APPROACHES TO MEASURING HULL AND PROPELLER PERFORMANCE

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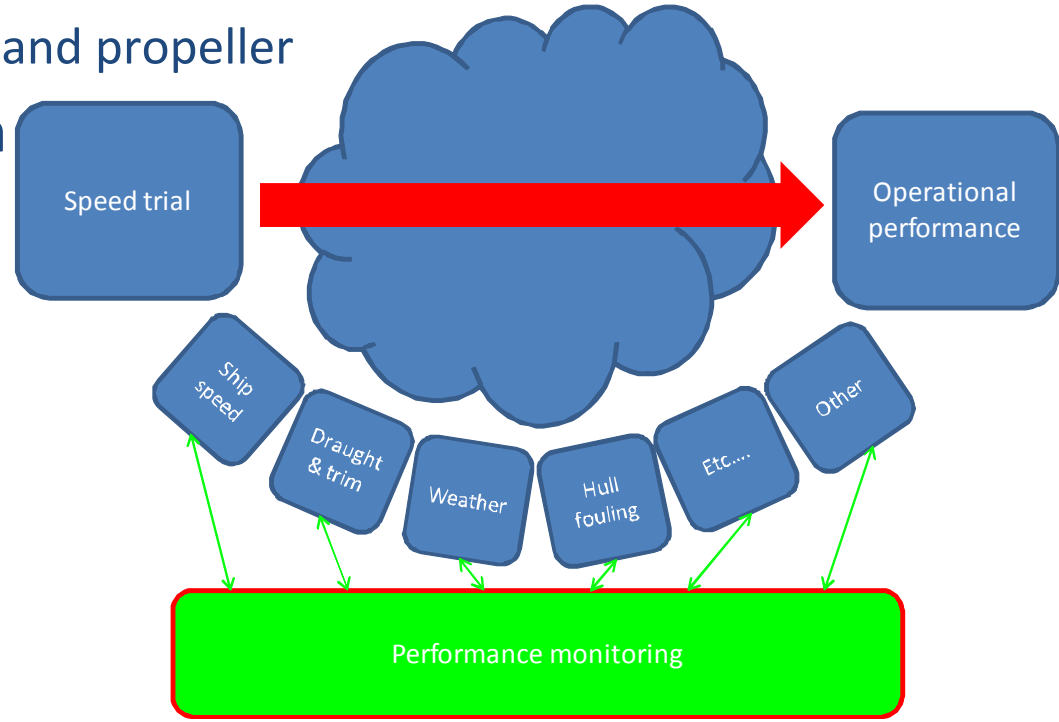
Oslo, January 15, 2013

OBJECTIVE OF PERFORMANCE MONITORING

- Fuel saving
- Hull and propeller condition monitoring
  - Planning of propeller and hull cleaning
  - Recognised damage to hull and propeller
- Performance optimisation
  - Trim
- Contract validation
  - Charter contracts
  - performance guarantee



DO OBJECTIVES INFLUENCE APPROACH?

YES! But how:

- Required accuracy
  - -> approach to performance monitoring
- Required output
  - -> approach to performance monitoring
  - -> approach for performance analysis

- Other influences:
  - Person in charge of performance monitoring
  - Available resources
  - Operational profile of the ship
  - Ship type

HOW DO WE DEFINE PERFORMANCE?

$$\Delta x = x_f - x_i \qquad \Delta v = v_f - v_i$$

$$\vec{v} = \frac{\Delta \vec{r}}{\Delta t} \qquad \vec{a} = \frac{\Delta \vec{v}}{\Delta t}$$

$$v = |\vec{v}| = \sqrt{v_x^2 + v_y^2} \qquad \theta = \tan^{-1}\left(\frac{v_y}{v_x}\right)$$

$$v_x = v\cos(\theta) \qquad v_y = v\sin(\theta) \qquad \theta = \cos^{-1}\left(\frac{v_x}{v}\right) \qquad \theta = \sin^{-1}\left(\frac{v_y}{v}\right)$$

$$\omega = \frac{\Delta\theta}{\Delta t} \qquad \alpha = \frac{\Delta\omega}{\Delta t}$$

$$x = r\theta \qquad \omega = 2\pi f \qquad f = \frac{1}{T}$$

$$v = \omega r \qquad a = \alpha r$$

$$v = v_o + at$$
$$x = x_o + v_o t + at^2/2$$
$$v^2 - v_o^2 = 2a(x - x_o)$$
$$\bar{v} = \frac{v_f + v_i}{2} \qquad \Delta x = \bar{v}\,\Delta t$$

$$x \to x,y \qquad x_o \to x_o, y_o$$
$$v \to v_x, v_y \qquad v_o \to v_{ox}, v_{oy}$$
$$a \to a_x, a_y$$

$$\omega = \omega_o + \alpha t$$

$$I = \sum_i^{all} m_i r_i^2 \qquad \theta = \theta_o + \omega_o t + \frac{1}{2}\alpha t^2$$

$$\omega^2 - \omega_o^2 = 2\alpha(\theta - \theta_o)$$

$$v = \sqrt{\frac{T}{\rho}}$$

$$\mu N \qquad a = \frac{v^2}{R}$$

$$v = \lambda f$$

$$L = r_\perp p = mvr_\perp \qquad \tau = r_\perp F = rF_\perp$$

$$L = I\omega \qquad \tau = \frac{\Delta L}{\Delta t} \qquad \tau = I\alpha$$

$$\vec{F}_{tot} = m\vec{a}$$

$$\frac{1}{2} I\omega^2 \qquad \sum_i^{all} \vec{F}_i = 0 \qquad \sum_i^{all} \vec{\tau}_i = 0$$

$$E = K + U \qquad \Delta Q = (\text{quant.})\, C_{cond}\, \Delta T \qquad \Delta S \geq 0$$

$$W = F\, d_{\parallel} = F_{\parallel}\, d \qquad E_i = E_f \qquad \Delta Q_{into} = \Delta W_{by} + \Delta E \qquad \Delta Q = 1\,\Delta(\text{quant.}) \qquad PV = nRT$$

$$W_{tot} = \Delta(KE) \qquad \frac{1}{2}mv^2 \qquad C_P = C_V + R \qquad e = \frac{\Delta W}{\Delta Q} \qquad e = 1 - \frac{T_L}{T_H} \qquad P = \frac{F}{A}$$

$$\Delta U = -W_{if} \qquad \frac{RT}{2}\Big|_{\text{deg. freedom}}$$

$$\frac{1}{2}kx^2 \qquad \omega = \sqrt{\frac{k}{m}}$$

$$x = A\cos(\omega t) = \{or\}\ A\sin(\omega t)$$
$$v = -A\omega\sin(\omega t) = \{or\}\ A\omega\cos(\omega t)$$
$$a = -A\omega^2\cos(\omega t) = \{or\}\ -A\omega^2\sin(\omega t)$$

$$p = mv$$

$$\vec{P}_{init} = \vec{P}_{final}$$

$$\left(\sum_j^{all} m_j \vec{v}_j\right)_{init} = \left(\sum_j^{all} m_j \vec{v}_j\right)_{final}$$

$$M_e = 5.97(10)^{24}\ \text{Kg}$$
$$R_e = 6.37(10)^{6}\ \text{m}$$
$$G = 6.67\,(10)^{-11}\ \text{N m}$$

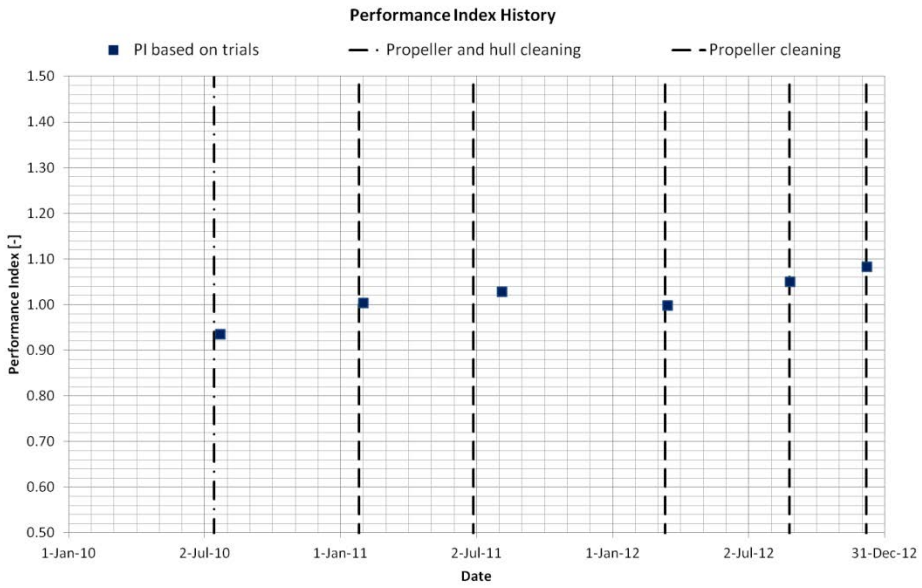
$$P_1 = P_2 \qquad \rho g\,\Delta h \qquad \rho_{liq} V_{disp} g \qquad v_1 = A_2 v_2 \qquad v^2 = \text{const.}$$

PERFORMANCE MEASUREMENT APPROACH

- Dedicated speed trials
  - Only for performance decay over time
  - Interesting effects may be missed due to time between trials
  - Most accurate measurement and analysis procedure
- Continuous monitoring
  - Less accurate analysis than dedicated speed trials
  - Large dataset containing valuable information
  - Large dataset containing inexplicable performance deviations
- Noon reports
  - Not accurate due to human interference
  - Time between ‘measurement points’ very large

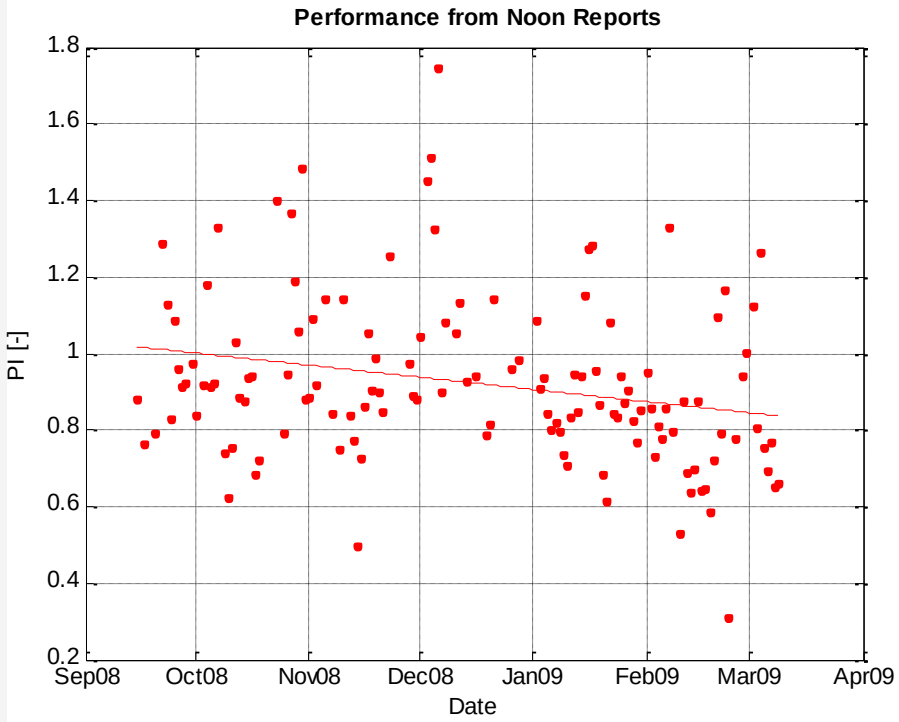
DEDICATED SPEED TRIALS

- Challenges:
  - Dedicated manoeuvres
  - Constant loading condition
  - Limited amount of data
- Advantages:
  - High accuracy
  - Understandability of results



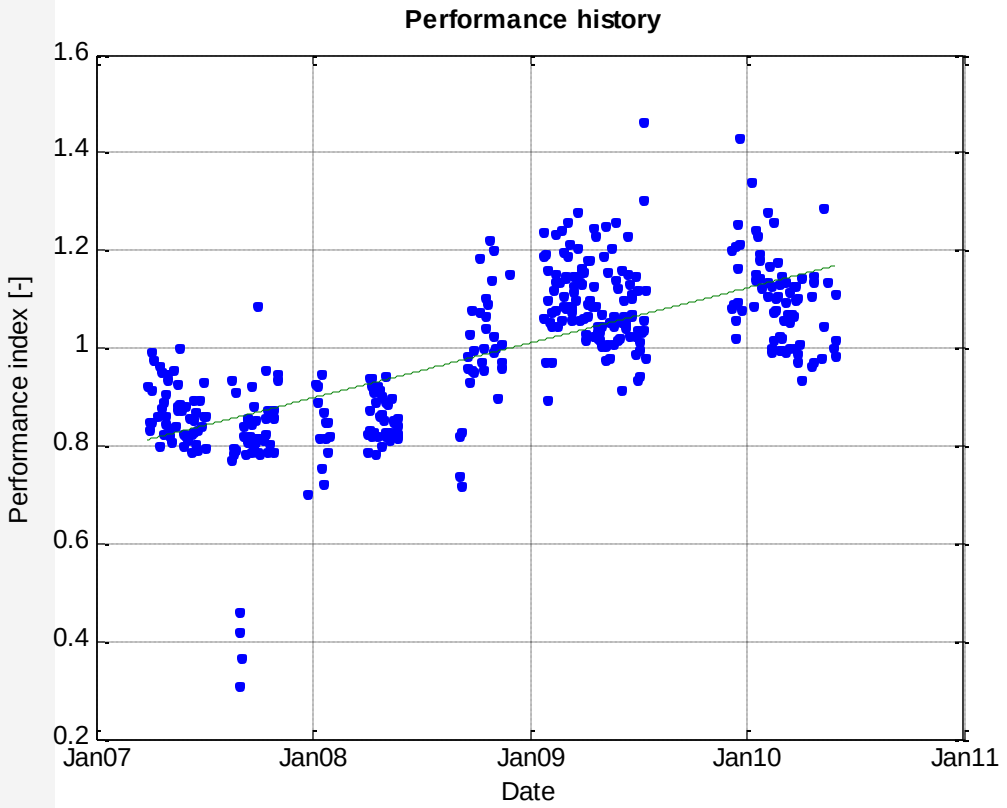
NOON REPORTS

- Challenges Noon reports:
  - Changing weather conditions over 24 hours
  - Acceleration and deceleration of vessel
  - Combining 24 hour average (speed, fuel consumption) with snap shot (weather, power)
  - Manual input from crew
- Advantages:
  - Easy implementation
  - Data is already there



CONTINUOUS PERFORMANCE MONITORING

- Challenges:
  - Measurement accuracy
  - Analysis procedure
  - Big volumes of data
- Advantages:
  - Big volumes of data
  - Detect short term changes in performance



CONCLUSION MEASUREMENT PROCEDURE

- Dedicated speed trials
  - High accuracy
  - Long term
  - Available budget
- Noon reports
  - very long term
  - low required accuracy
- Continuous monitoring
  - Moderate accuracy
  - Short and long term
  - available resources

TO NORMALISE OR NOT TO NORMALISE?

- Normalise for:
  - Wind condition
  - Wave condition
  - Loading condition
- Statistical approach:
  - Filter out bad weather
  - Filter out loading conditions
  - Assume normal distribution of effects of:
    - Wind
    - Waves
    - Drift
    - Loading condition

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NORMALISATION APPROACH

- Corrections for added resistance due to:
  - Wind
  - Waves
  - Water depth
- Strong points
  - Hydrodynamic meaningful output
- Challenges
  - Measurement accuracy
  - Unknown effects not accounted for (yet)

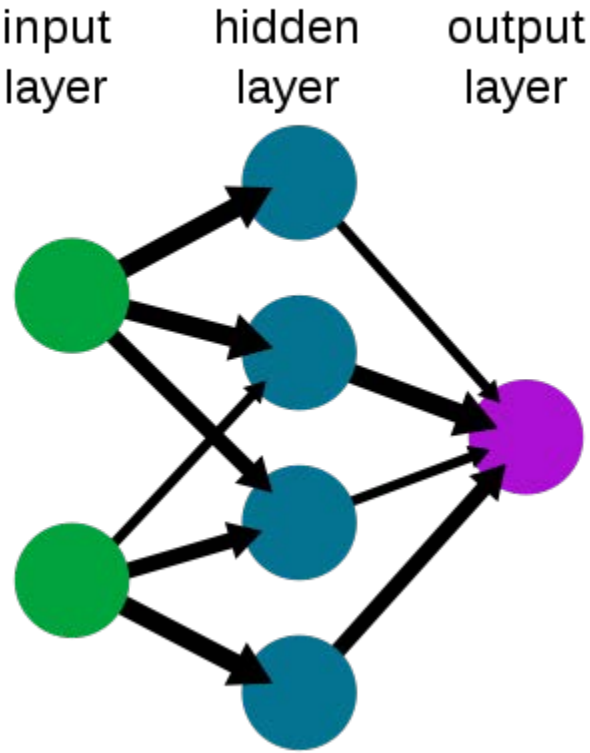
STATISTICAL APPROACH

- Effects will average out over long period:
  - Added resistance due to wind
  - Added resistance due to waves
  - Effect of trim
  - Sea water and air temperature
- Strong points:
  - Easy to implement
  - Easy to understand
- Challenges
  - Lack of hydrodynamic meaning of result
  - Limited application

SELF LEARNING

- Neural network
  - Links between parameters
  - Relation of links determined based on measurements
  - System updates when more data is available
- Strong points:
  - Accuracy
  - Ship specific
- Challenges:
  - Difficult to comprehend black-box approach
  - Knowledge of **all** influences of performance should be known

A simple neural network



REQUIREMENTS

- Accuracy
  - Effect to be proven by monitoring
  - Limited by measurement and analysis accuracy
- Transparency
  - Understand how results are generated
  - Understand deviations in performance
- Understandability
  - Closely related to transparency
  - Output should have a hydrodynamic meaning

COMBINED APPROACH

- Use filtering technique from statistical approach and normalise the remaining data

- Filter data based on hydrodynamic knowledge
- Filter bad weather conditions
- Exclude conditions which cannot be normalised
- Normalise for:
  - Wind
  - Waves
  - Loading condition

Never filter out data without a solid explanation

AVAILABLE METHODS

- Jotun Hull Performance Measurement Method
- MARIN SPA method
- MACSEA Hull Medic
- Propulsion Dynamics CASPER
- BMT SMART^{POWER}
- Etc. Etc. Etc.

CONCLUSIONS ANALYSIS METHOD

- Statistical approach
  - Long term
  - Relative performance
  - Moderate accuracy
- Normalisation approach:
  - Short and long term
  - High required accuracy
  - Good understanding of hydrodynamics
- Self learning

THE WAY FORWARD

- Further development should focus on:
  - Improving measurement accuracy
    - Relative wind speed and direction
    - Speed log
  - Improving analysis accuracy
    - Understand missing effects on performance
    - Filter parameters
    - Improving empirical correction methods

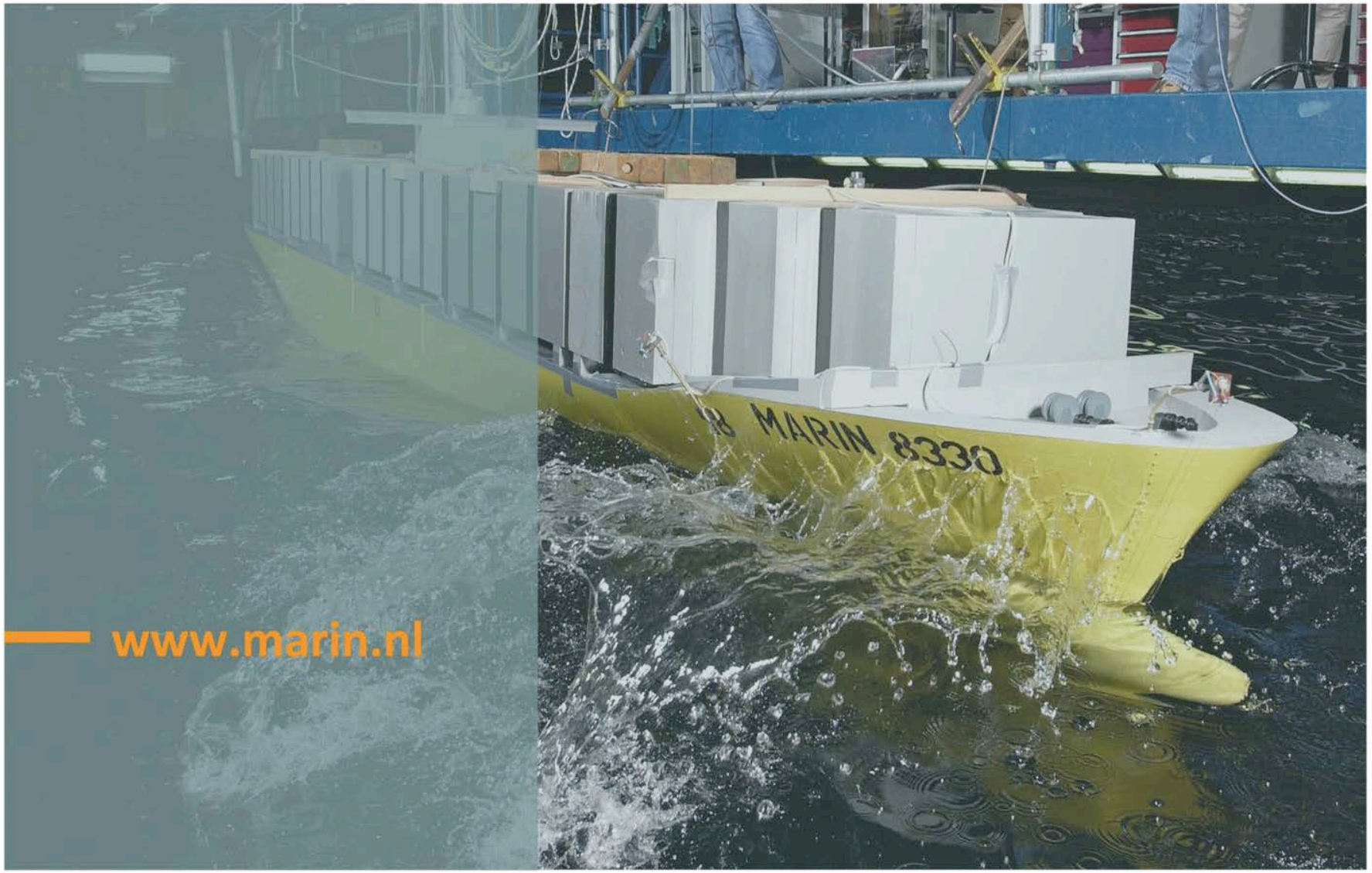
SUMMARY

- Choice measurement approach depends on monitoring objective
- Choice analysis approach depends also on experience
- One standard for performance monitoring is not possible
- Room for improvement of measurement and analysis methods
  - Too early to standardise

DISCUSSION

- Is it time for a standard?
- What should the standard focus on?
  - Data collection
  - Data analysis
  - Data collection and analysis
- What are the limits of the standard?
  - Engine performance
  - Hull and propeller

THANK YOU!



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