# Land & Sea division overview

**MARINE**
- Leading supplier of ship designs, power and propulsion systems, deck machinery and through-life support services
- Global leader in integration of complex mission-critical systems for commercial and defense vessels
- Environmental solutions

**ROLLS-ROYCE POWER SYSTEMS**
- Suppliers in gas turbine, propulsion and distributed energy systems
- Marine propulsion and power generation systems
- Marine and industrial gas turbines
- Maritime satellite services
- Marine and industrial services

**NUCLEAR**
- Suppliers in gas turbine, propulsion and distributed energy systems
- Nuclear power generation systems
- Nuclear marine management services
- Marine and industrial services

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# Marine

A world leader in vessel design, the integration of complex systems and the supply and support of power and propulsion equipment.

- Clean, efficient, and smart systems
- 4,000 customers worldwide, including 70 navies
- Equipment installed on more than 25,000 vessels
- MT30 – World's most powerful in-service gas turbine on major US, UK and Korean programmes
- No. 1 for pure gas marine engines
- No. 1 for underwater mountable thrusters

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# Our global business

<table>
<thead>
<tr>
<th>LAND &amp; SEA</th>
<th>POWER SYSTEMS</th>
<th>MARINE</th>
<th>NUCLEAR</th>
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# Financial data: FY2014

<table>
<thead>
<tr>
<th>SEGMENT</th>
<th>ORDER BOOK</th>
<th>UNDERLYING REVENUE</th>
<th>UNDERLYING PROFIT</th>
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<td>OFFSHORE</td>
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<td>COMMERCIAL</td>
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<td>NAVAL</td>
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<tr>
<td>SERVICES</td>
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</tbody>
</table>

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*Yrjar Garshol*
VP Marketing, Commercial Marine
Marine highlights

• World’s largest rim-driven permanent magnet thrusters (2 x 500kW) onboard MS “Gunnerus”
• Installation of the Unified Bridge on PSV “Shi Luna”
• 12 UUC thrusters on the world’s largest ship “Pioneering Spirit” (length 382m, breadth 124m)
• Rolls-Royce established as a leader at the forefront of ship intelligence
• Powered the world’s longest journey at sea by LNG with “Kvitbjørn” from Nor Lines

Commercial marine
Long experience in system integration and ship design

The benchmark of the offshore oil & gas industry
• Almost 600 UT designs in operation or under contract
• Well positioned as oil and gas exploration and production continues to move into deeper waters
• Delivering the widest range of products in the marine industry

Solutions for the cargo, passenger and tug boat market:
• Achieving optimised through-life costs for customers whilst enabling compliance with increasing environmental requirements

Services
Professional service, every port, every day

• Our focus is preventing downtime and loss of operation for our customers
• We provide conventional services, provision of spare parts, equipment repair, overhaul and exchange programmes and upgrades
• Several upgrades offer improved performance and efficiency
• Innovative new services, such as the condition monitoring, are helping to further reduce vessel downtime and provide operators with additional service options
• Our support philosophy is a recognition that customers have different and often unique requirements based on their fleet operations
**Customer product training**

**Sharing our knowledge**

- As product experts, we can provide a crew with the knowledge of how to get the best economic and environmental value out of equipment and systems.
- Our product training ensures crews are equipped to operate mission critical systems safely and efficiently in the broadest range of operational and maintenance scenarios.
- Courses are structured to provide theoretical and practical experience, as well as simulator time to ensure crews operate safely and efficiently.

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**Global service and support network**

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**Why Permanent Magnet (PM) Technology?**

**1. EFFICIENCY**
- No energy is used for excitation of rotor
- Higher efficiency over entire speed range
- Low heat generation in the machine components
- Best candidate for applications where fuel save is important

**2. SIMPLICITY**
- Permanent rotor magnets field
- Single construction
- Robust candidates for high reliability applications
- Best candidate for integrated product

**3. COMPACTNESS**
- High torque density machine
- 95% more compact than asynchronous machine
- Slim stator and rotor due to high pole design
- Strong dynamic performance (forced ventilation rotor - stator or direct water cooling in the application)
Why PM Technology for Thrusters?

**Efficiency**
- Asynchronous induction motor (high efficiency is 90%)
- Integrated synchronous permanent magnet machine (efficiency is above 97%, higher for partial loads)
- Oil filled, geared thruster unit

**Robustness (impeccable)**
- Multiple moving parts
- Pitch system
- Mechanical transmission line

**Compactness**
- Multiple moving parts
- Pitch system
- Mechanical transmission line

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*Prop. curve, Operating profile & Efficiency*
- 60%
- 30% 40% 50% 60% 70% 80% 90% 100%

**Efficiency**
- 12% average efficient improvement

**Robustness (impeccable)**
- Reduction in fuel cost for 4 PMTT2000 (Simplicity)
- Energy cost 0.808 NOK/kWh
- PMTT 943400 kWh

**Compactness**
- TT Async w Gear
- Mechanical design (max efficiency is 96%)

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**Why PM Technology for Thrusters?**

**Efficiency**
- Multiple moving parts
- Pitch system
- Mechanical transmission line

**Robustness (impeccable)**
- 1 moving part (propeller)
- Steerable gear with improved classic design

**Compactness**
- >4,6m
- 3,1m
Why PM Technology for Thrusters

- Efficiency
- Robustness
- Compactness

>4.6m

Location & footprint in vessel

Technology demonstration phase

- 50 kW test unit
- 800 kW technology demonstrator
- "Shaftless design" – rotor spins on circumferential bearings
- AHTS "Olympic Octopus", 2006-2009
- Installation in stern, next to TT2000, 883 kW

2001 - 2009

Industrialization phase

- Revised design, central shaft design
- Hydrodynamic analysis iterations
- Assembly cell and production system
- Quay test rig for full scale testing
- Reintroduced as stern thruster for "Olympic Octopus", 2012 – currently 4000 hours and no maintenance needed.

2010 - 2015
**Lessons learnt**

- Electromagnetic design
- Hull integration design
- Bearing system design
- Hydrodynamic performance
- Manufacturing to scale

**Multi-discipline teamwork!**

- Hydrodynamics
- Electromagnetic
- Mechanical
- Materials
- Manufacturing
- Control systems
- Ship Design
- El. Power System
- Materials
- Manufacturing to scale
- Bearing system design
- Hydrodynamic performance

**PM Azimuth, installed on R/V Gunnerus**

- R/V Gunnerus, built 2006
- Propulsion system: 2x500kW, 440V, 60Hz
- Length: 31.25m
- Breadth: 9.6m

- Removed: Rudder with steering gear
- Nozzle with propeller
- Shaftline Gear
- Electrical motor
- Frequency converter
- Bridge control system

- Installed: PM Azimuth including steering gear
- Lubrication system
- Helicon control system
- Frequency Converter
- HEMOS

**Design and in-house testing**

500 kW azimuth thruster driven by a PM motor placed inside the nozzle.

- Mechanical strength 1000kW
- Rudder from space for a 1000kW PM motor
- Reuse elements from PM azimuth thruster
- Helicon II control system
- HEMOS frequency converters
- HEMOS data acquisition system

- Design and production: 2012 to Nov 2014
-Issued Dec 04
- Delivered: Dec 04
- Installed: March-April 15

**Power vs. speed before / after PMAZM retrofit**

- Comparison of power consumption
- The results, when corrected for increased displacement, indicate significant savings:
  - 8.9 kn: 13 % Saving
  - 10.5 kn: 11 % Saving
  - 11.5 kn: 7 % Saving

**Preliminary**
### Product design & features

- Robust "H-frame" construction, no shaft dynamics
- Oil for circulation only, very low volumes
- Designed for Under Water Installation (UWI)
- Power source:
  - Active Power (AP), alternatively
  - 12 (or 18/24) pulse drives

<table>
<thead>
<tr>
<th>Type</th>
<th>PMTT1600</th>
<th>PMTT2000</th>
<th>PMAZM 1900</th>
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<tbody>
<tr>
<td>Power (Max)</td>
<td>1000 kW</td>
<td>1600 kW</td>
<td>1000 kW</td>
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<tr>
<td>Propeller diameter</td>
<td>1600 mm</td>
<td>2000 mm</td>
<td>1900 mm</td>
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<tr>
<td>Electrical efficiency</td>
<td>97.5%</td>
<td>97.7%</td>
<td>97%</td>
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<tr>
<td>RPM (Max)</td>
<td>338</td>
<td>277</td>
<td>~209</td>
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<tr>
<td>NPSM RPM</td>
<td>% of max</td>
<td>% of max</td>
<td>% of max</td>
</tr>
<tr>
<td>VGP Compliant</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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### PM technology explained

**Permanent Magnet synchronous motor**
- Sealed, submerged stator
- Rotor with permanent magnets
- 690 V

**Frequency controlled**
- AFE or 12 pulse VFD
- Overload protection built into drive
- Sensorless, closed loop control

**No mechanical transmission line**
- Monoblock fixed pitch propeller integrated in rotor
- Fixed, non-rotating shaft

### Noise and Vibration – “the human ear”

- 5 dB less measured noise...
- 50% less perceived noise...
Noise measurements – “Olympic Octopus”

- Airborne noise: 4-8 dB
- Structure borne noise: 6-12 dB
- Noise emitted to sea: 5-6 dB

Measurements conducted by DNV, April 2013

Life Cycle Cost

- Plug Play agreement
- PM motor requires no maintenance
- Less wear, 1 rotating part
- High energy efficiency

- Compared with conventional tunnel thruster, 50% less maintenance cost is expected
- The electrical motor is always included

Future priorities

1. Larger size PM Azimuth thrusters
   - Offshore
   - Technology demonstrator project ongoing
   - Manufacturability

2. Larger size tunnel thrusters
   - Related demand for larger tunnel thrusters
   - Manufacturability

3. Auxiliary thrusters
   - Design
   - Manufacturability

Permanent Magnet driven Thrusters

- Cruise liner, 2xPMTT2000 - 1.6 MW
- Pipelayer, 1xPMTT2000 - 1.6 MW
- Research vessel, 2xPM AZM 1900 - 0.5 MW
- OCV vessel, 2xPMTT2000 - 1.6 MW

- Efficient
- Robust
- Compact
Trusted to Deliver Excellence
Thank you