Ship efficiency – Permanent Magnet technology

-PMazimuth, main propulsion for R/V Gunnerus
-PMTT, tunnel thrusters.

By: Gunnar Johnsen-Head of Electrical System R&T
Olav Haug Vikebak- VP sales

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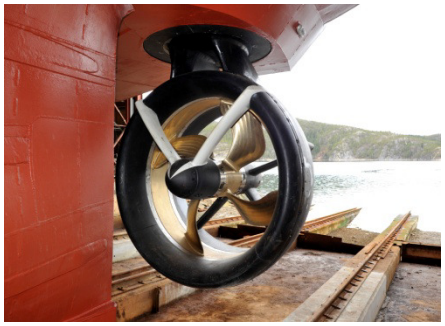
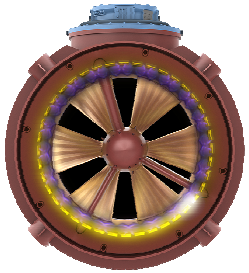
Content

- Rolls-Royce Marine permanent magnet history
- Why propulsion system based on Permanent Magnet (PM) Technology.
- Agreement between Rolls-Royce Marine and Norwegian University of Science and Technology (NTNU)
- The PMazimuth
  - Design
  - Inhouse testing
  - Systems
    - Frequency converter
    - Control system
    - Lubrication system
  - Installation
  - Seatrial
- Preliminary results





Permanent Magnet Thruster development timeline

1998-2004

Evaluation of technology and development of preliminary design/sketches

50 kW prototype design, build and start-up

50 kW thruster testing (functional and water tank test)

2005-2007

Full-scale (800kW) technology demonstrator development

Installation on "Olympic Octopus"

2008-2010

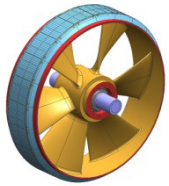
Technology Demonstrator returned to Ulsteinvik

Product testing and design qualification

2010-2011

Assembly of 1st commercial ***PMTT1600, 800kW***

Design approval– modified design (Central Shaft bearing design)



Decision to do quay side testing – October 2011

PMazimuth units installed on R/V Gunnerus

Commissioning of test rig and test start March 2012

PMTT finished October 2012

Commissioning on "Olympic Octopus" Jan 2013

2012-2013 | **2014** | **2015**

R/V Gunnerus PMazimuth

PMTT sales release at SMM Hamburg September 2012

Design and review of PMazimuth

Pmazimuth FAT tests and delvery

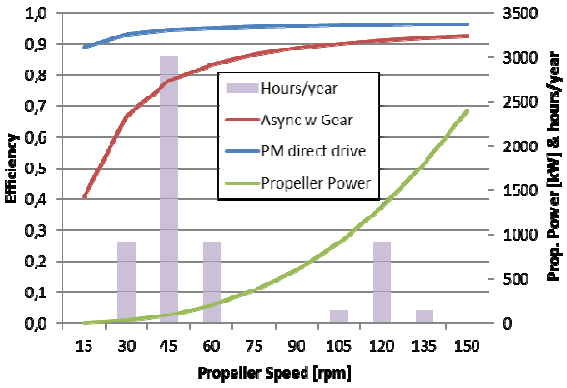
PMTT deliveries

Pmazimuth Seatrial

Why Permanent Magnet (PM) Technology?

1. EFFICIENCY

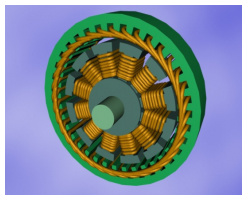
- *No energy is used for excitation of rotor*
- *Higher efficiency over entire speed range*
- *Low heat generation in the machine components*
- *Best candidate for applications where fuel save is important*

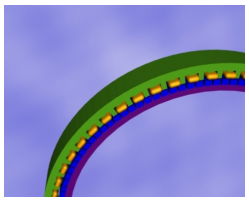


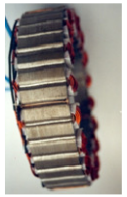
Machine Efficiency

2. SIMPLICITY

- *Permanent rotor magnetic field*
- *Simple construction*
- *Robust candidate for high reliability applications*
- *Best candidate for integrated product*



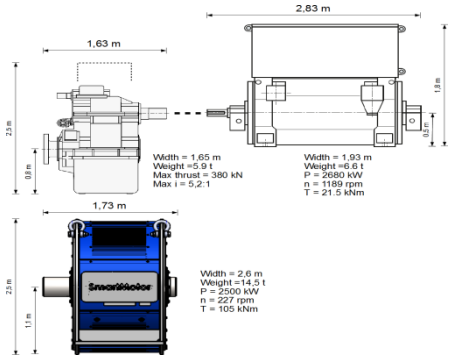




Machine Configuration

COMPACTNES

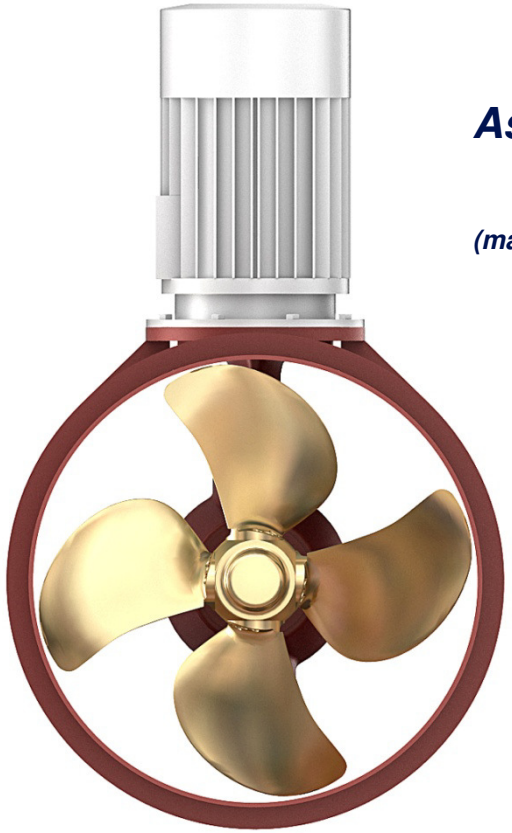
- *High torque density machine*
- *50 % more compact than asynchronous machine*
- *Slim stator and rotor due to high pole design*
- *Strong dynamic performance (synchronization rotor - stator*
- *Best candidate where space is valued in the application)*



Machine size and weight

Why PM Technology for Thrusters?

Efficiency | **Robustness** (Simplicity) | **Compactness**

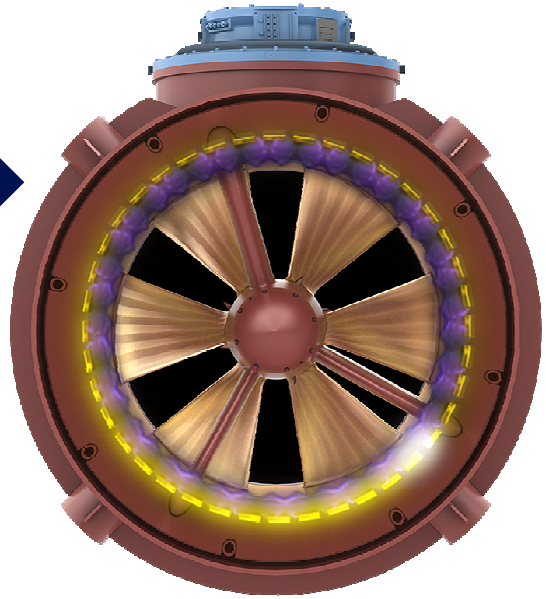


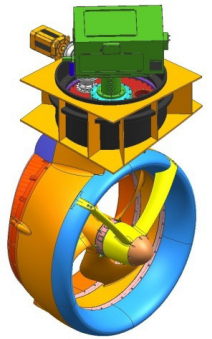
Asynchronous induction motor
(max efficiency is 96%)

+

Oil filled, geared thruster unit

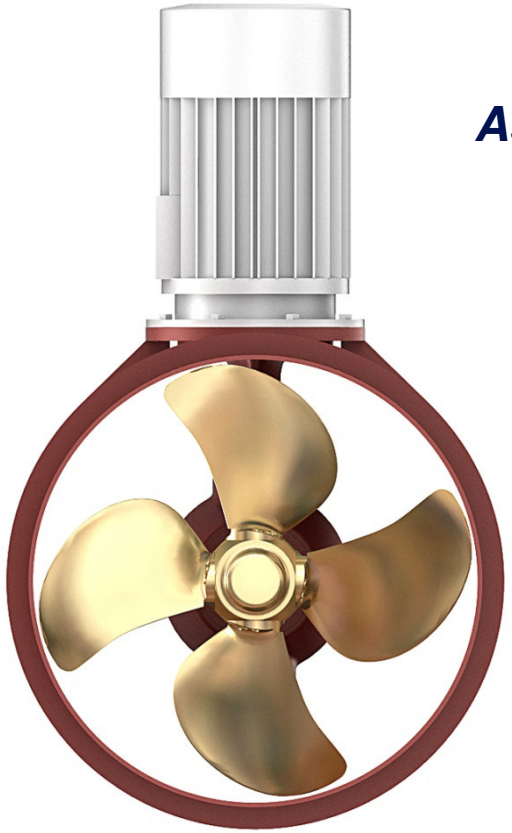
Integrated synchronous permanent magnet machine
(efficiency is above 97% . higher for partial loads)





Why PM Technology for Thrusters.

Efficiency | **Robustness** (Simplicity) | **Compactness**

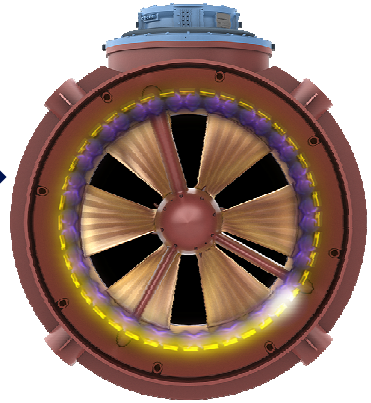


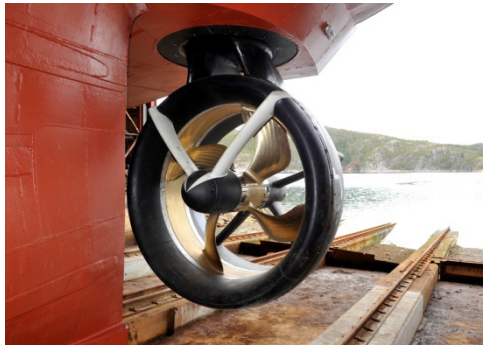
Asynchronous induction motor

\+

Oil filled, geared thruster unit

Integrated synchronous permanent magnet machine





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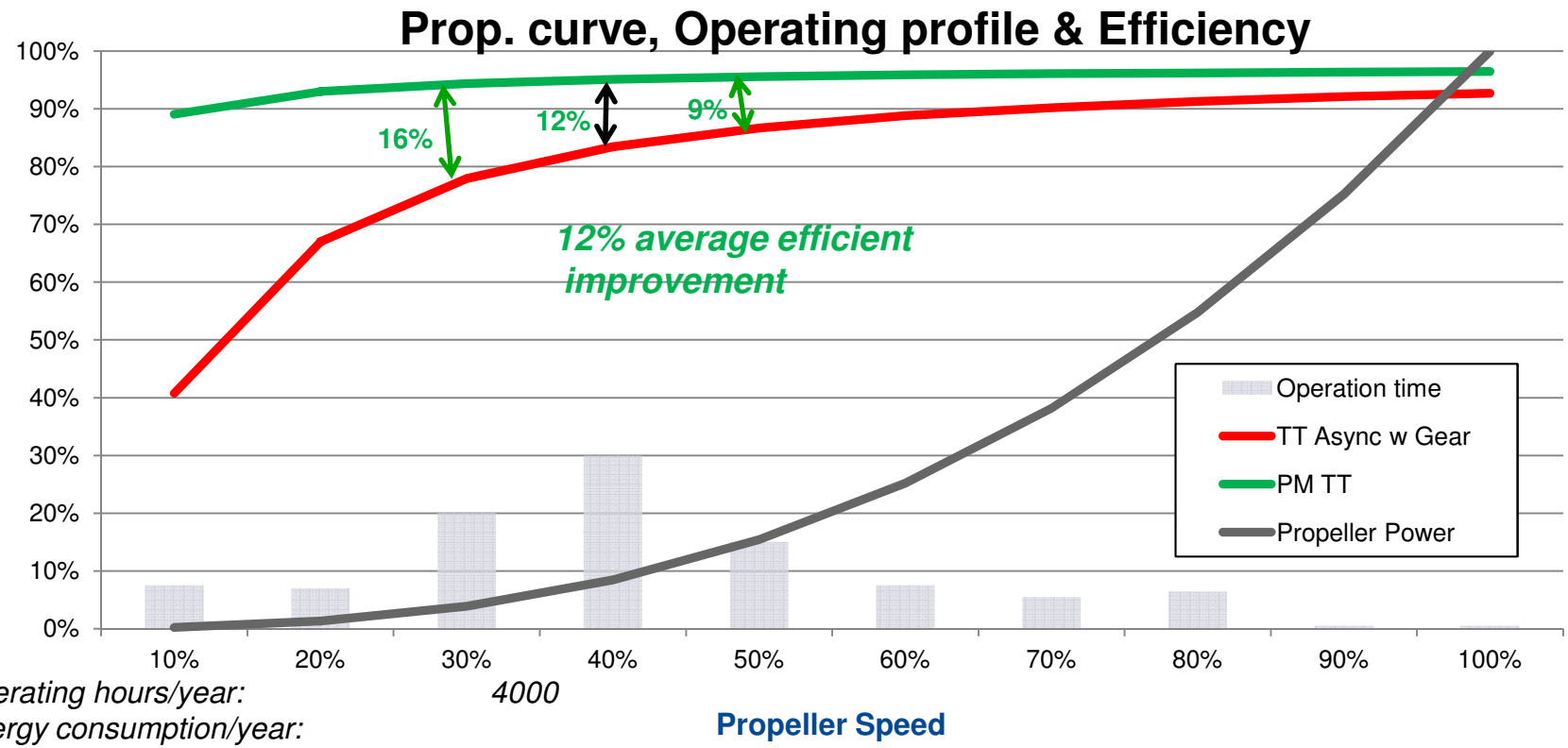
Why PM Technology for Thrusters?

Efficiency | **Robustness** (Simplicity) | **Compactness**



Operating hours/year: *4000*

Energy consumption/year:

Asynch w/gear

1015400 kWh

PMTT

943400 kWh

Energy saved (kWh/year): 72004 kWh

Energy cost 0,808 NOK/kWh

Reduction in fuel cost for 4 PMTT2000

NOK/year 250 000

NOK/lifetime 7 500 000

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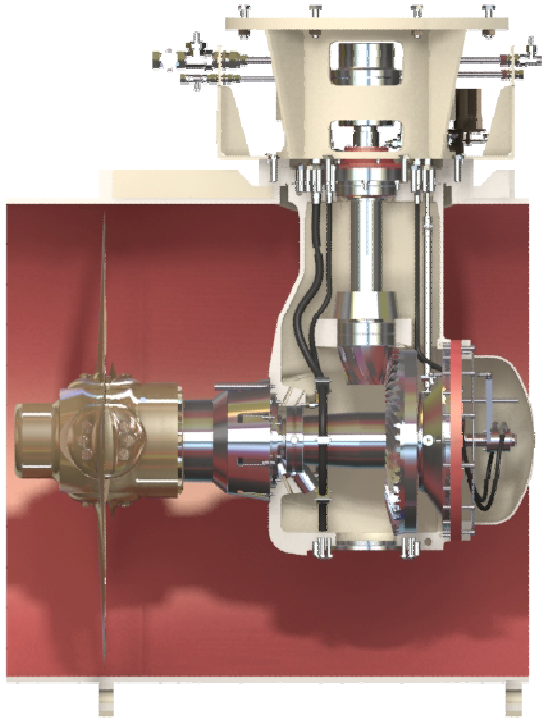
Why PM Technology for Thrusters?

Efficiency	**Robustness** (Simplicity)	Compactness

Multiple ***moving parts***

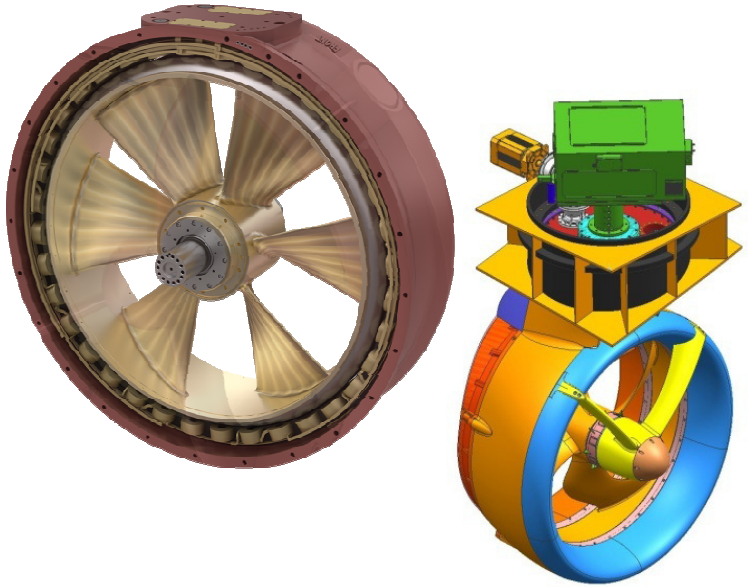


Pitch system

+

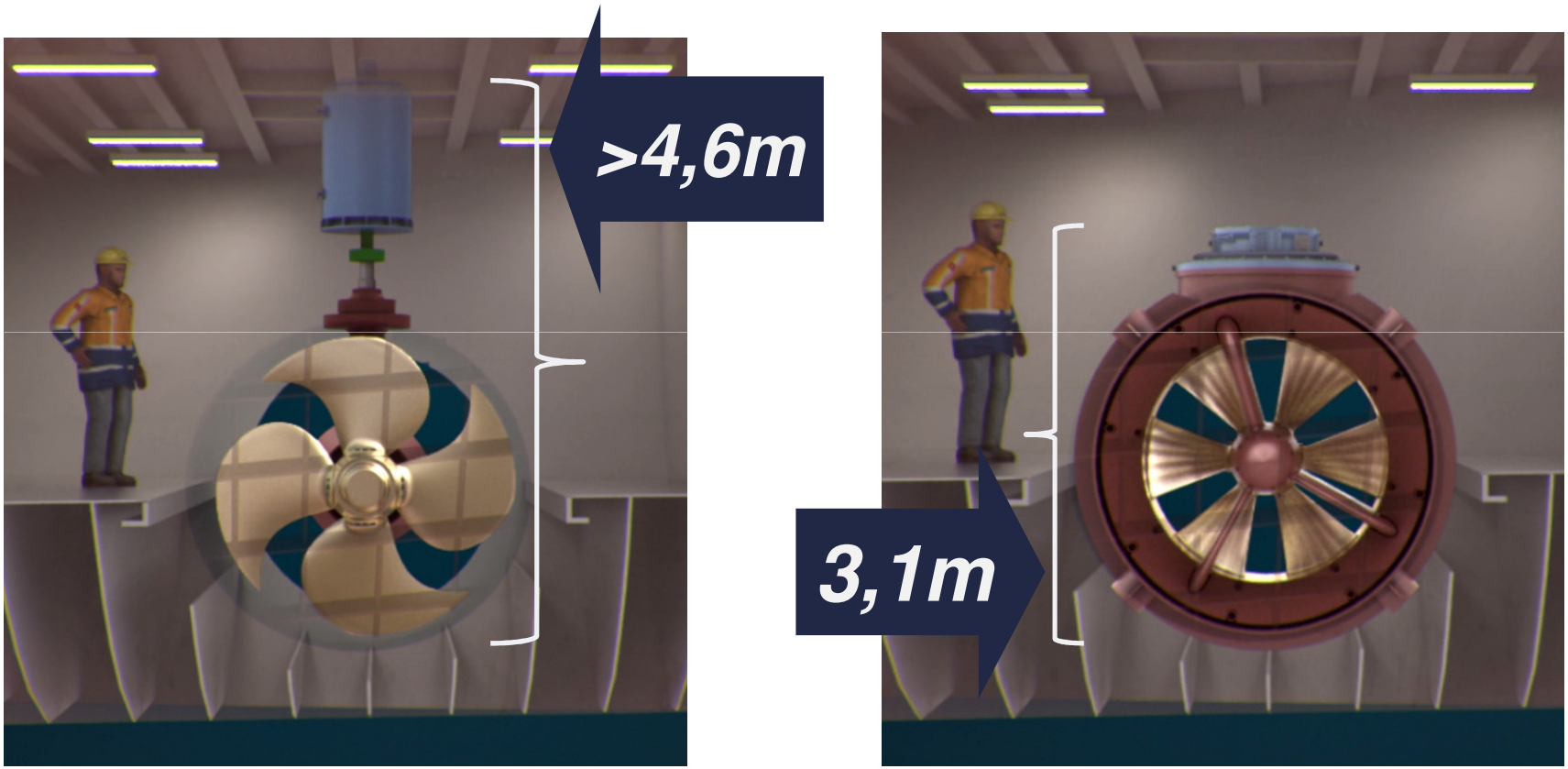
Mechanical transmission line

1 ***moving part (propeller)***
Steering gear with improved classic design



Why PM Technology for Thrusters?

Efficiency	Robustness (Simplicity)	Compactness



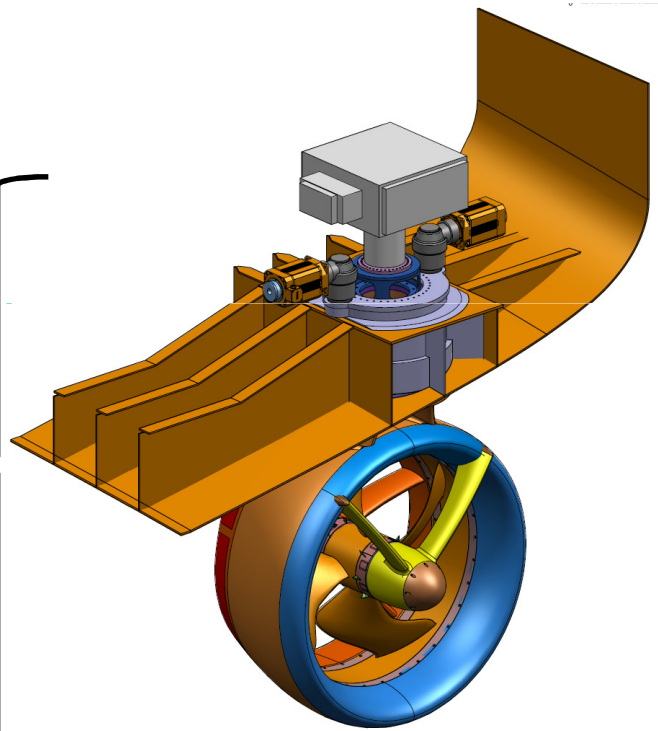
Why PM Technology for Thrusters

Efficiency	Robustness (Simplicity)	Compactness

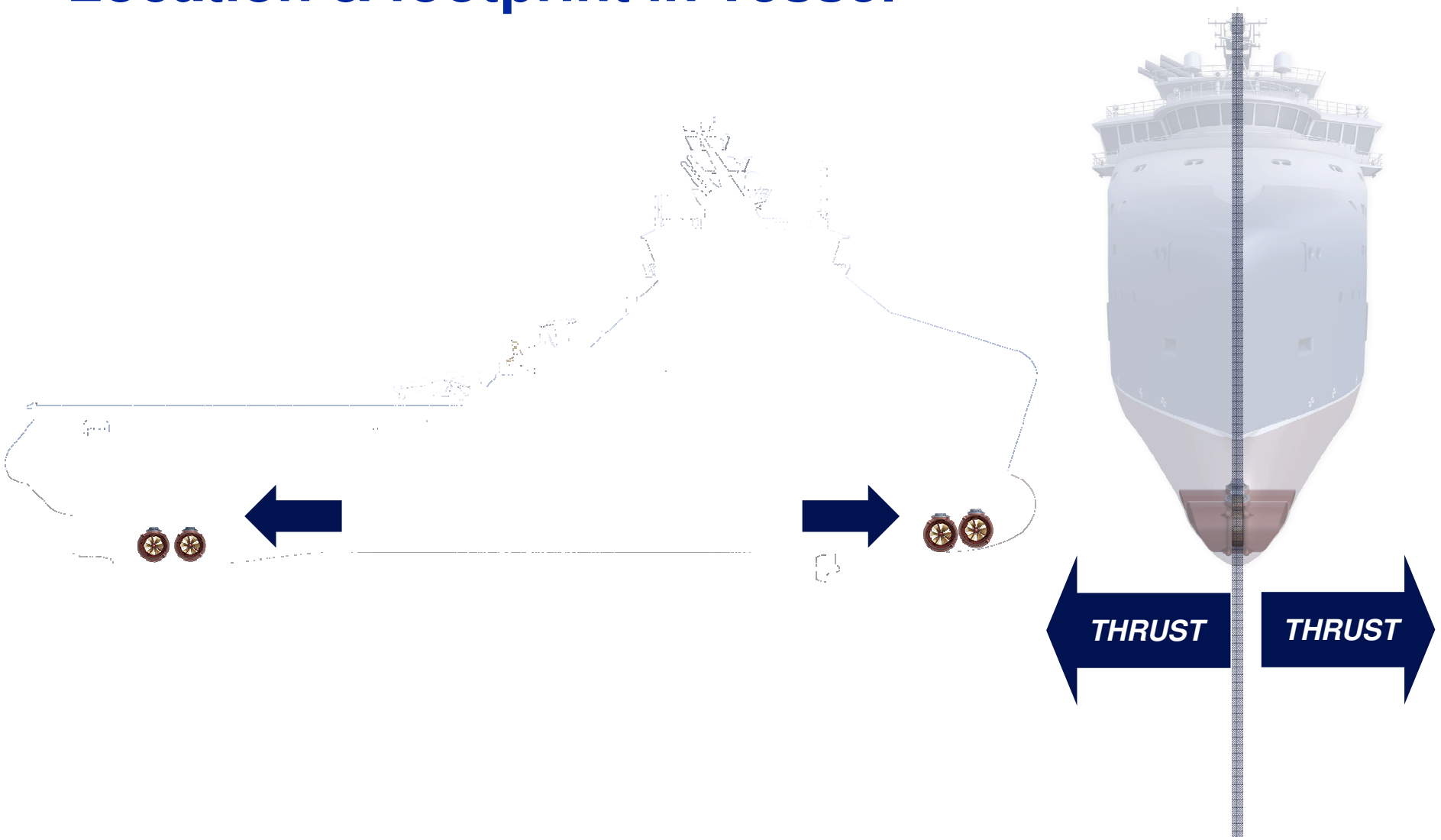
>4,6m

Total 3,6m
Inside:
1,5M

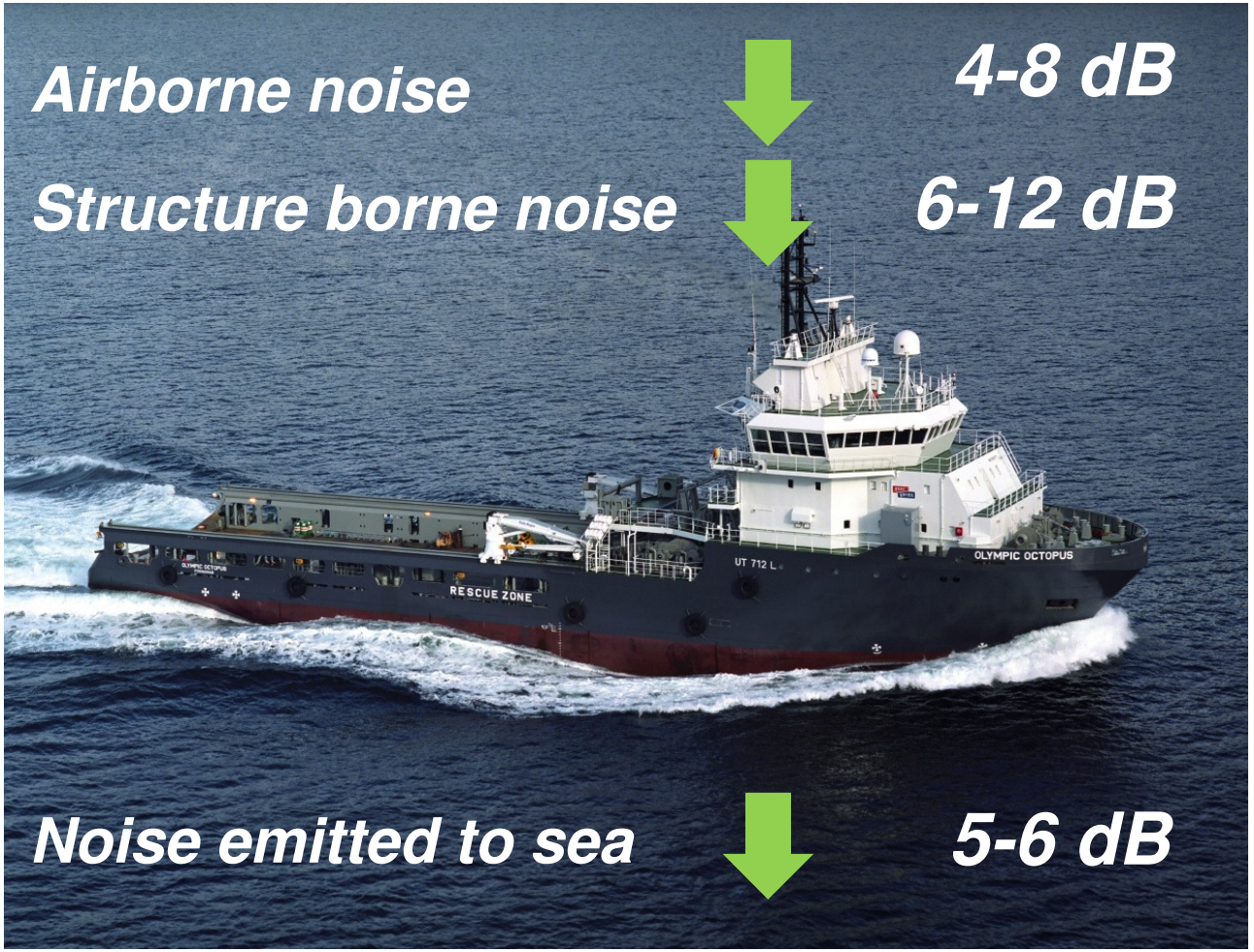
All parts
in 1 room

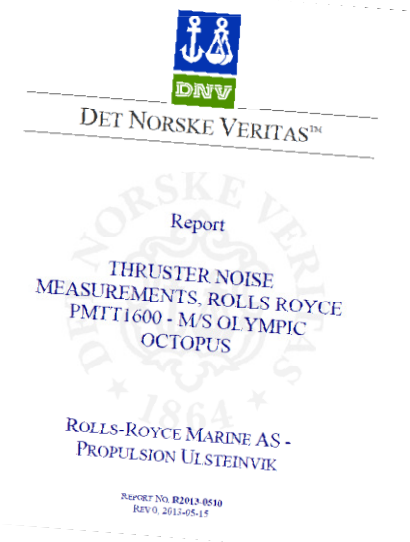


Location & footprint in vessel



Noise measurements – ”Olympic Octopus”




DET NORSKE VERITAS™

Report

THRUSTER NOISE MEASUREMENTS, ROLLS ROYCE PMTT1600 - M/S OLYMPIC OCTOPUS

ROLLS-ROYCE MARINE AS - PROPULSION ULSTEINVIK

REPORT NO. R2013-0510
REV.0, 2013-05-15

Measurements conducted by DNV, April 2013

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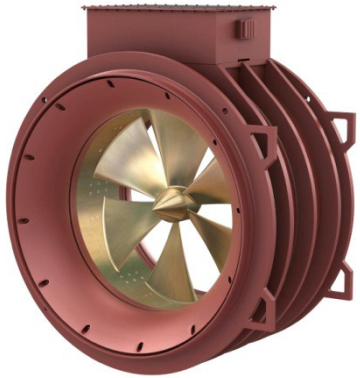
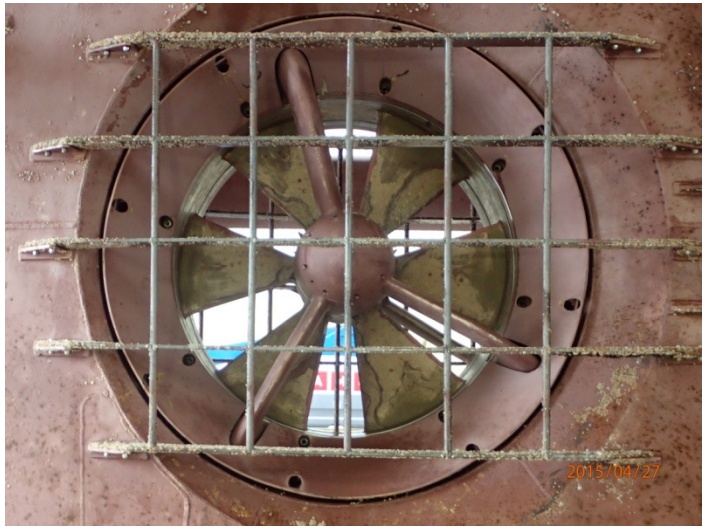
M/S Olympic Octopus PMTT1600 installation

- *Operation hrs: 1200*
- *Commercial unit installed oct 2012*
- *Stern installation, next to TT2000, 883 kW*
- *PMTT operation hrs so far: 3860*
- *No maintenance required during this period*
- *Owner is very pleased with the unit.*





Commercial: PMTT1600, 1000kW and PMTT2000, 1600kW

Permanent Magnet azimuth for R/V Gunnerus

Jointly project between Norwegian University of Science and Technology and Rolls-Royce Marine

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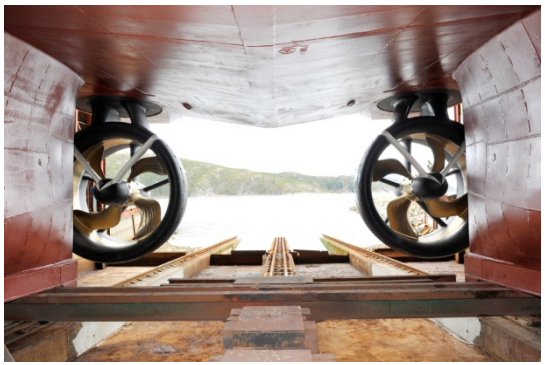
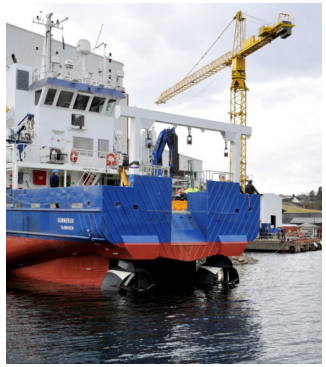
PMazimuth, main propulsion demonstrator installed on R/V Gunnerus. Vessel is owned by Norwegian University of Science and Technology (NTNU)

Project funding by Rolls-Royce and Norwegian Research Council, NTNU allowed us to use R/V Gunnerus as test vessel.



Propulsion system : 2x500kW, 440V 60Hz
"Classic diesel electric "
Length: 31,25m
Breath: 9,6m



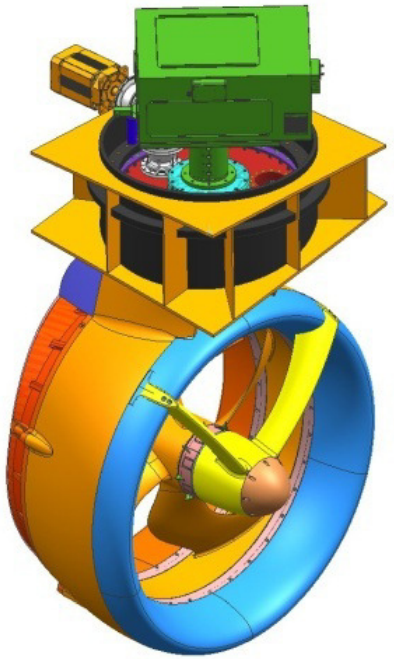
Remove:
Rudder with steering gear
Nozzle with propeller
Shaftline
Gear
Electrical motor
Frequency converter
Bridge control system

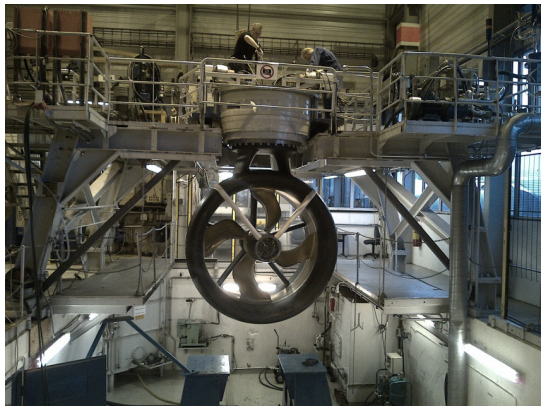
Install:
- **PMazm including steering gear**
- **Lubrication systems**
- **Helicon- control system**
- **Frequency Converter**
- **HEMOS**

Design and inhouse testing

- 500 kW azimuth thruster driven by a PM motor placed inside the nozzle.
- Mechanical strength is 1000kW.
- Nozzle have space for a 1000kW PM motor.
- Reuse elements from PMTunnel thruster.
- Helicon-X control system,
- RR PES Frequency converters.
- HEMOS data acquisition system,

- Design and production: 2012 to Nov 2014
- FAT. Nov-Dec- 2014
- Delivered Dec-14
- Seatrail: March-April-15





Control system and frequency converters

Helicon-X control system and Rolls-Royce frequency converters, well proven products

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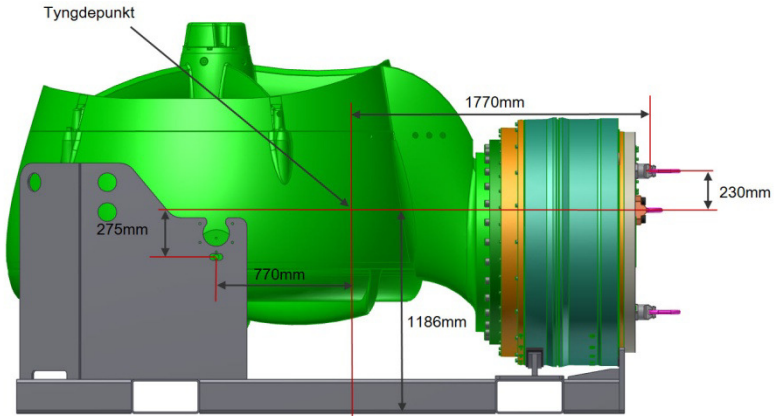
Installation

Delivered in transportation and installation frame.



Hoisted in place using crane and tackle blocks

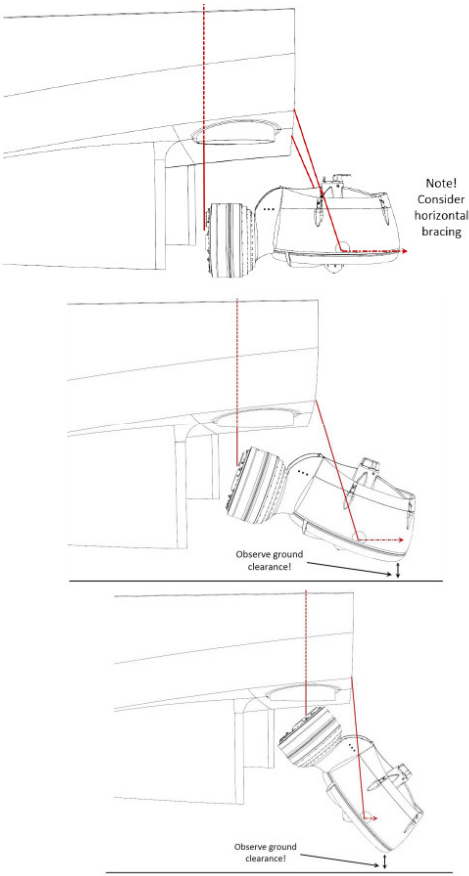


Figure 3.2-9 Lifting and up-ending thruster

Commissioning and Seatrial document

SEA TRIAL PLAN — Rolls-Royce

Title	RR Part No.	Issue No.
PMAZM 1900 Prototype @ R/V GUNNERUS Sea Trial Plan		B

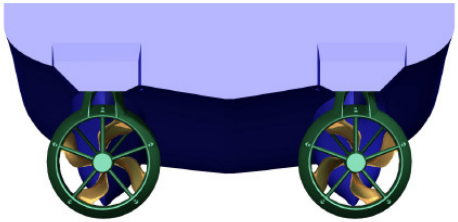
Authors	Date
Steinar Aasebø	05.12.2014

Summary

Sea trial plan for R/V Gunnerus after installation of PMAZM1900-Prototype.

Quay tests: 6 days.

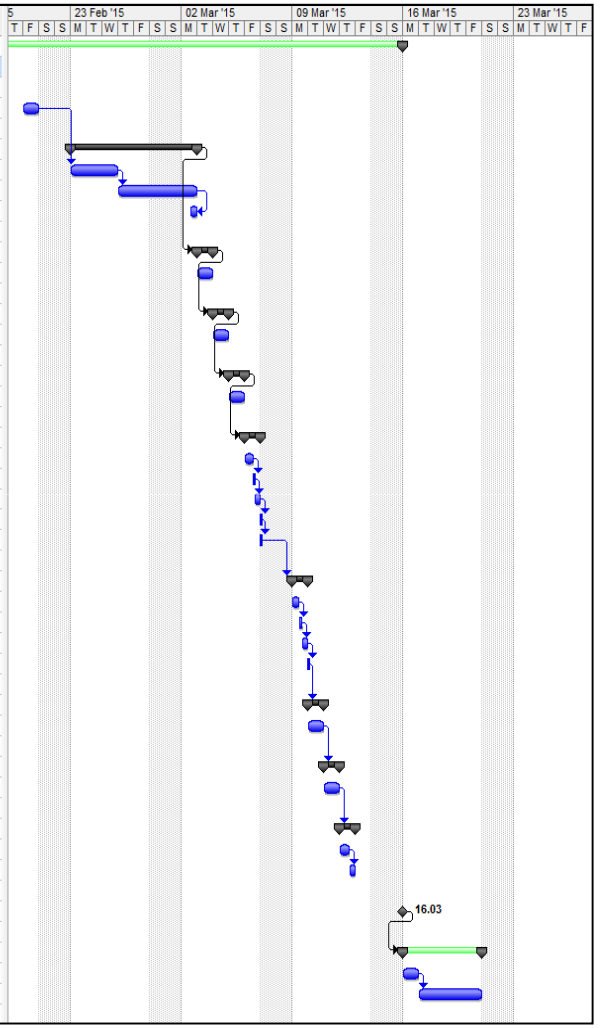
Yard sea trials, including DNV hydroacoustic measurements: 8 days (10 hrs/day).



Circulation:	Approved by:
Gunnar Johnsen	

Project: PMAZM 1900 Prototype		
Customer: Rolls-Royce Marine AS	Project number	Charge Element
Security classification: Restricted	Title: PMAZM 1900 Prototype @ R/V GUNNERUS	Page: 1 of 11

Task Name	Duration	Start
Yard	52 days	Thu 01.01.15
Gunnerus to yard	0 days	Mon 05.01.15
PMAZM delivered from RR	0 days	Thu 01.01.15
Gunnerus to sea	1 day	Fri 20.02.15
Quay tests	6 days	Mon 23.02.15
PMAZM startup	3 days	Mon 23.02.15
Setup of control system	3 days	Thu 26.02.15
FMEA and alarm tests	0.5 days	Mon 02.03.15
Sea trial day 1 (max 10hrs)	1 day	Tue 03.03.15
Running in PMAZM	10 hrs	Tue 03.03.15
Sea trial day 2 (max 10hrs)	1 day	Wed 04.03.15
Adjustment of HCX3 parameters	10 hrs	Wed 04.03.15
Sea trial day 3 (max 10hrs)	1 day	Thu 05.03.15
DP tuning and test	10 hrs	Thu 05.03.15
Sea trial day 4 (max 10hrs)	1 day	Fri 06.03.15
Autopilot tuning	5 hrs	Fri 06.03.15
Speed trials	2 hrs	Fri 06.03.15
Steering tests zig-zag	1 hr	Fri 06.03.15
Steering tests turning circle	1 hr	Fri 06.03.15
Acceleration test	1 hr	Fri 06.03.15
Sea trial day 5 (max 10hrs)	1 day	Mon 09.03.15
Crash stop test by azimuth	3 hrs	Mon 09.03.15
Crash stop test by reversing	3 hrs	Mon 09.03.15
FMEA test - take me home	2 hrs	Mon 09.03.15
FMEA test - manouvring with one unit	2 hrs	Mon 09.03.15
Sea trial day 6 (max 10hrs)	1 day	Tue 10.03.15
Endurance test	10 hrs	Tue 10.03.15
Sea trial day 7 (max 10hrs)	1 day	Wed 11.03.15
DNV hydroacoustic	1 day	Wed 11.03.15
Sea trial day 8 (max 10hrs)	1 day	Thu 12.03.15
DNV hydroacoustic	6 hrs	Thu 12.03.15
Visual inspection of thrusters by camera	4 hrs	Thu 12.03.15
Handover	0 days	Mon 16.03.15
NTNU	5 days	Mon 16.03.15
Transit to Trondheim	1 day	Mon 16.03.15
NTNU manouevring tests	4 days	Tue 17.03.15



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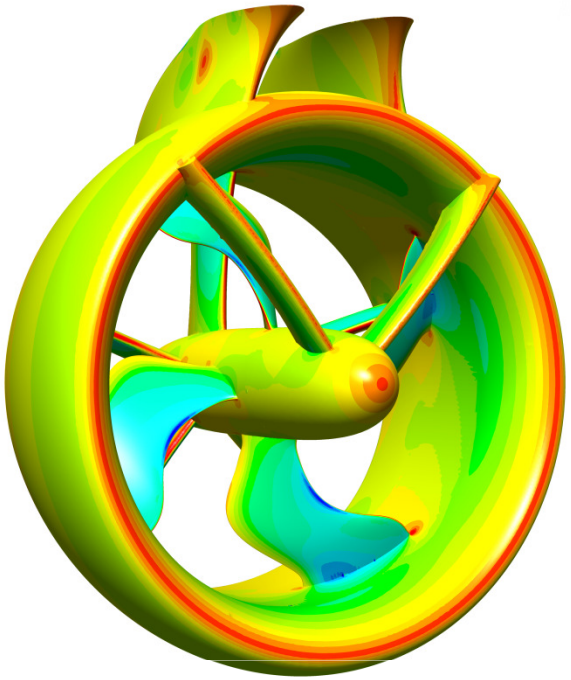
Commissioning and Seatrial

- Standard PMAZM commissioning procedures and check lists are described in the installation manual.
- Control system (HCX3) and the drive system (PES) have their own standard commissioning procedures
- Start-up procedures for PMAZM units, HCX3 and PES dirves are closely connected, and will be coordinated to meet all requirements.

R/V Gunnerus with PMAZM

- Two PMAZM1900 prototypes installed at R/V Gunnerus
- Propeller diameter: 1,9 m
- Speed trials March 27th, 2015



SPEED TRIAL SUMMARY - PMAZM - AS MEASURED

DRAUGHT		INFO	SOG	TOTAL POWER	LOAD
m			kn	kW	%
FP	2.20	Run 1	8.575	225	22.5 %
AP	3.60	Run 2	10.35	467	46.7 %
		Run 3	11.3	721	72.1 %
		Run 4	12.1	994	99.4 %

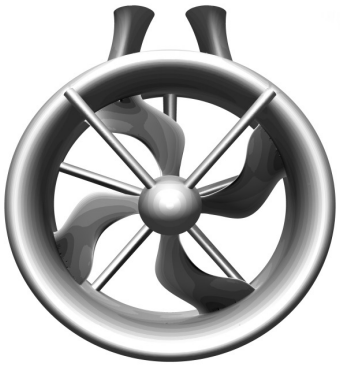
Power vs. speed before / after PMAZM retrofit

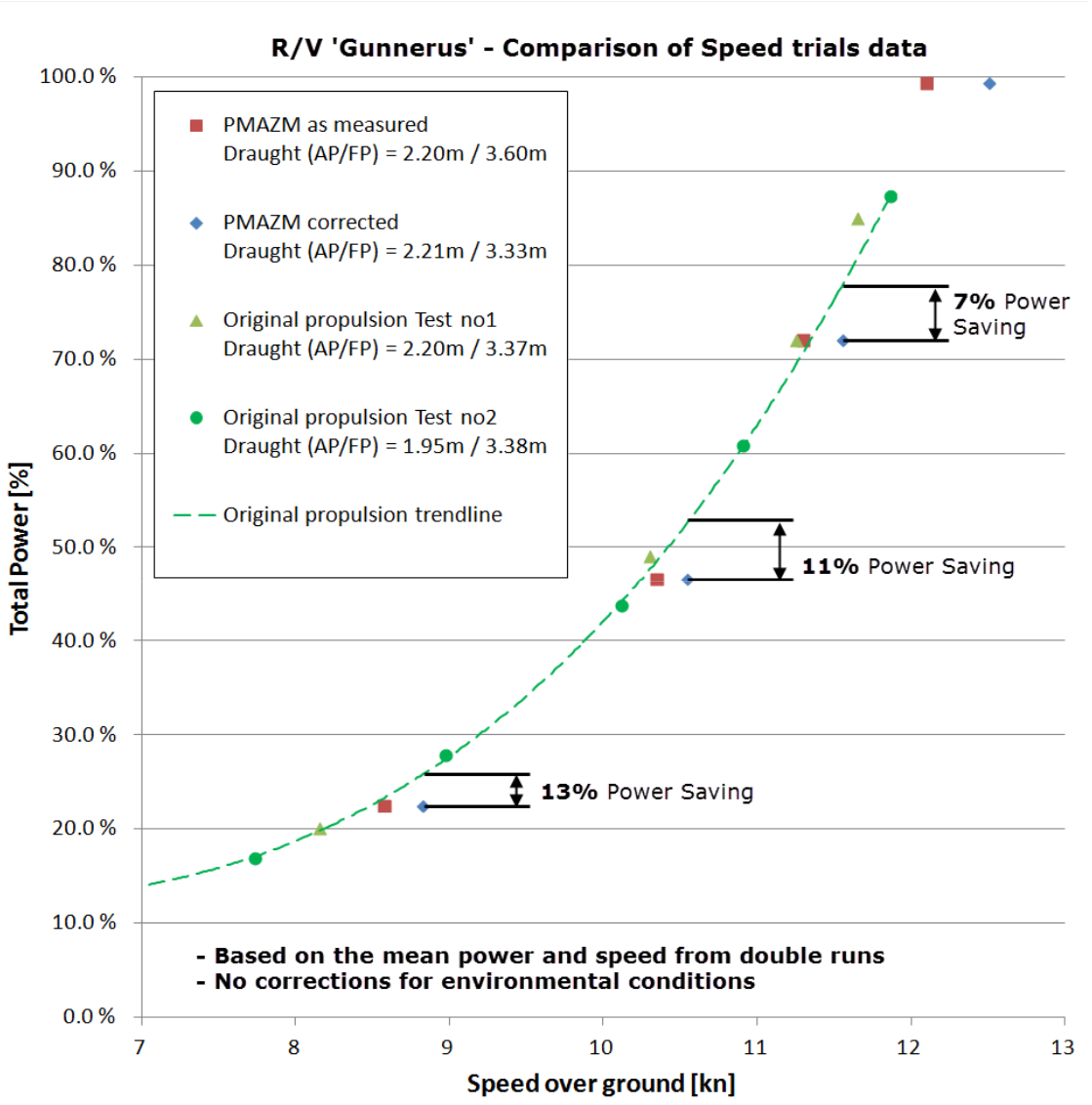
- **Comparison of power consumption .**
- **The results, when corrected for increased displacement, indicate significant power savings:**

8.8 kn ; **13 %** Saving

10.5 kn ; **11 %** Saving

11.5 kn ; **7 %** Saving





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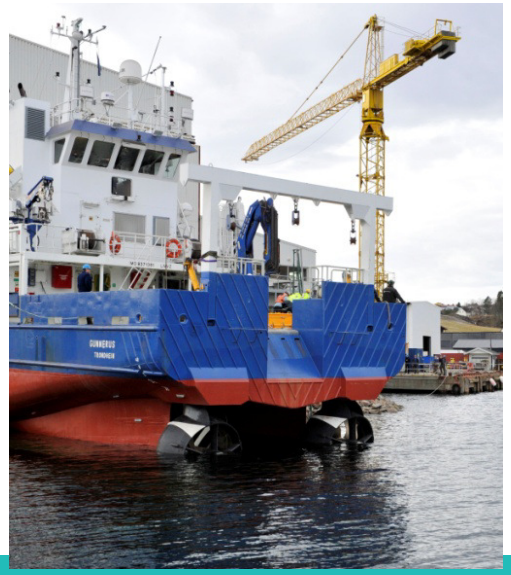
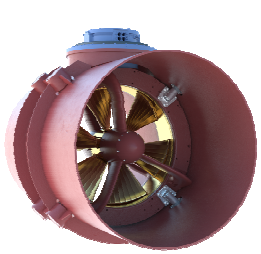
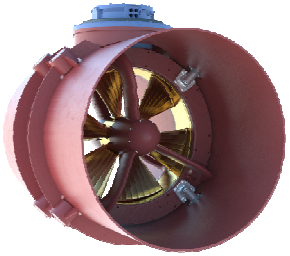
PMazm summary

- **Even though the units only have been in operation for some weeks, some of the operational benefits are already clear:**
  - **Improved efficiency**
  - **Low vibration and noise**
  - **Quick response, (azimuth and rpm)**
  - **Good manoeuvrability**



Product design & features



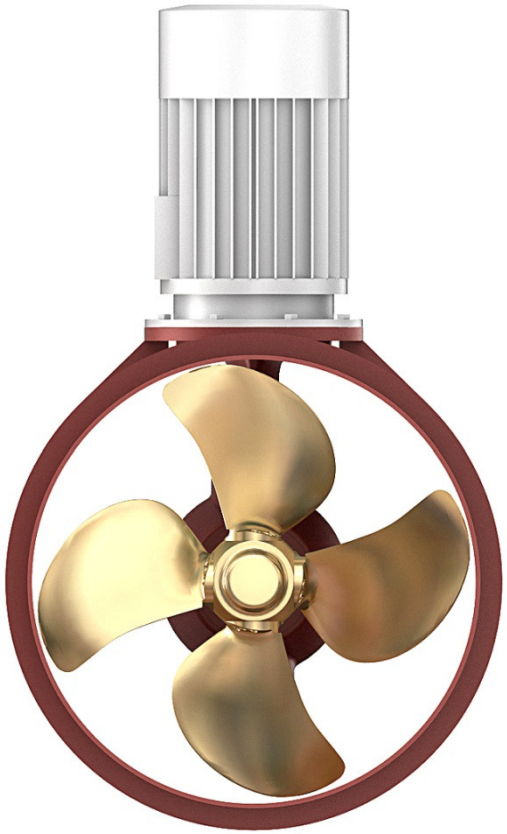


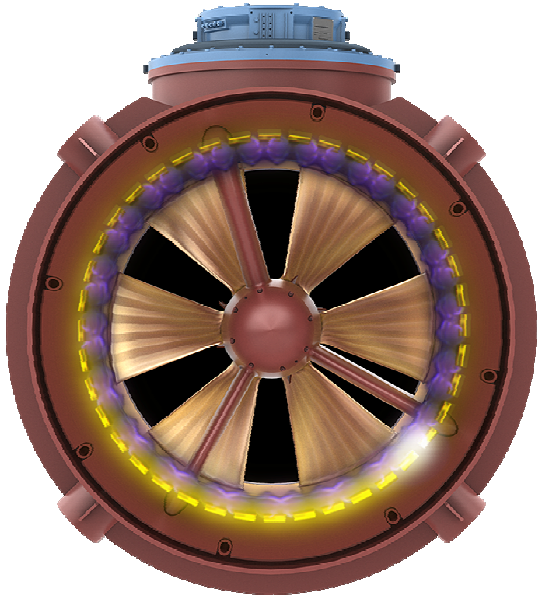
Type	PMTT1600	PMTT2000	PMAZM 1900
Power (Max)	1000 kW	1600 kW	500-1000kW
Propeller Dia	1600 mm	2000 mm	1900 mm
Electrical eff.	97,5%	97,7%	97%
RPM (Max)	338	277	~209
- +100% RPM	~6 sec or as wanted	~6 sec or as wanted	~6 sec or as wanted
VGP Compliant	Yes	Yes	Yes

- *Water Installation (UWI)*
- *Power source:*
  - *Active Front End (AFE), alternatively*
  - *12 (or 18/24) pulse drives*

Life Cycle Cost

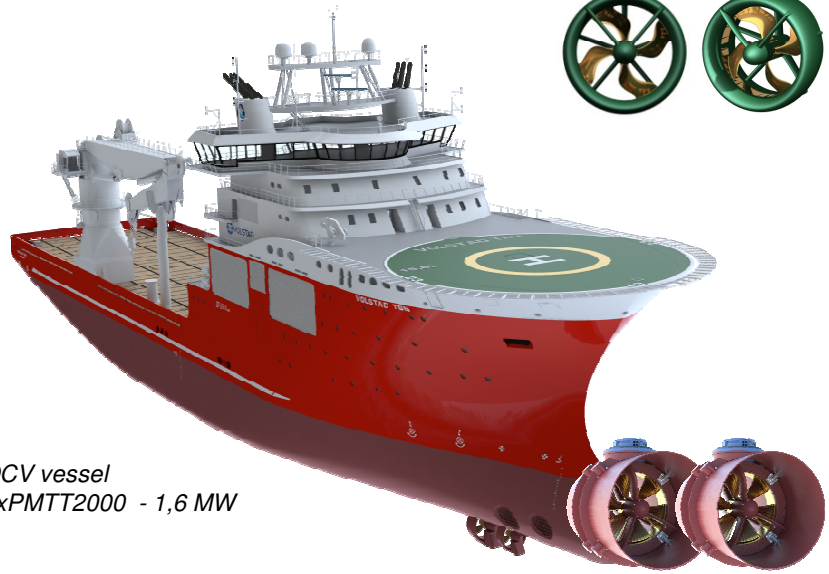
Plug / play agreement possible
PM technology needs no maintenance
Supervision of lubrication system





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

Permanent Magnet driven Thrusters



OCV vessel
2xPMTT2000 - 1,6 MW

Efficient **Robust** **Compact**

Rolls-Royce

The FUTURE