Recent developments in **MARINE ANTI-FOULING COATINGS** with an emphasis on **ENERGY EFFICIENCY**

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Background

- Preventing the attachment of fouling and hence **minimising drag** is the main objective of marine antifouling coatings

- There are other ways of keeping **ship hulls clean** but none so far proven to be viable for the vast majority of the world’s fleet

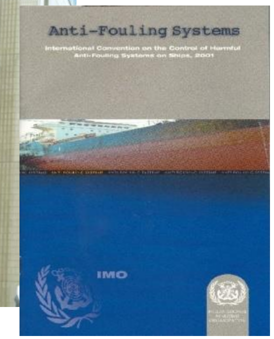
- Keeping **ships’ propellers free of fouling** is equally important for the ship’s performance point of view

- Recent **drivers** have resulted in the increased applications of **Foul Releasing (FR)** type **coatings**, hence more focus on these coatings because….




Background

- **Ever increasing and unpredictable fuel prices due to financial climate**
  - Ship operators are looking at cost more closely than ever



- **IMO and National Legislations**
  - Ship operators have antifouling on their agenda by law
    - *IMO/AFS Convention (October 2001)*
- **New coating technologies and associated products**
  - Non TBT / Non-biocidal (FR) / Hybrid; Ship operators are confused by the claims and counter claims regarding to antifouling performance

- **The environment matters more than ever**
  - Operators want to be environmentally compliant (e.g. ISO)
  - Ships have to be energy efficient in design (EEDI) and operation (EEIO) by law *(as a result of MEPC's "IMO GHG Study")*
  - Ships even may have to radiate less underwater noise in design and operations by law in near future *(MEPC Correspondence Group report "Noise from commercial shipping and its adverse impacts on marine life")*

Some R&D highlights on antifouling coatings - Summary

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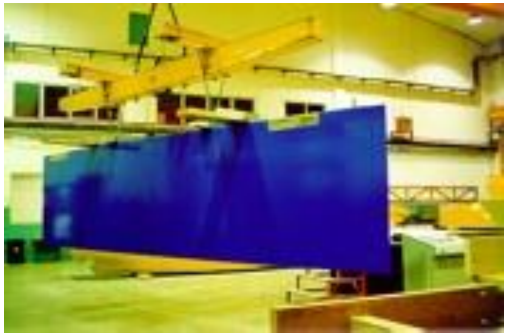
- Comparative **Drag & Boundary layer tests** with different type coatings (e.g. SPC & FR) in different towing tanks, tunnels using different testing bodies (e.g. flat plane, rotating drum, axisymmetric body)

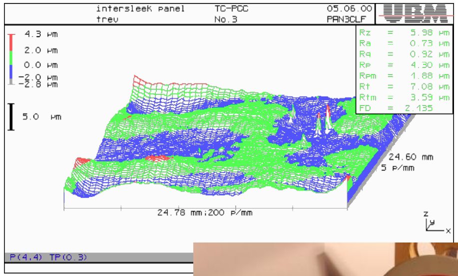
- **Surface roughness measurements** and characterization using different equipment. Drag-Roughness correlations

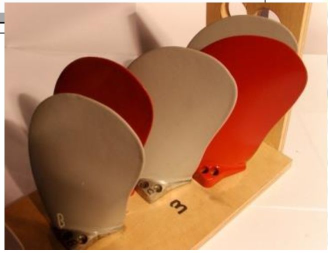
- Activities in major **European collaborative (FP) projects** involving novel FR coating development and **holistic energy efficiency** of ships

- **"In-service" issues** of FR coatings

- **Dedicated monitoring systems** for energy efficiency of coatings







R&D Highlights – Drag and Boundary Layer tests

- **Drag tests** (in Towing tanks / Rotor) confirmed that freshly applied FR coating gave less drag increase with reference to the uncoated surface than the freshly applied SPC coating

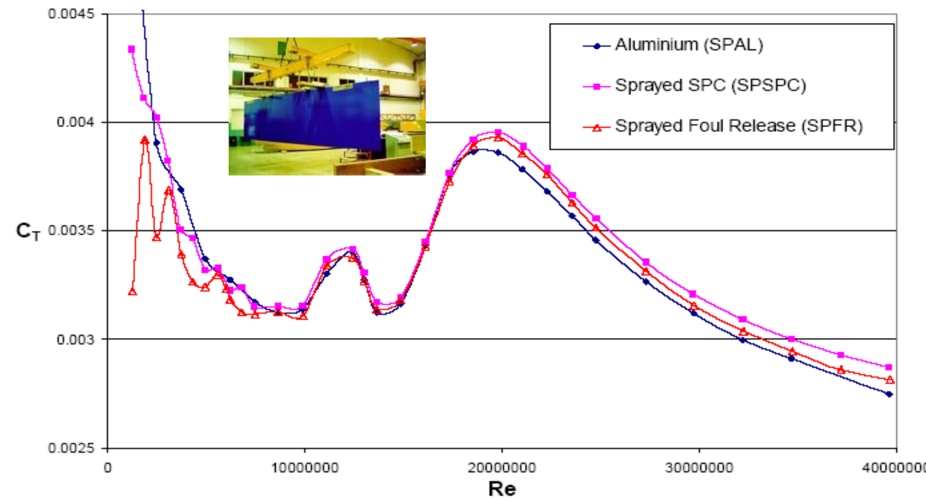
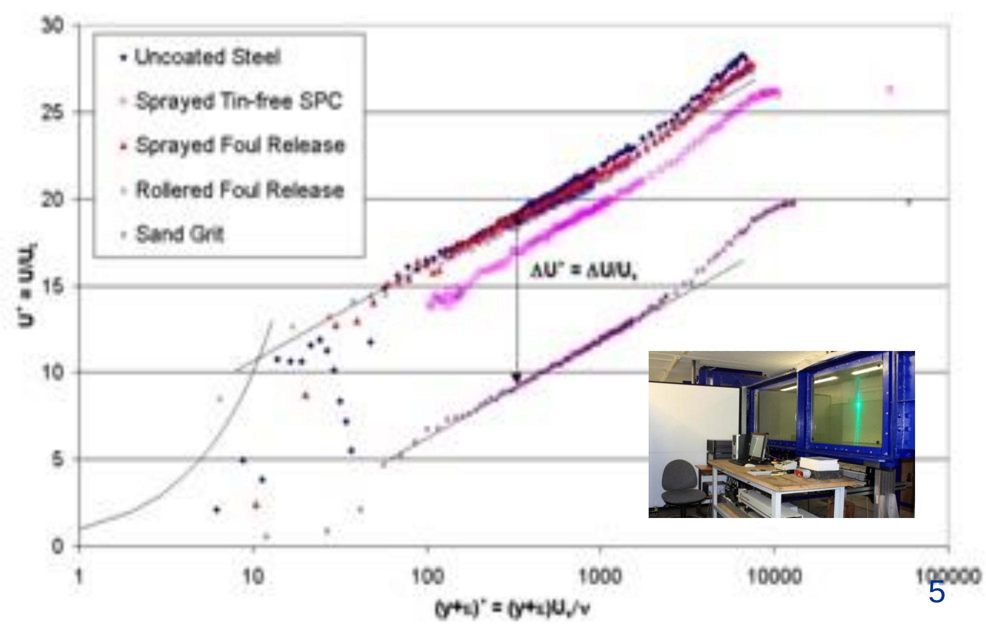


Figure 4. Total resistance coefficients against Reynolds number in the CEHIPAR Calm Water Tank (in between brackets are the codes of the surfaces as used in Table 1).

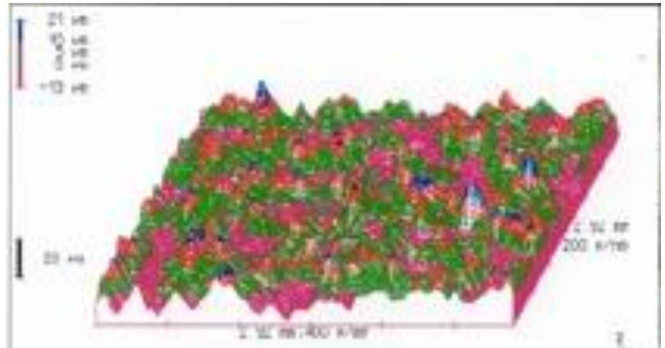
- The roughness functions of the different surfaces from the **BL tests** indicated that on average the FR surfaces exhibit less drag than SPC surfaces, which is in agreement with the findings from the towing tank and rotor experiments



R&D Highlights – Surface roughness measurements

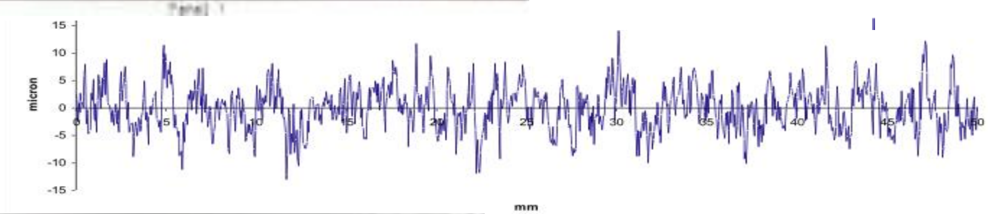
• Detailed **roughness analysis** revealed that the main difference between the FR and SPC systems lies in the texture characteristics.

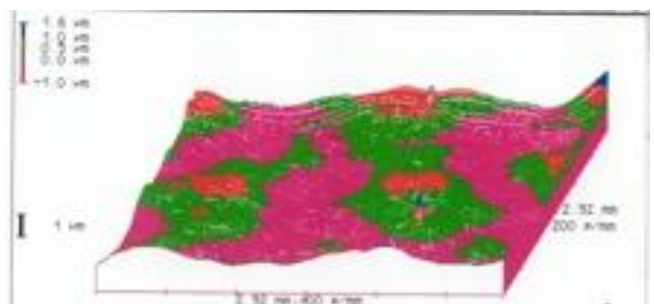
• Whereas the SPC surfaces display a typical spiky ‘closed texture’, the FR surfaces exhibit a wavy, ‘open texture’.



Freshly sprayed SPC

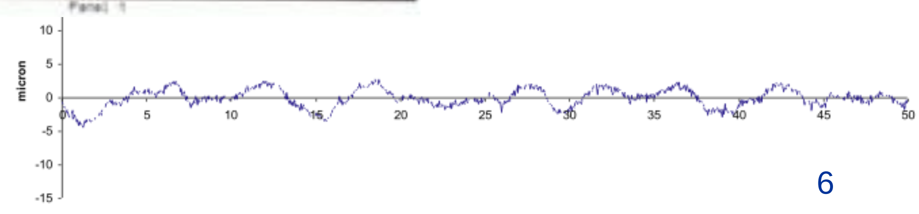
SPC Roughness profile:
Ra = 3.26
Rq = 4.04
Rt = 19.98
Sk = 0.01
Ku = 3.29
Sa = 1.90





Freshly sprayed F/R

Foul Release Roughness profile:
Ra = 1.10
Rq = 1.21
Rt = 4.50
Sk = -0.87
Ku = 5.04
Sa = 0.23

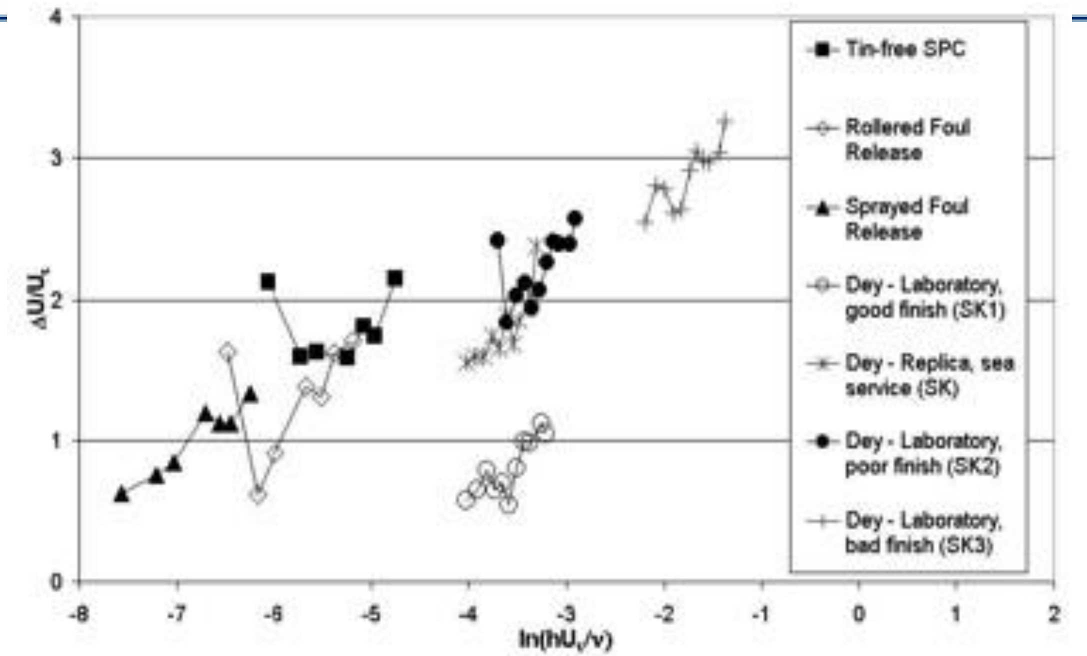


R&D Highlights – Drag-roughness correlations

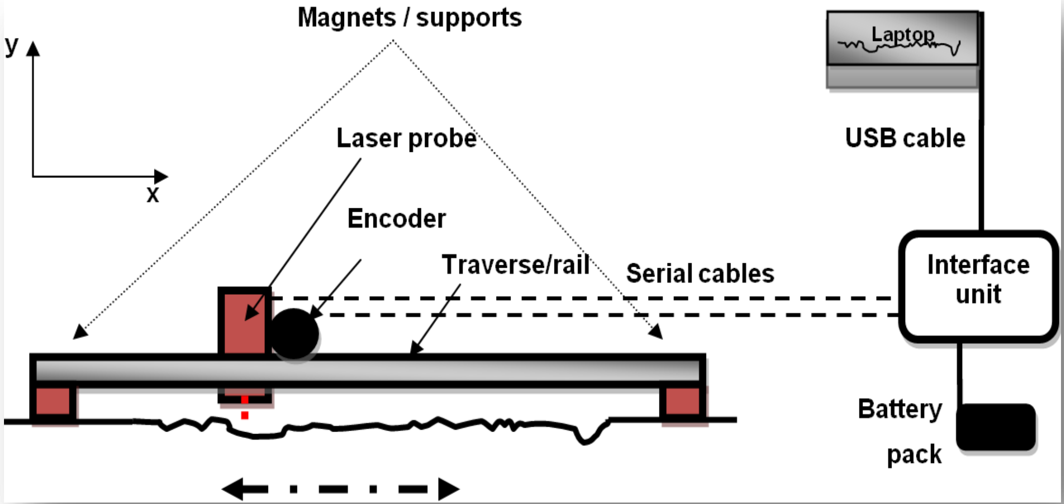
- <u>Correlation of roughness</u> with drag for FR coatings could not be done using solely a single roughness parameter. It is necessary to find other parameters <u>to represent the effect of paint texture.</u>

- Even the <u>measurement of the single roughness</u> parameter using a stylus based equipment (e.g. BMT Roughness Analyser) is extremely <u>difficult and open to question for FR coated hull surfaces</u>.

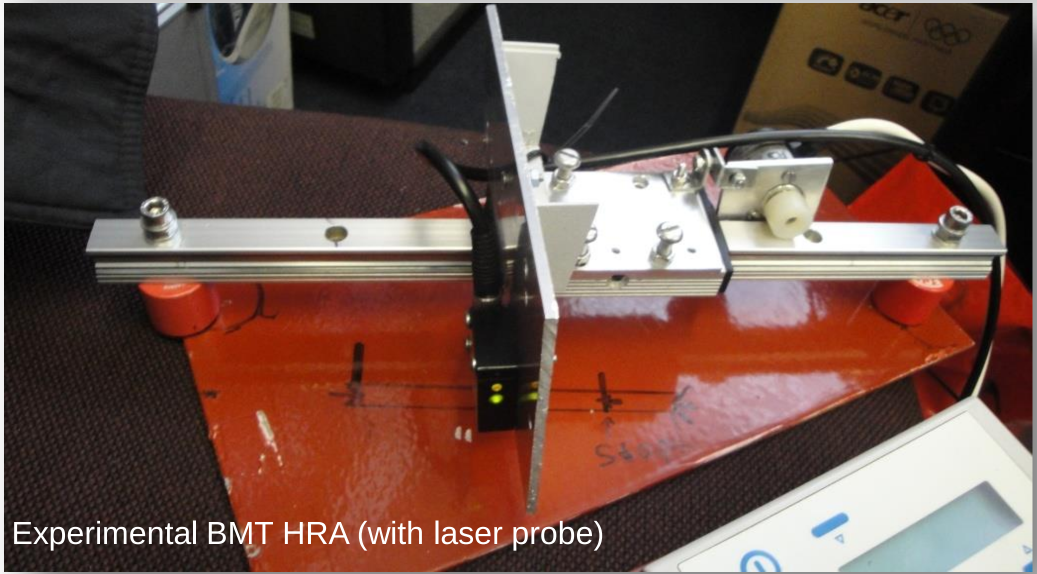
- <u>Measurement of texture parameters requires modification of this equipment</u> as well as consideration of other measurement techniques (e.g. optical) implemented on a robust, industrial device.



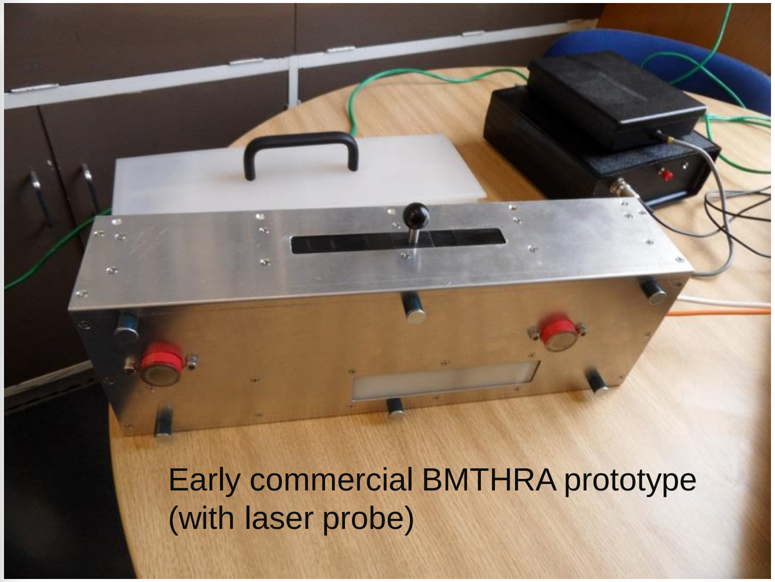
R&D Highlights – Enhanced BMT hull roughness analyser



Standard BMT HRA (with stylus probe)

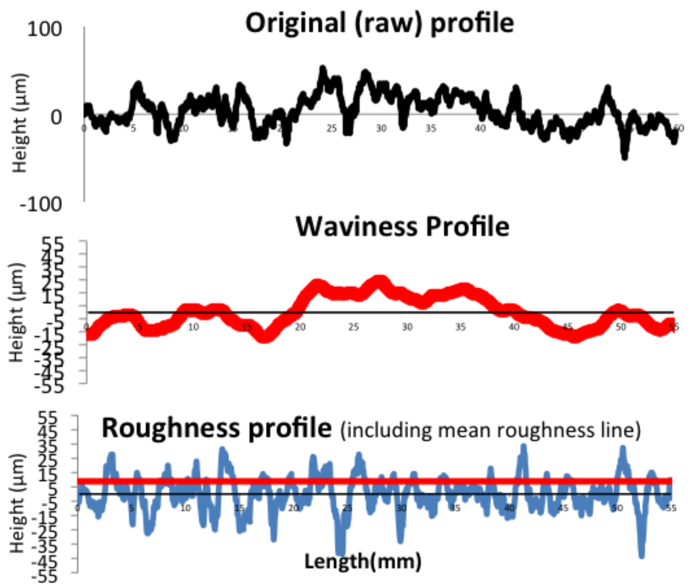


Experimental BMT HRA (with laser probe)



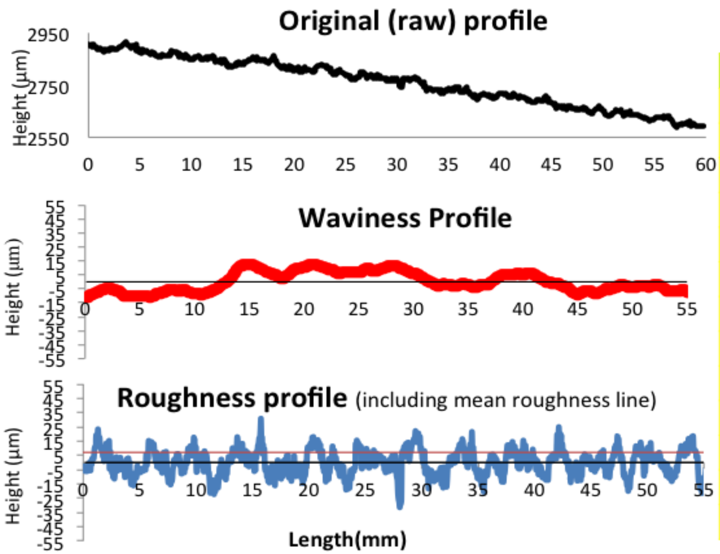
Early commercial BMTHRA prototype (with laser probe)

R&D Highlights – Enhanced BMT hull roughness analyser



Lc (mm)	5
Ra	7.041
Rq	8.790
Rt	39.480
Sk	-0.230
Ku	2.722
Sa	3.315
λα	12.848
m_2	0.006
De	8.820
Dz	2.798
α(1)	13.395
m_4	1.45E-05
α(3)	25.911

Desktop laser profilometer results (Cut-off length: 5mm)

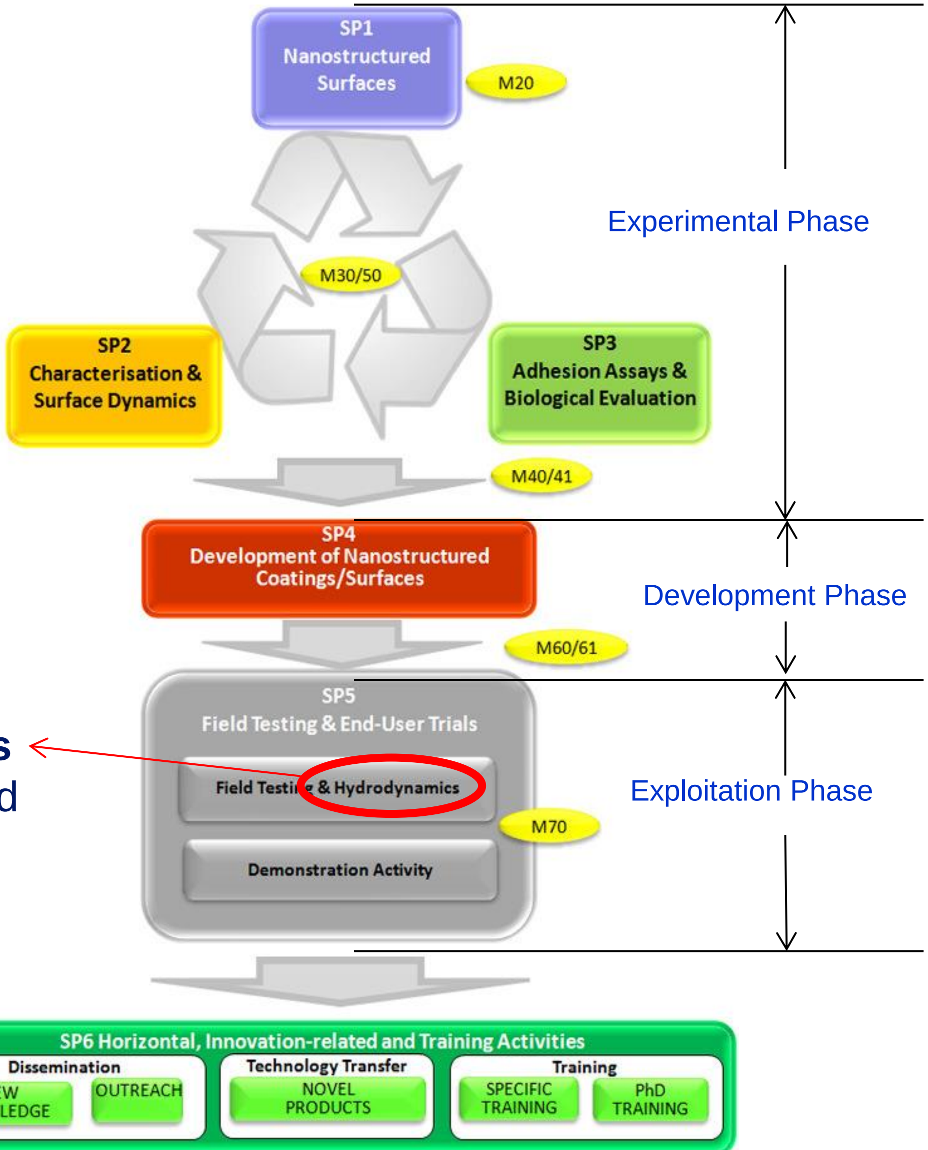


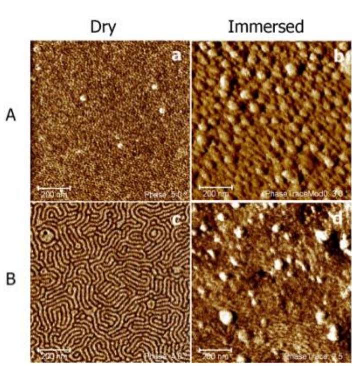
Lc (mm)	5
Ra	7.533
Rq	9.265
Rt	40.658
Sk	-0.015
Ku	2.654
Sa	3.288
λα	13.669
m_2	0.006
De	9.273
Dz	2.846
a(1)	10.796
m_4	1.67E-05
a(3)	40.871

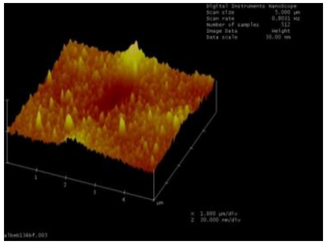
New (modified) BMT profilometer results (Cut-off length: 5mm)

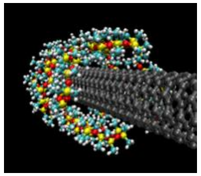
R&D Highlights – Novel FR coating hydrodynamic performance

- Integrated EU-FP6 Project AMBIO (NMP4-CT-2005-011827)
- Advanced nanostructured surfaces for the control of biofouling)
- 5 years project with 31 members and 20M Euro budget; completed in 2010
- 500 different nanostructured coatings (64 generic chemistries) were developed at laboratory-scale
- 15 were down-selected for field testing and end user tests; 5 novel coatings were patented
- In AMBIO **hydrodynamic drag characteristics** of some promising novel coatings were explored

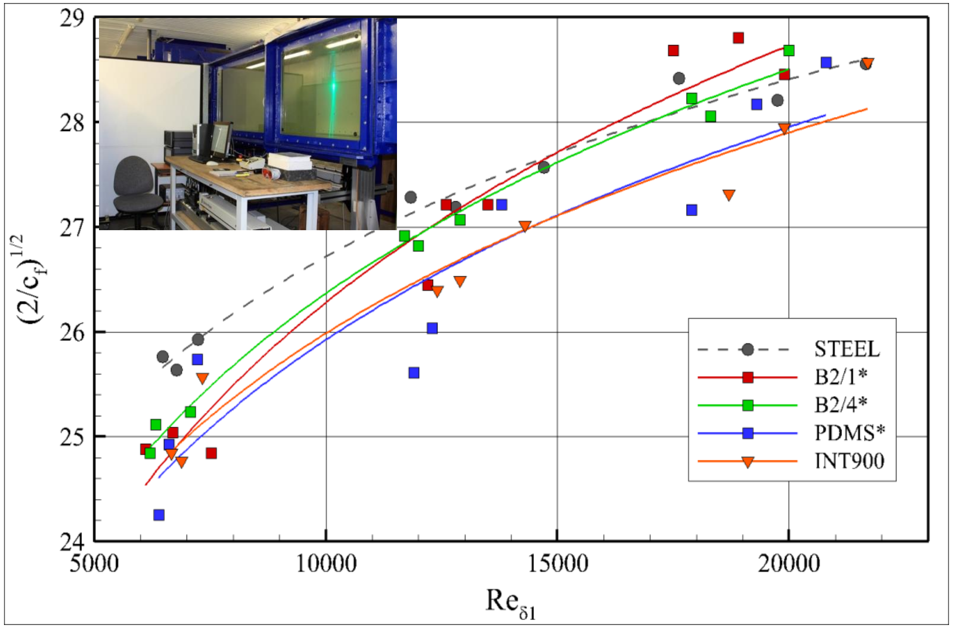


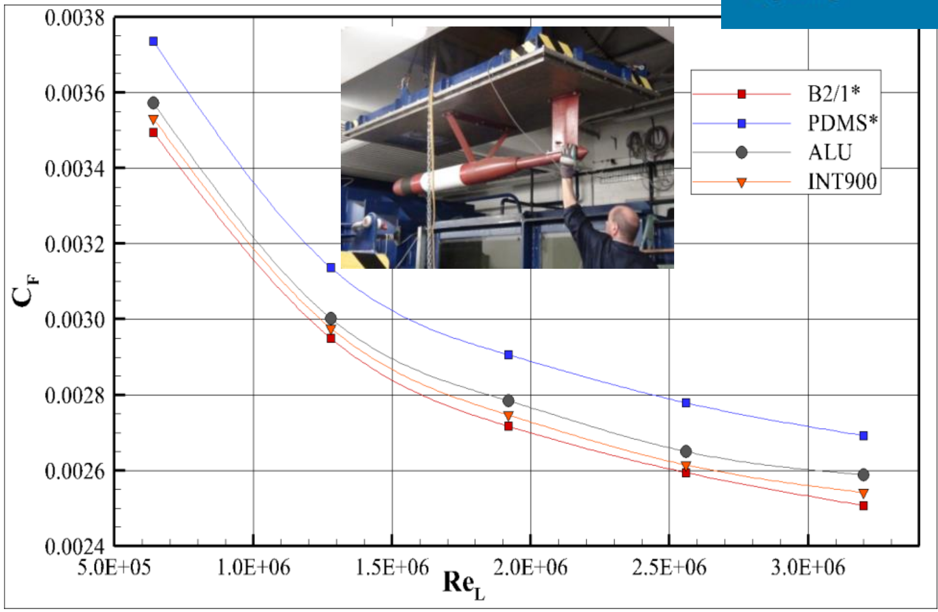






R&D Highlights – Novel FR coating hydrodynamic performance

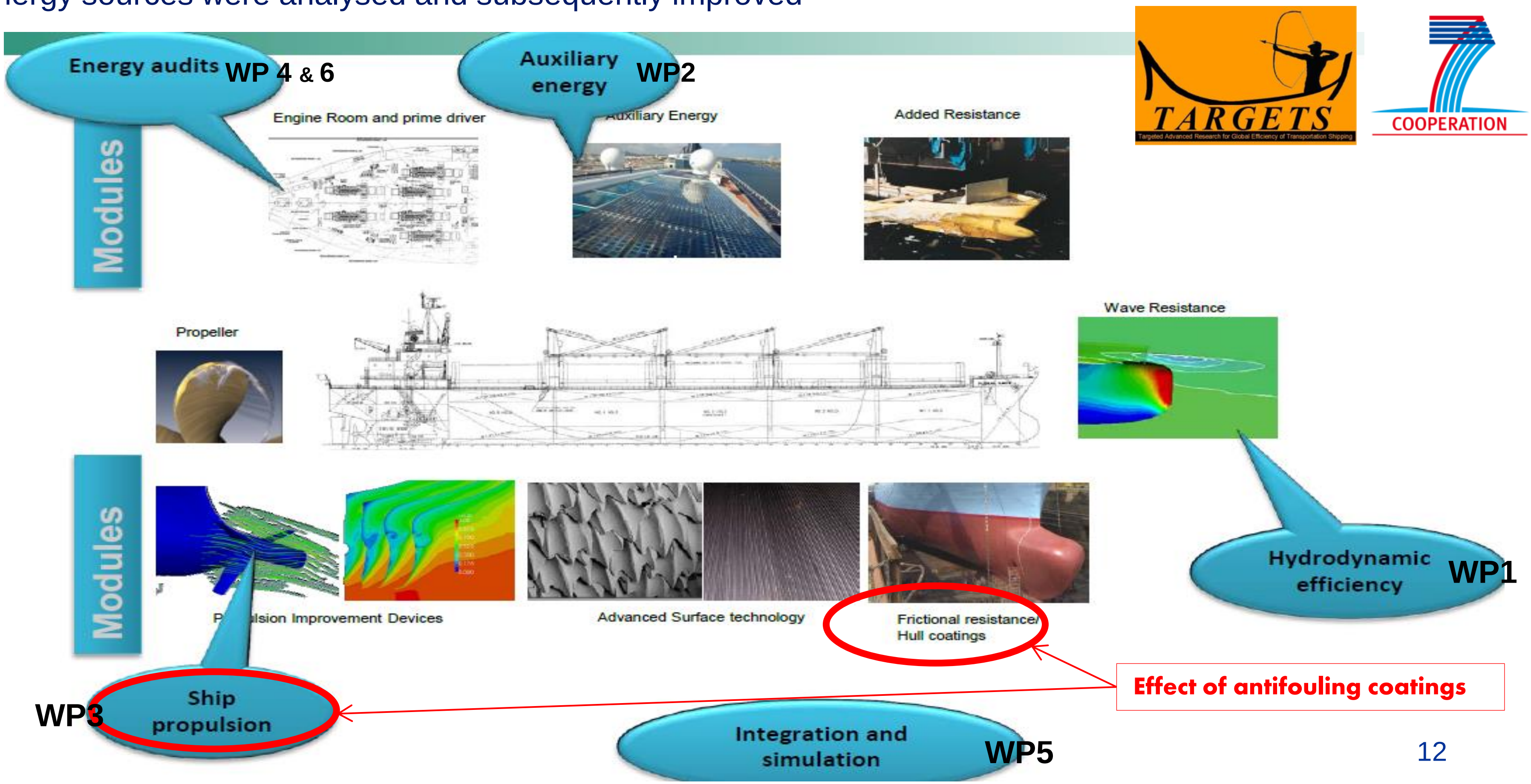




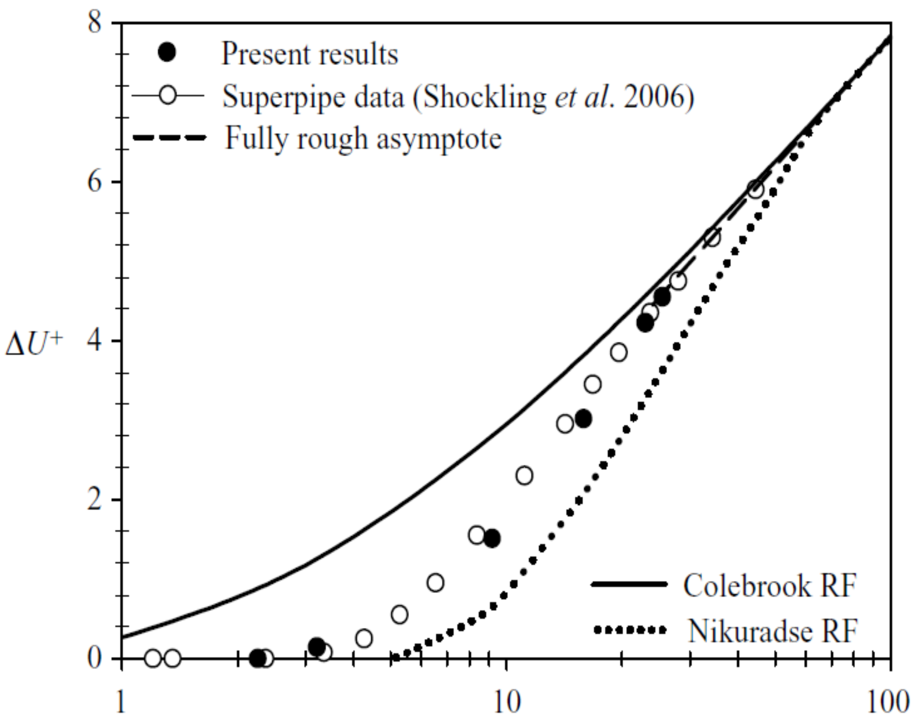
- One of the novel nano-structured AMBIO coatings (**Fluorinated Polymer** based) displayed **drag reduction behaviour** over a state-of-the-art commercial FR coating
- **Similar behaviour** was also observed with other novel nano-structured coating (**sol-gel with clay platelets** based**)** applied **on a coated propeller** model
- Modern anti-fouling coating development is **interdisciplinary** involving chemists, marine biologist, hydrodynamicist etc. with **different priorities** although the overall objective is effective control of biofouling in completely environmentally manner
- Although the drag reduction behaviour was an attractive finding it was not a **priory development objective.**

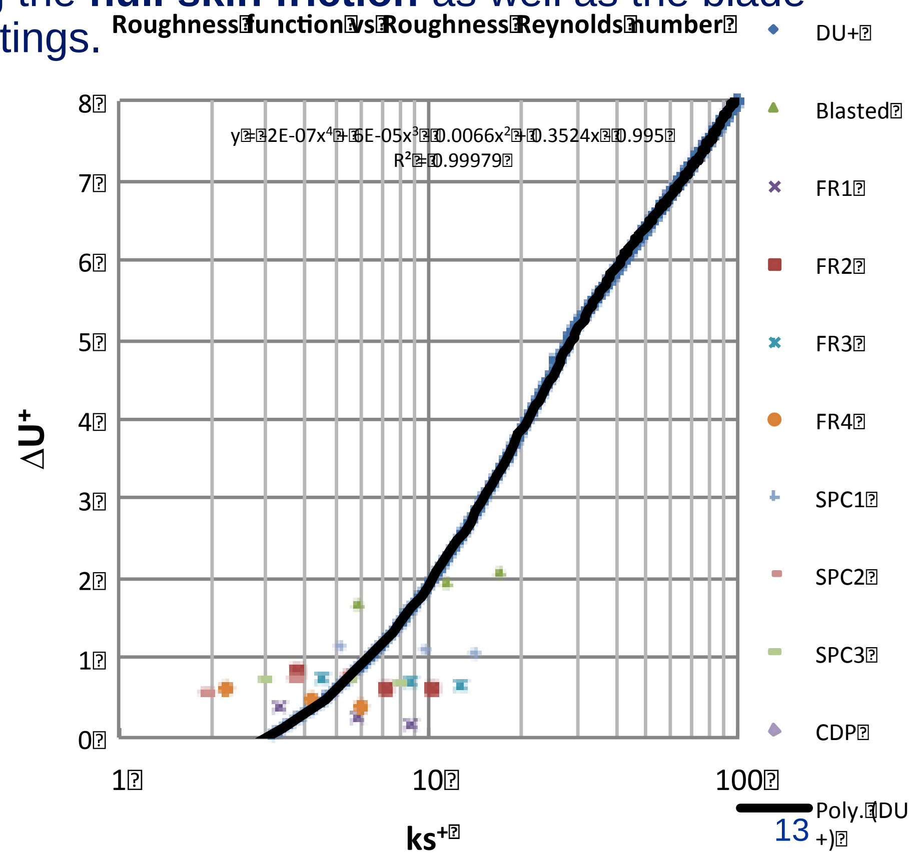
R&D Highlights – Global energy efficiency of ships

- **EU-FP7 Project TARGETS** (FP7-SST-2010-RTD-1- 266008): www.targets-project.eu
- **TARGETS** – **T**argeted **A**dvanced **R**esearch for **G**lobal **E**fficiency of **T**ransportation **S**hipping
- 3 years **RTD project** with 11 members and 3.6M Euro budget; to be completed in 2013
- To develop **holistic simulation and optimisation** concept to improve **energy efficiency** in shipping transport
- Based on a **Dynamic Energy Model** the most energy consumers on board and the use of new, alternative energy sources were analysed and subsequently improved



- In TARGETS the effect of anti-fouling coatings in the Dynamic Energy Model formulated based on the procedure proposed by Schultz (2007)
- In this procedure the Roughness Function data base for "**Typical clean antifouling**" has been enhanced for the state-of-the art FR and SPC type coatings based on the test data accumulated in Newcastle cavitation tunnel
- The enhanced data base was used in modifying the **hull skin friction** as well as the blade section **friction of propellers** coated by FR coatings.



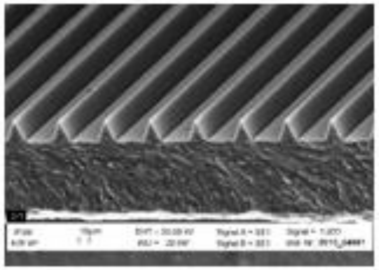


R&D Highlights – Novel FR coating hydrodynamic performance

www.seafront-project.eu

- **EU-FP7 Project SEAFRONT** (No: 614034) (Synergetic Fouling Control Technologies)
- 4 years project with 18 members and 11.2M Euro budget; to be completed by end of 2017
- Project aims: a) Reduced environmental foot print; b) 50% improvement in bifouling deterrence; c) 5% Efficiency gain
- Three different fouling control coating technologies: 1) Surface structure based; 2) Surface chemistry based; 3) Bio-based/Bio-active combined with drag reduction technologies (e.g. Riblets)
- In SEAFRONT foul release coatings are re-formulated to make them suitable for Riblet prints

WP1: Surface structure based biofouling control technologies:



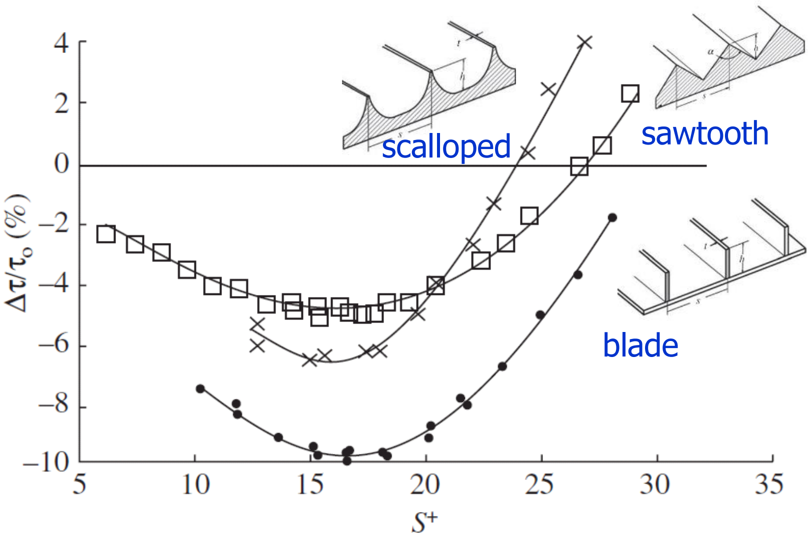
WP2: Surface chemistry based biofouling control technologies:

WP3: Bio-based and bio-active biofouling control technologies:

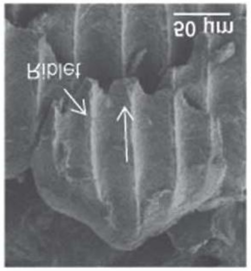
WP4: Fundamental understanding, performance prediction, and characterization

WP5: Benchmarking and performance monitoring in-situ:

R&D Highlights – Novel FR coating hydrodynamic performance

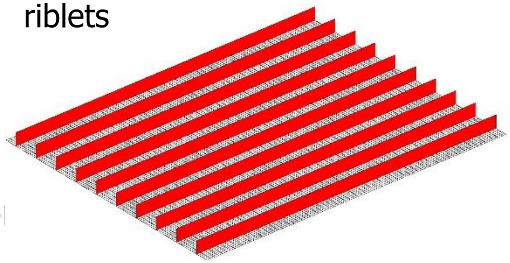


Shark Skin Riblets

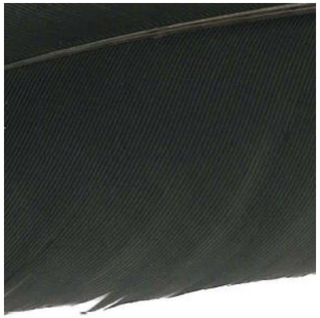


Figures: Dean & Bhushan, 2010, Bechert et al., 1997

Modelled shark skin blade riblets

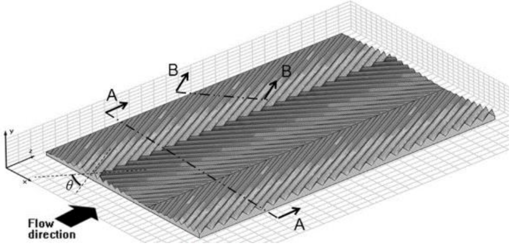


Bird Flight Feather Riblets

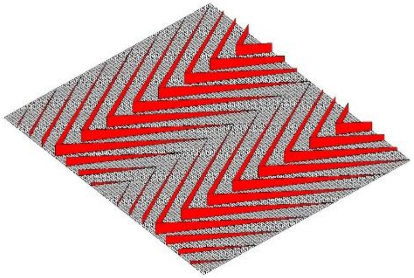


Flow over bio-inspired 3D herringbo
wall riblets

- First study of these riblets (Chen et al 2014)
- Experimental study
- Claimed 20 % DR



Modelled bird flight feather riblets



Propeller coatings – Full-scale observations

- Application of F/R coatings on propeller keeps the propeller <u>free from major fouling</u> as clearly observed in full- scale and <u>prevents the increase in roughness over the time</u>

14 months uncoated

Newly coated

After 12 months

After 24 months

After 36 months

37 months later

R&D Highlights - "In-service" issue

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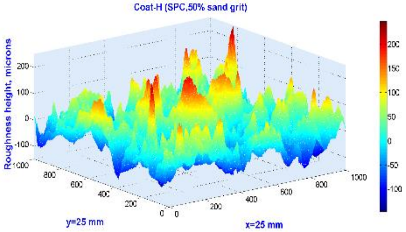
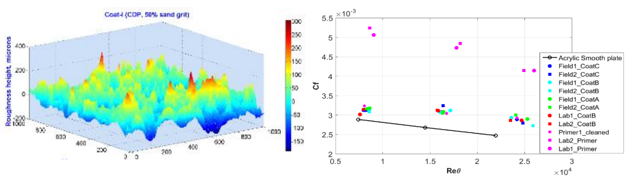
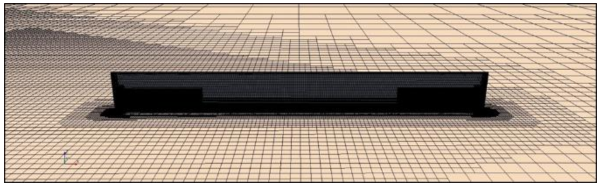
It is a well-known fact that performance characteristics of **coatings "in-service"** differ and **effect of deteriorating hull roughness & biofilm** on FR surfaces can be investigated in a simplified manner:

- Micro/macro **hull roughness** severity can be mimicked/**simulated** on sample test plates
- Simulated surfaces can be exposed to **biofilm development** dynamically in sea or laboratory conditions
- **Roughness** of the simulated surfaces are analysed and **drag** characteristics (roughness functions) are **measured** by using special flumes
- Measured data are **extrapolated** to full-scale using appropriate **theory** and **CFD** methods



R&D Highlights – "In-service" issue





Extrapolation to Full-scale

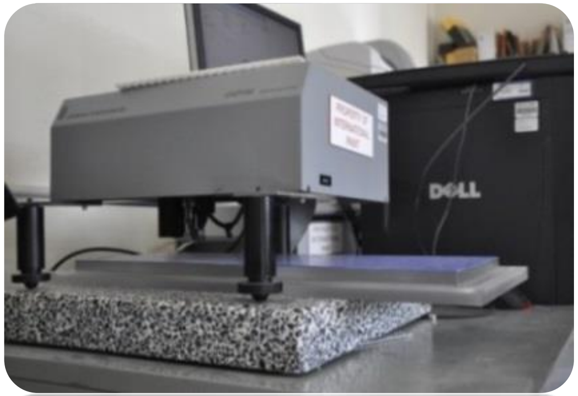
Slime Cultivating Farm

The panels can be deployed when the vessel on the water.

The Moon pool strut in place

The RV Princess Royal with the moon pool strut

Research Vessel "The Princess Royal"

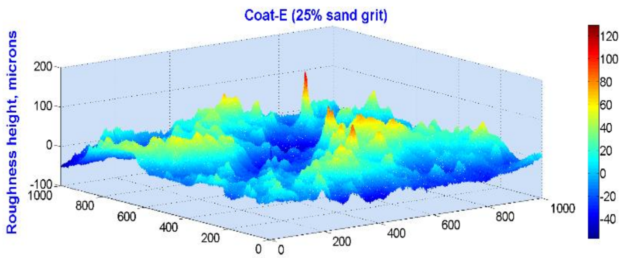


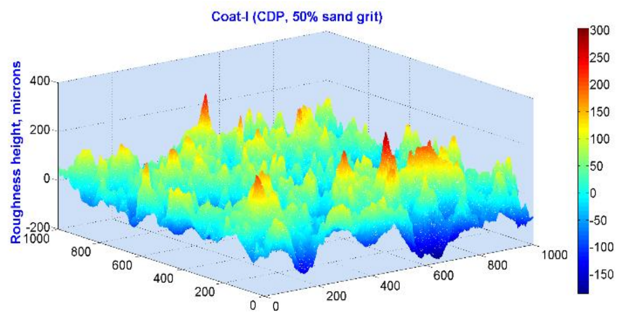
Optical Laser profilometer

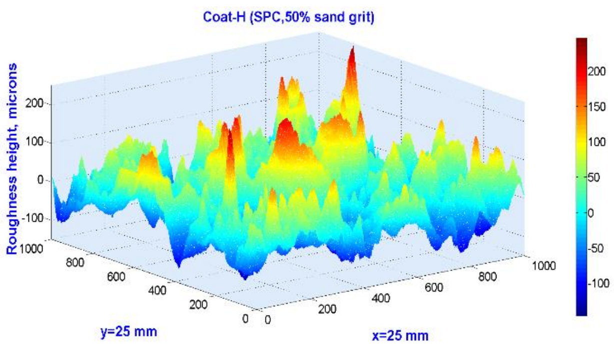
Standard Testing plate: Length=600mm Width=218mm

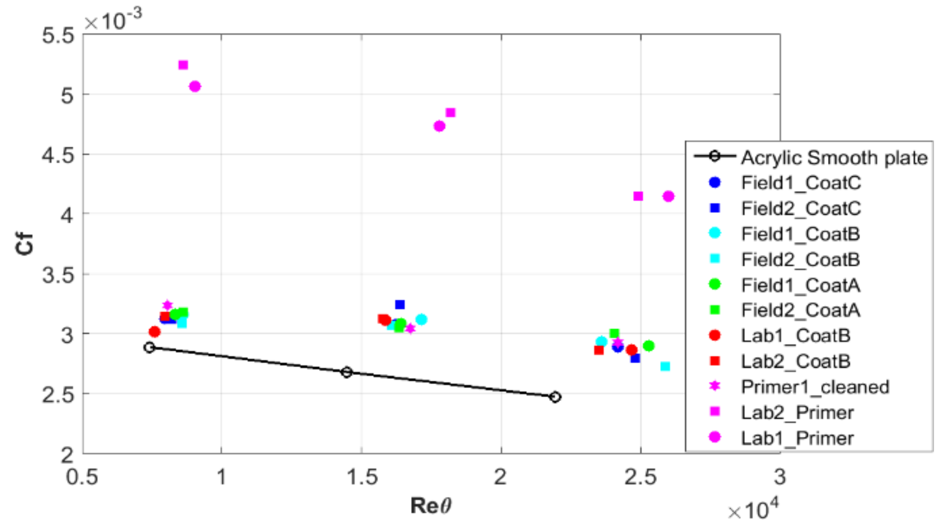
Turbulent channel set-up for "Roughness Function" measurement

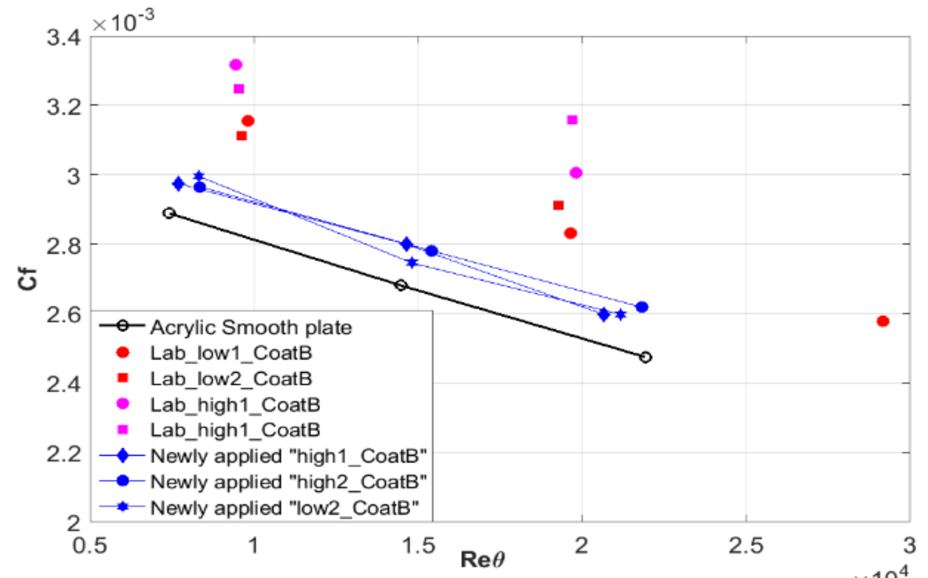
R&D Highlights - “In-service” issue







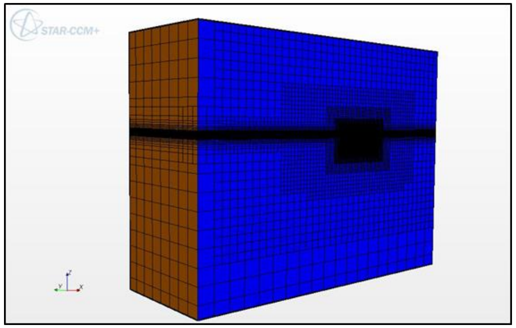


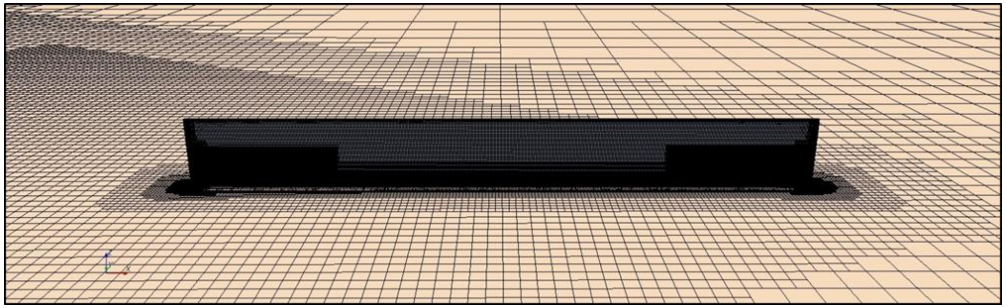


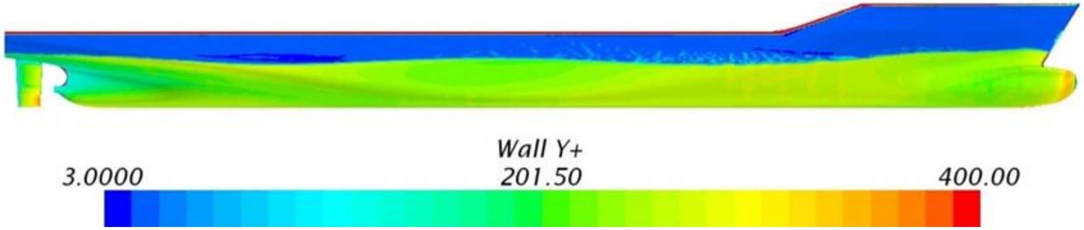
- Scanned area for the topography, $A = 25\text{mm}^2$
- Scan points for: x=1000 and y=1000;
- Scan resolution: 25µm

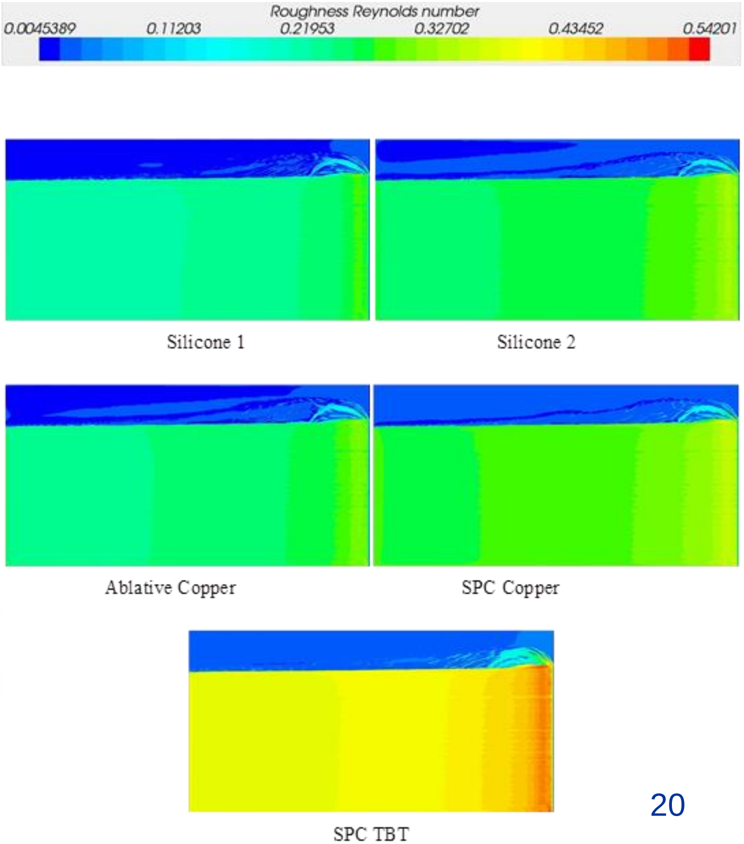
Modelling the Roughness Effects of Marine Coatings and Biofouling on Ship Frictional Resistance

- A fully nonlinear URANS CFD method has been developed to model the roughness effects of marine coatings and biofouling on the resistance of a 3D full-scale ship or other submerged marine surfaces.









R&D Highlights - "in-service" issue

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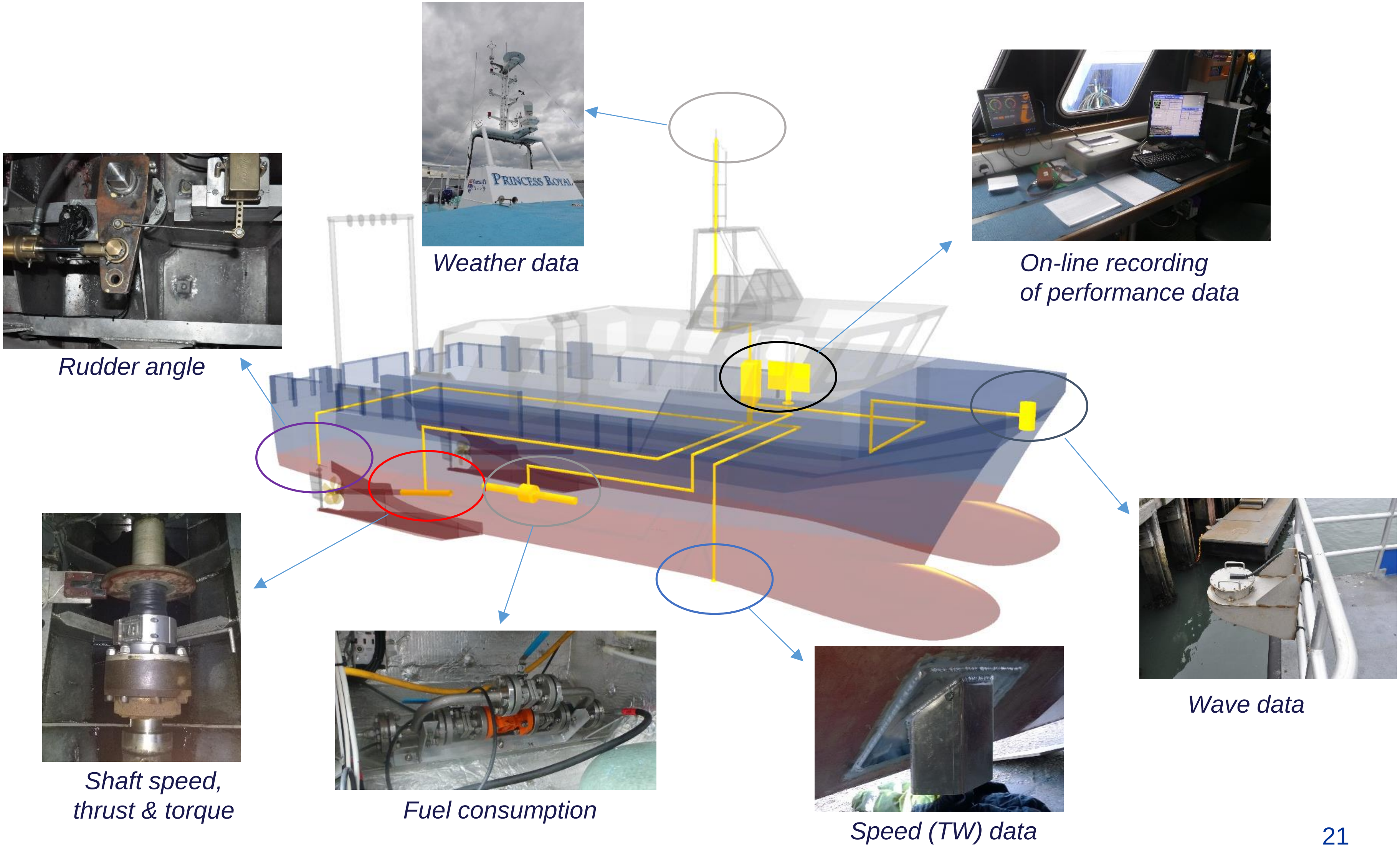
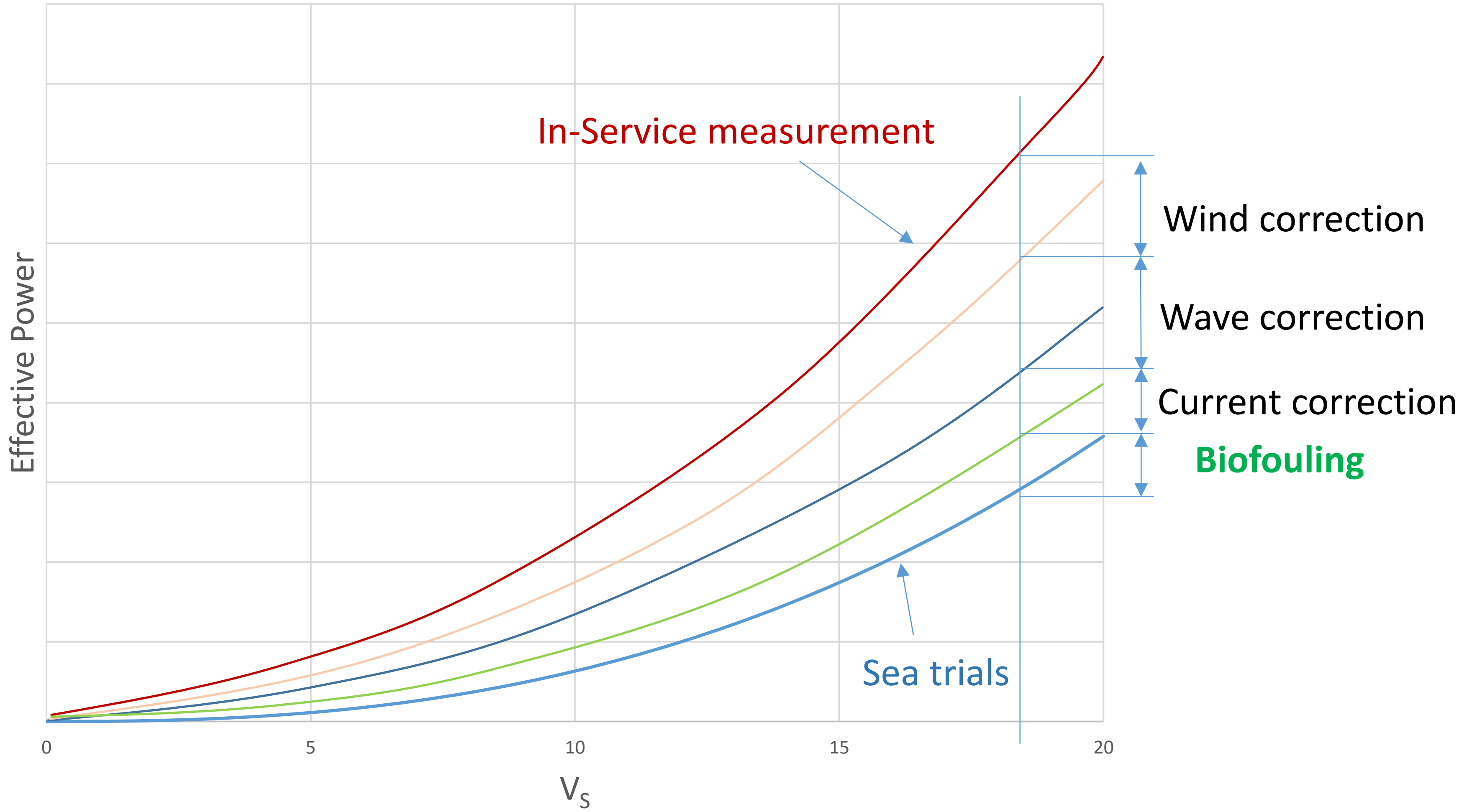
Performance measurement on-board *"The Princess Royal"* RV



R&D Highlights - "in-service" issue

Performance analysis (deterministic)

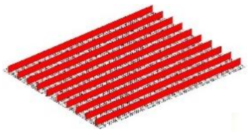
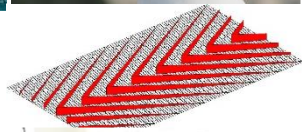


Summary & further R&D needs

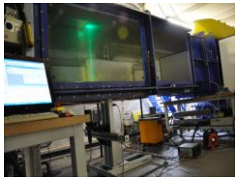
- For **energy efficiency,** R&D on the antifouling coatings will continue with more emphasis on "**Fouling Release**" type coatings as well as **other green coating technologies** in parallel**.**

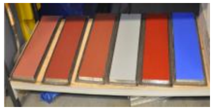
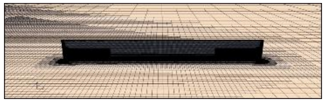

- More effective energy efficiency with ship hull/propellers can be achieved by the **combination** of green coating systems with promising **drag reduction technologies,** preferably **passive** ones (e.g. riblets, compliant surface, hydrophobicity etc)



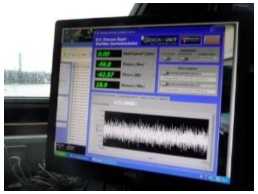



- R&D on anti-fouling performance predictions should continue by using **laboratory based methods** and effective hydrodynamic testing tools supported by **advanced CFD methods**. Emphasis should be placed on "i**n-service**" performance prediction.



- Coating performance prediction "in-service" needs validation and hence real performance measurements at sea. This requires **dedicated performance monitoring systems onboard** ships to make further progress.

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THANK YOU

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