuel oil consumption (g/kWh) 1940 – 2015, 2-stroke engines
Innovative technologies
• Collection and reporting of ship fuel consumption data, all ships > 5,000 GT on international voyages

Co2: IMO Data Collection System (DCS)

- Collection and reporting of ship fuel consumption data, all ships > 5,000 GT on international voyages

1st Reporting Period:
- BDN’s
- Bunker fuel tank monitoring
- Flow Meters

Aggregate and report the data collected in the calendar

Verify Reported Data

Issuance of SoC

Transfer to the IMO Ship Fuel Oil Consumption Database

1 January 2019

31 March 2020

30 June 2020

31 December 2019

31 May 2020
CO₂: EU Monitoring, Reporting and Verification

• Ships above 5,000 GT on voyages to, from and between EU ports

1 January 2018
31 August 2017
31 December 2018
30 June 2019
30 April 2019
Performance Monitoring

• Monitor operations for
  - Energy efficiency
  - Environmental compliance
  - Machinery condition
  - Predictive maintenance

• Analyze operations towards
  - Operational profile
  - Different operational modes
  - Reference baseline for each mode, KPI’s

• Improve operations
  - Auto log performance data (continuous) vs. noon reports
  - Benchmark data and analysis KPIs
  - Situation awareness for operators and crew
ECA Operation: Tier III NOx Compliance - EGR

- Reduction of NOx emissions requires advanced engine features:
  - Electronic fuel injection, common rail, turbocharging, miller timing, variable valve timing
- Exhaust Gas Recirculation established in automotive, truck, off road and rail applications – no aftertreatment
- Requires SOx scrubber or low sulphur fuel …
- Integrated with engine, more compact than SCR, low load operation OK, increase in SFOC approx. 1 – 2%
ECA: NOx Compliance - SCR

- Selective Catalytic Reduction (SCR) aftertreatment can be used for Tier III compliance
- Slow speed SCR installed before (HP) or after (LP) turbocharger
- Ammonia introduced via Urea solution as a reductant
  - Urea consumption: ~15 ltr/MWh
- Typically needs exhaust temperatures > 300°C
- Challenges
  - Transient response, fuel sulphur content, Urea availability/cost, Urea slip, fouling, soot blowing
  - Space for SCR reactor and Urea storage
  - Integral part of engine and control system
  - Increased SFOC, especially at low engine loads
2020: Low Sulphur Fuels

• Low sulphur fuels, ‘hybrid’ fuels can generate new concerns
  - Low viscosity
  - Lack of lubricity
  - Compatibility of fuels
  - Catalytic fines
  - Loss of capacity/leakage issues
  - Purification system
  - Heating/cooling arrangements
  - Changeover times and procedures
  - Cylinder oil dosing rates
  - Corrosion control
  - Oil BN – oil changeover

• LNG
Building the ‘Smart Ship’

- **Real-time Connection**
- **Large Data Transfer**
- **Onshore Data Processing**
  - Fleet management and benchmarking
  - Condition-based maintenance
  - Data analytics
    - Performance model
    - Vessel performance analysis
- **Data Acquisition**
  - Sensor technology
  - Electronic log book
  - Data link to equipment
- **Data Infrastructure**
  - Data transfer
  - Data storage
  - Data processing
- **Unified Dashboard and Reporting**
  - Real-time and early warning
  - Decision support
  - Vessel and performance monitoring
  - Voyage and trim optimization
  - Commercial and management report
The Human Element
Thank You
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