**DYNAMIC POSITIONING CONFERENCE**
**October 11-12, 2016**

**THRUSTERS**

# Improved DP-Capability with Tilted Thrusters and Smart Controls Algorithims

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# Improved DP-capability with tilted thrusters and smart controls algorithms

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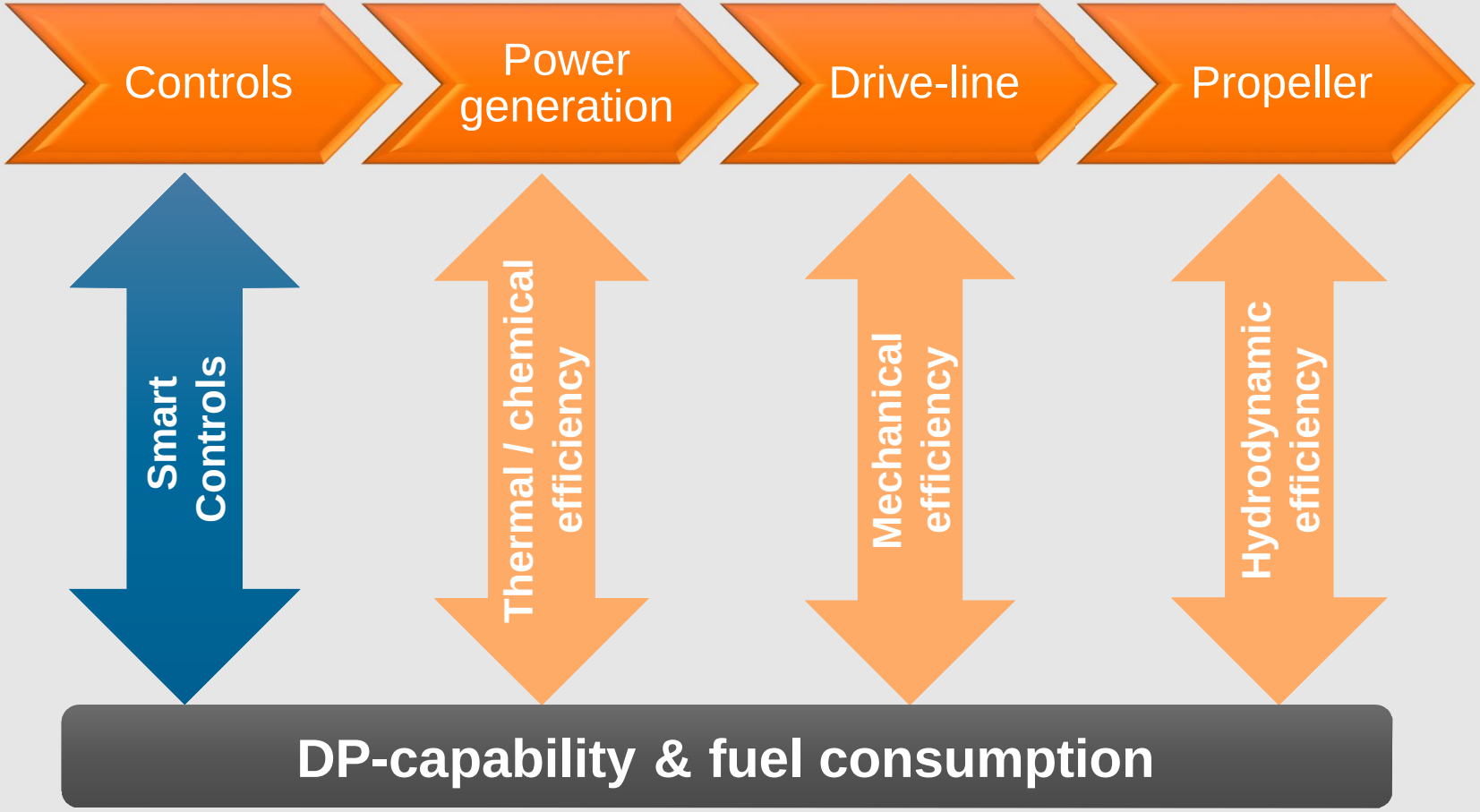
# Contents

- Introduction
  - System integration on DP-capability
- Thruster bollard pull performance
  - Impact of tilt configurations
  - Impact on hull-interaction losses
- Thrust allocation / controls algorithms
  - Corridor approach
  - Load balancing
- Conclusions

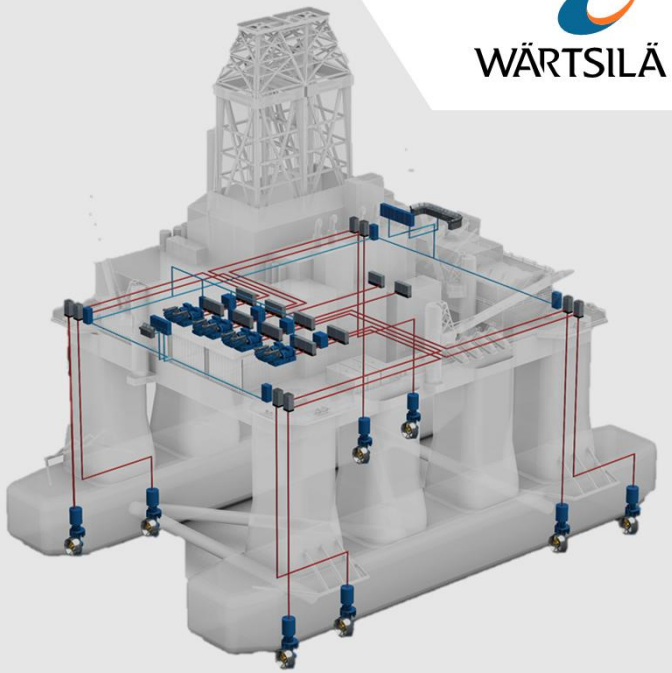
*Animation:*
*Courtesy of mr Albert Drost*

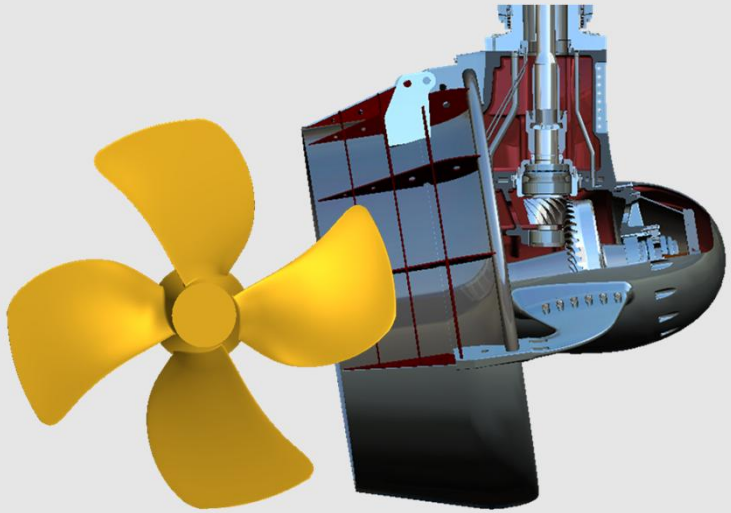
# System integration: impact on DP-capability and fuel consumption



# Steerable thrusters for Dynamic Positioning

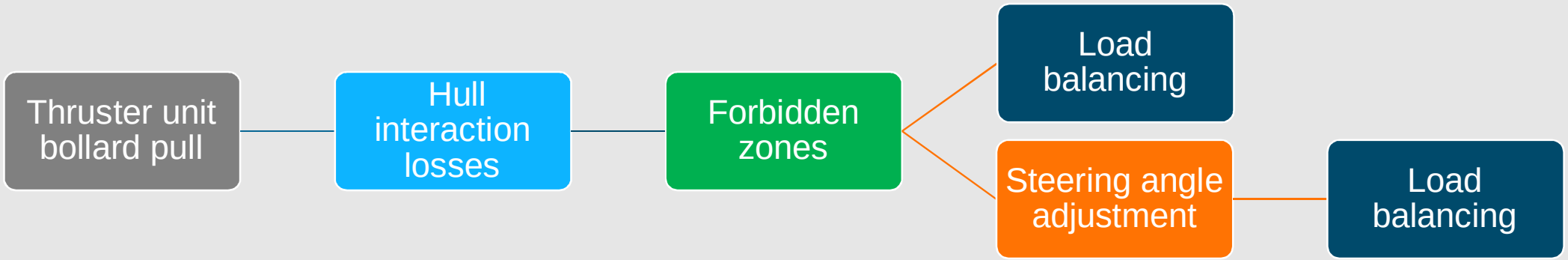
- Overall efficiency of the dynamic positioning system depends on:
  - **Hydrodynamic efficiency** of steerable thrusters
  - Thruster interaction losses with hull and other thruster units
  - **Smart controls systems** to set the right steering angle and power to each thruster on the vessel

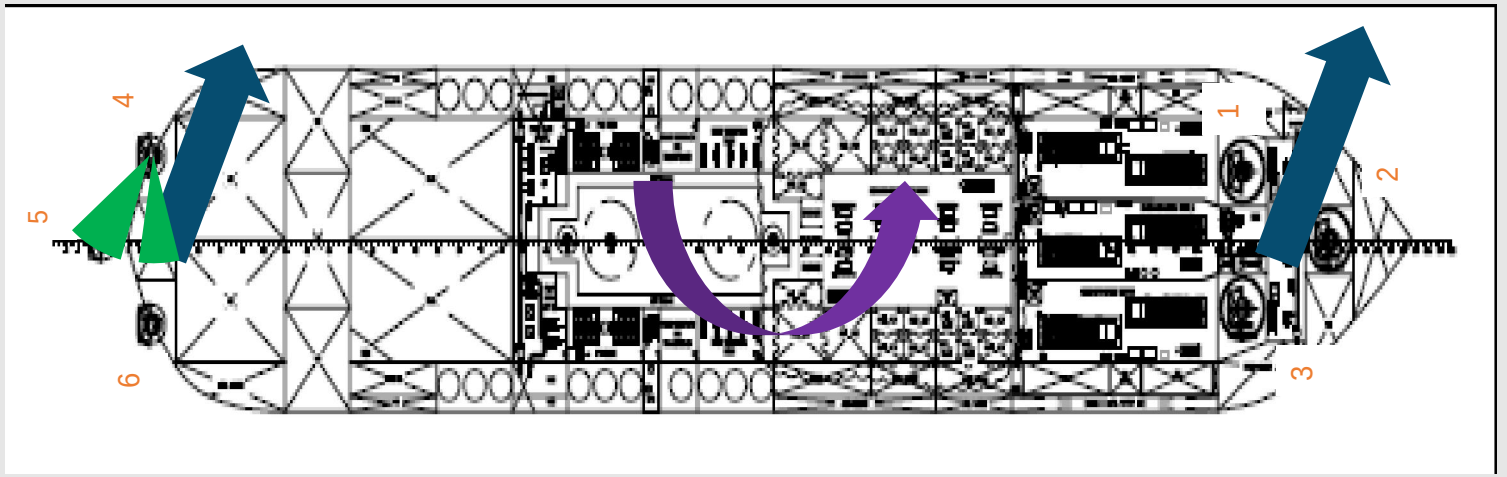




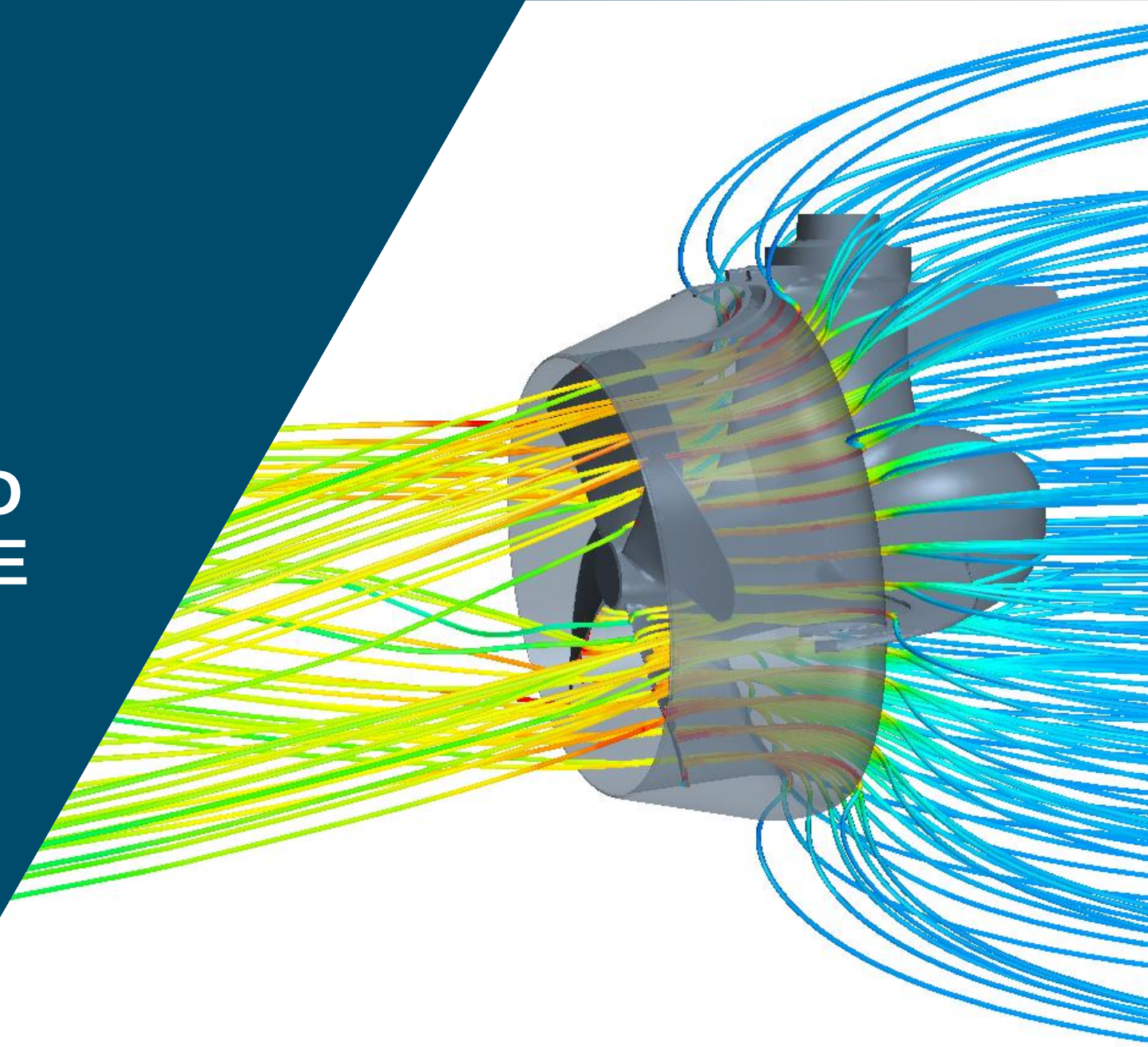
# DP thrust calculation steps

- The following steps can be identified in the DP-thrust allocation process



# THRUSTER BOLLARD PULL PERFORMANCE



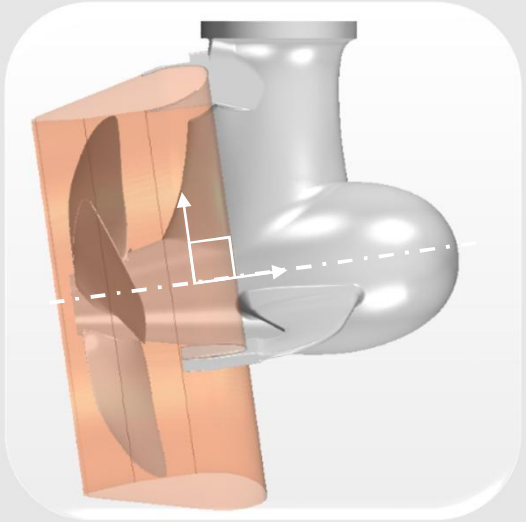
# Thruster DP-performance evaluation

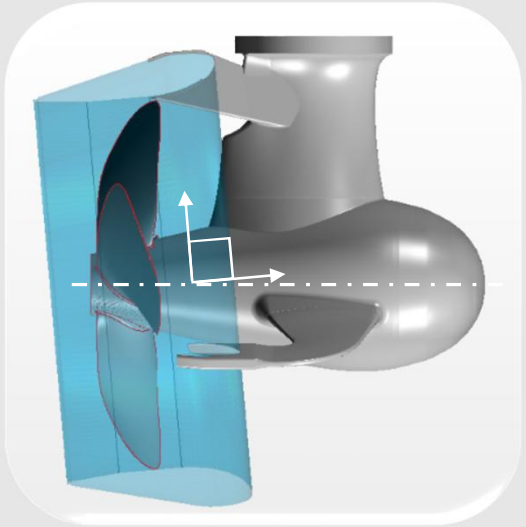
- A detailed hydrodynamic analysis of the Dynamic Positioning capabilities of two steerable thruster types has been made.

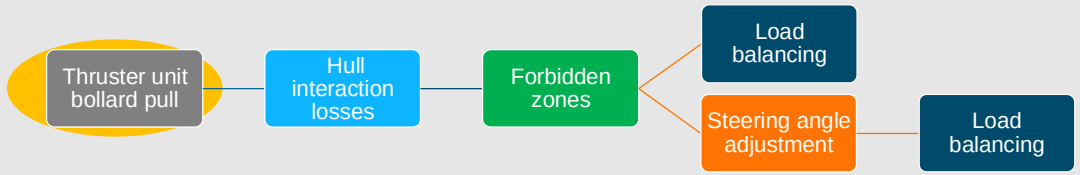
- The following thruster types have been reviewed:

| Type | Power [kW] | Diameter [mm] | Tilt concept | Tilt angle |
|---|---|---|---|---|
| WST-55U | 5500 | 3900 | Shaft | 8 |
| Reference unit | 5500 | 4100 | Nozzle | 5 |

- The analysis focusses on:
  - 1) Open water performance
  - 2) DP-capability for a drill ship (3 units in the bow and 3 in the stern)

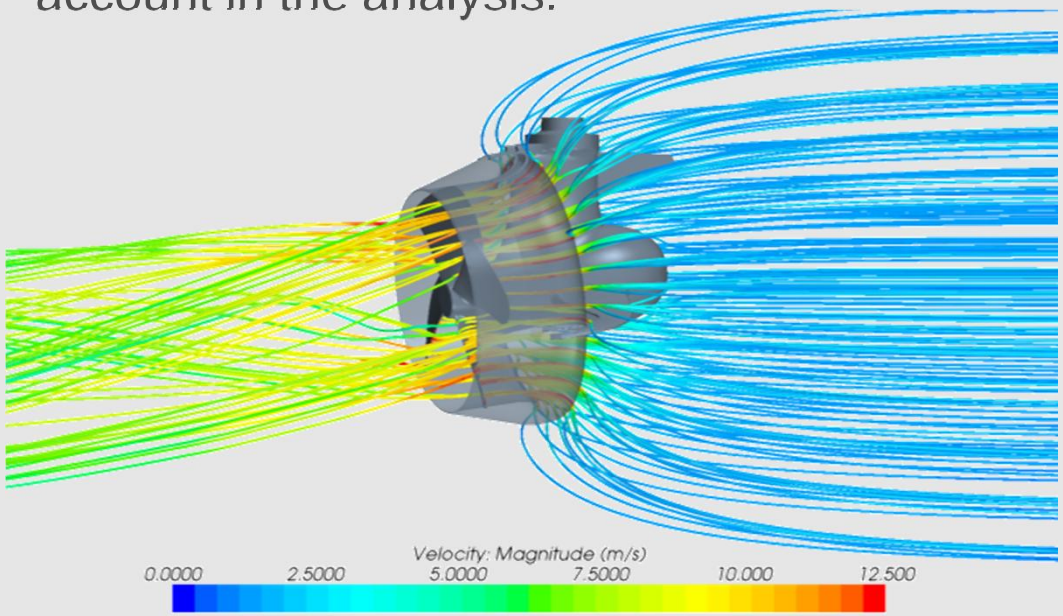


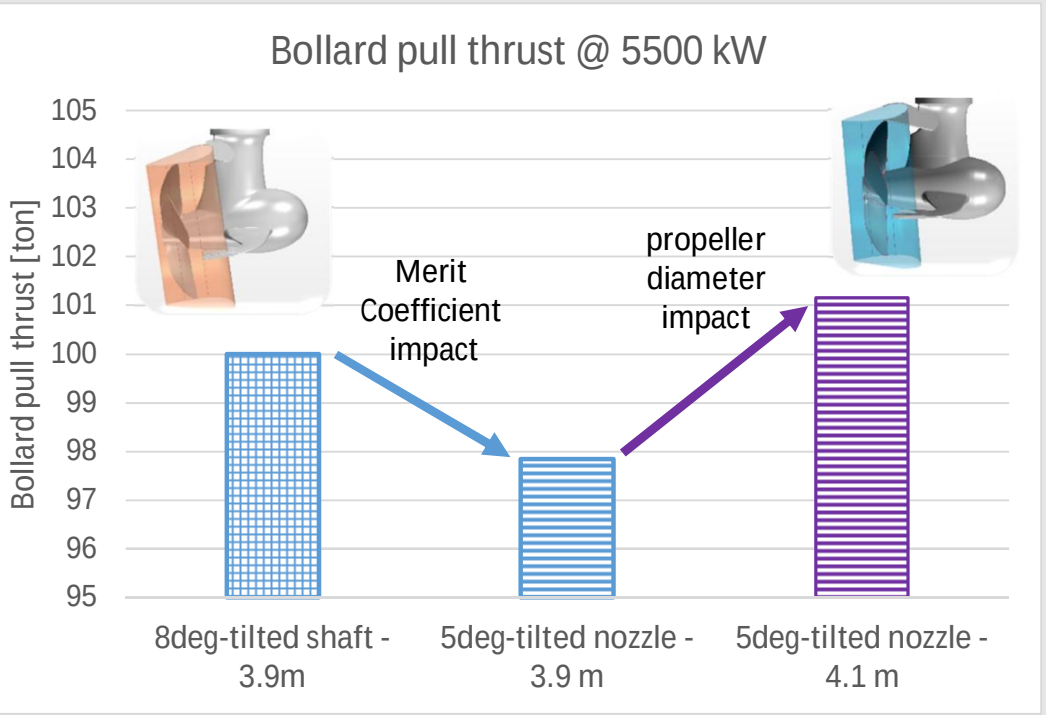




# Steerable thruster unit thrust performance

- Full scale performance determination based on CFD simulations of complete thruster unit.
- The impact of propeller diameter and propeller blade tip-clearance have been taken into account in the analysis.



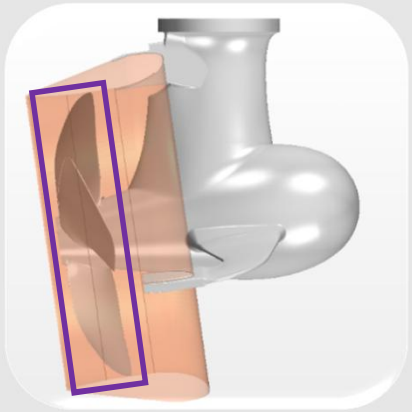




- The hydrodynamic performance of the **tilted shaft configuration is better**.
- Compensation can be found in a larger propeller.

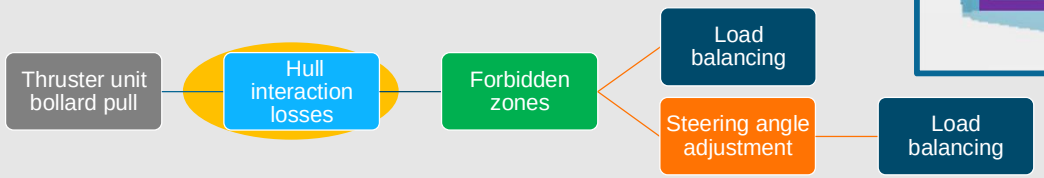
# Steerable thruster hull-interaction

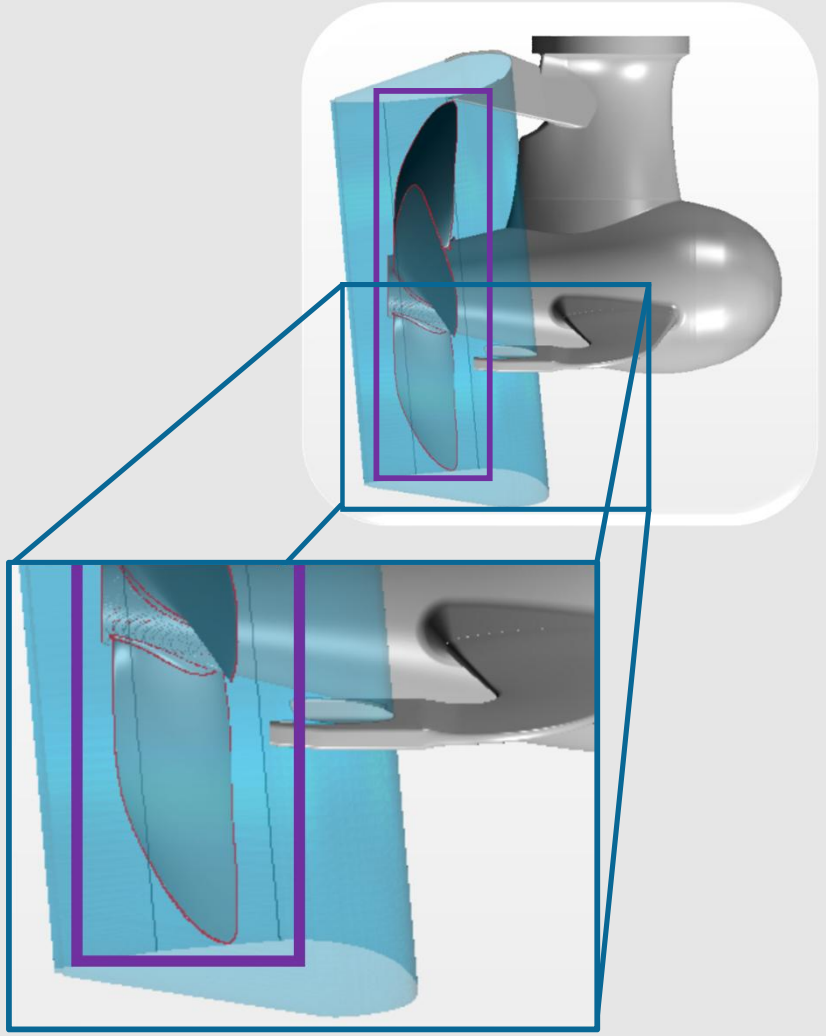
- For a proper numerical simulation of the wake of a thruster a transient CFD simulation is required.

- The 8° tilted shaft unit can be analyzed with Moving Mesh or Overlapping Grids.
- In case of misalignment between propeller and nozzle the Overlapping Grid option is the only option.



- The industry reference unit with **5° tilted nozzle** can now be analyzed in proper way with the available **Overlapping Grid** method.

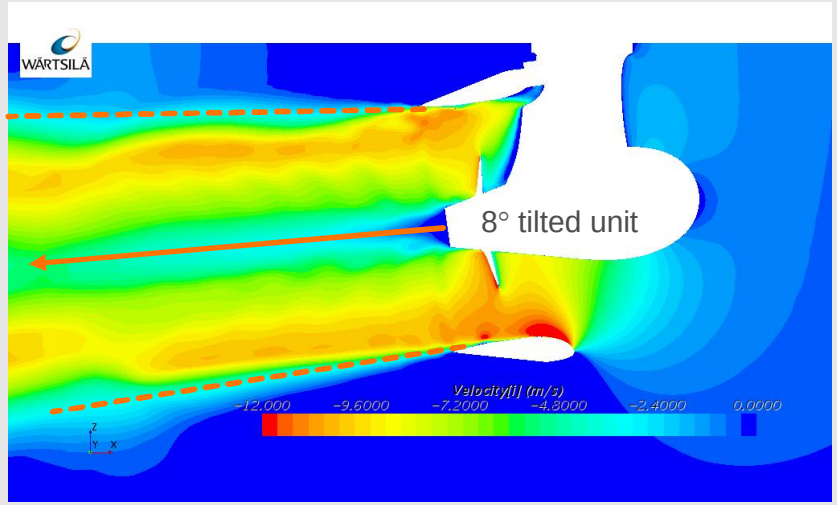


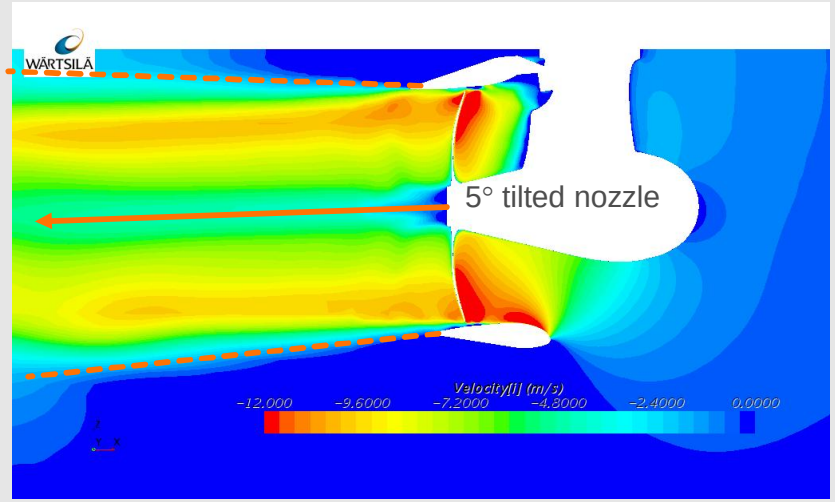



# Steerable thruster hull-interaction

- Thruster-hull interaction has been determined for the 8° tilted shaft unit and for the 5° tilted nozzle reference unit.
- Significant differences in wake deflection can be seen.
- Once the wake hits the hull, the hull-interaction losses will increase significantly.
- Only for the **8° tilted unit** the deflection is sufficient to **avoid these interaction losses**.

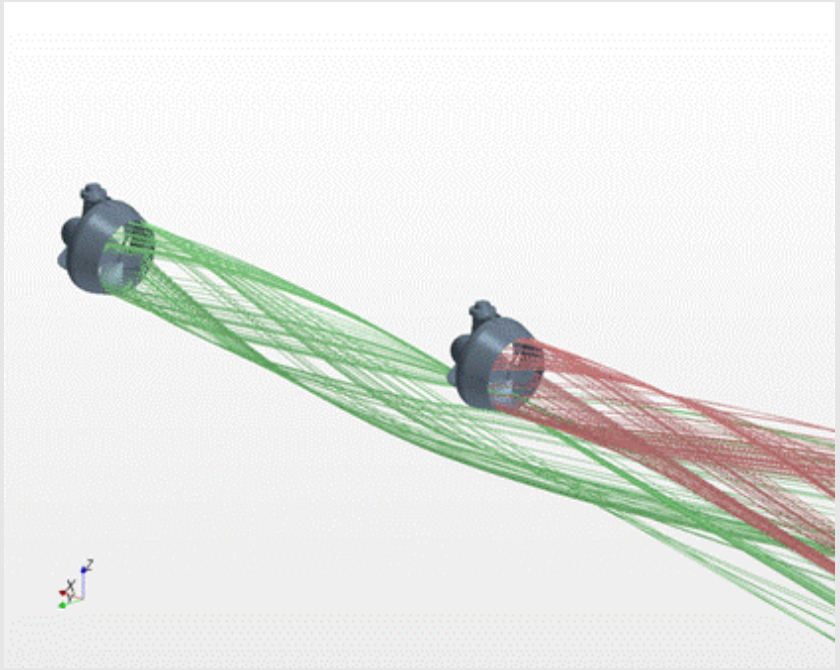
| Configuration | Average wake deflection | Minimum wake deflection |
|---|---|---|
| **8° - tilted shaft** | **-5°** | **-1°** |
| **5° - tilted nozzle** | **-2°** | **+2°** |
| 0° - conventional | 0° | +4° |

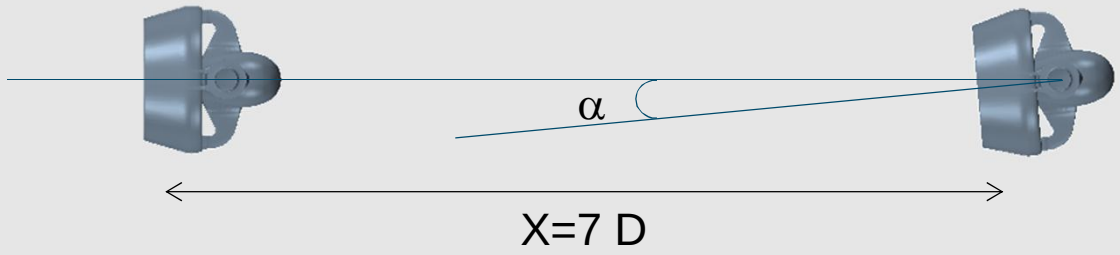


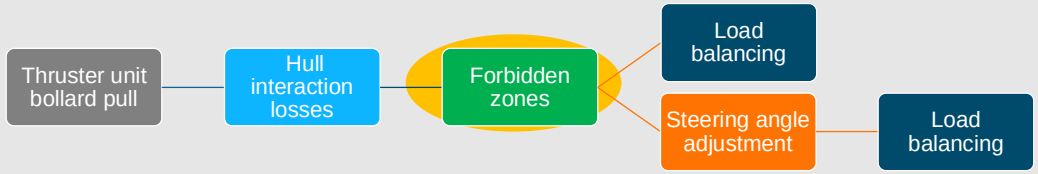
# Thruster-thruster interaction

- The thrust losses of the interaction with a second steerable thruster have been determined with aid of numerical flow simulations (CFD).
- A CFD model has been made with two thruster units. The steering angle of the upstream unit and the distance has been varied to determine the overall performance.





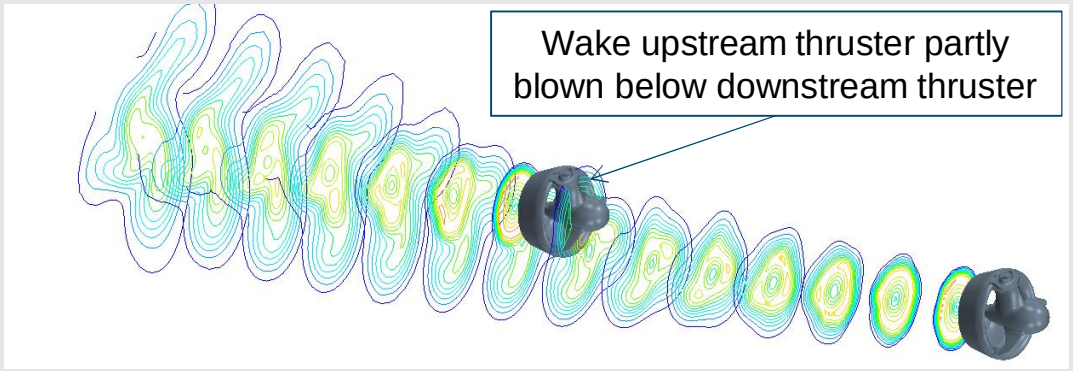

- The total thrust of two units has been determined for each condition.
- Based on this analysis the **optimum steering angle** has been determined.



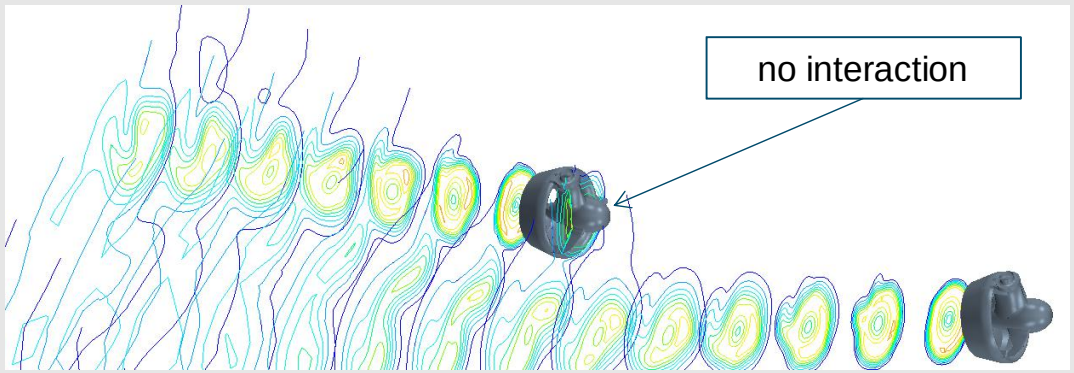
# Thruster-thruster interaction: effect of steering

- The jets out of the upstream thruster depends on the steering angle.
- Results for two steering angles of the upstream thruster unit are shown below for the thruster with 8° tilted shaft.

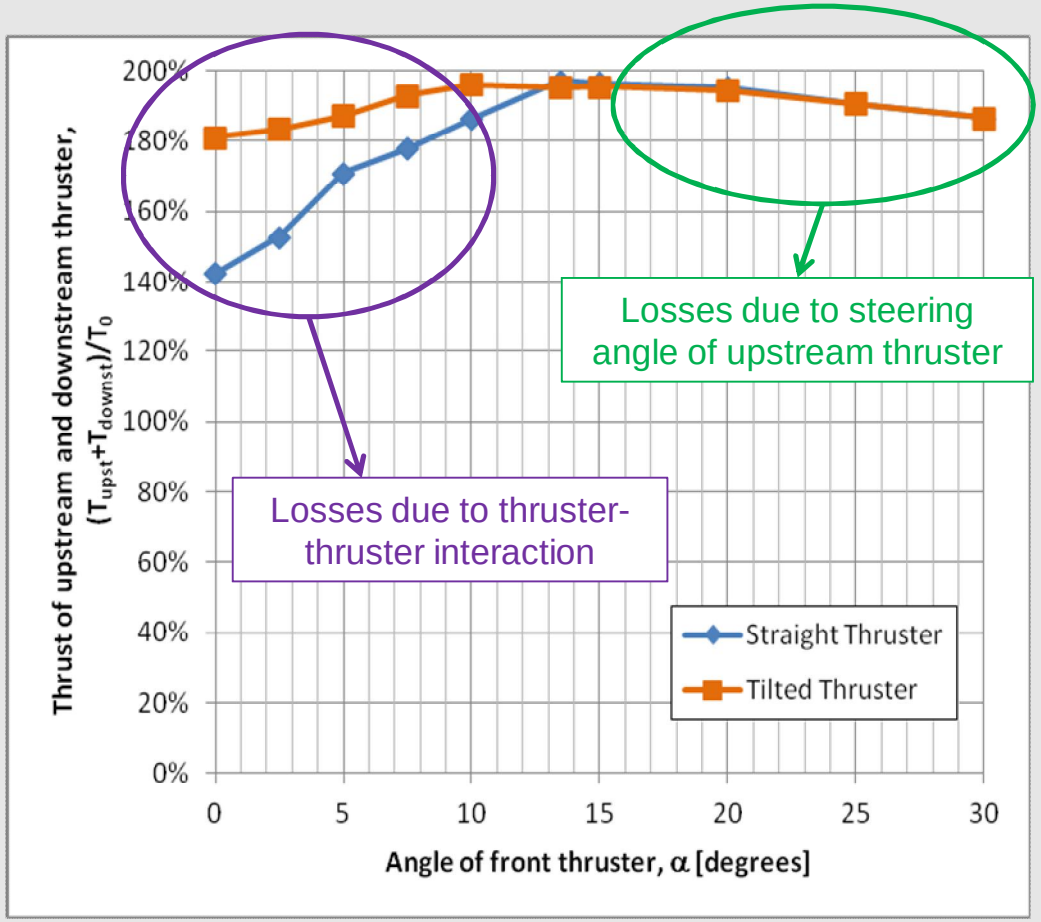
$\alpha$ = 0 degrees




$\alpha$ = 13.5 degrees

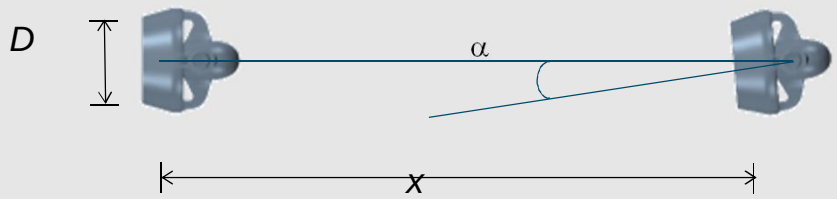


# Optimum Thrust Angle determination



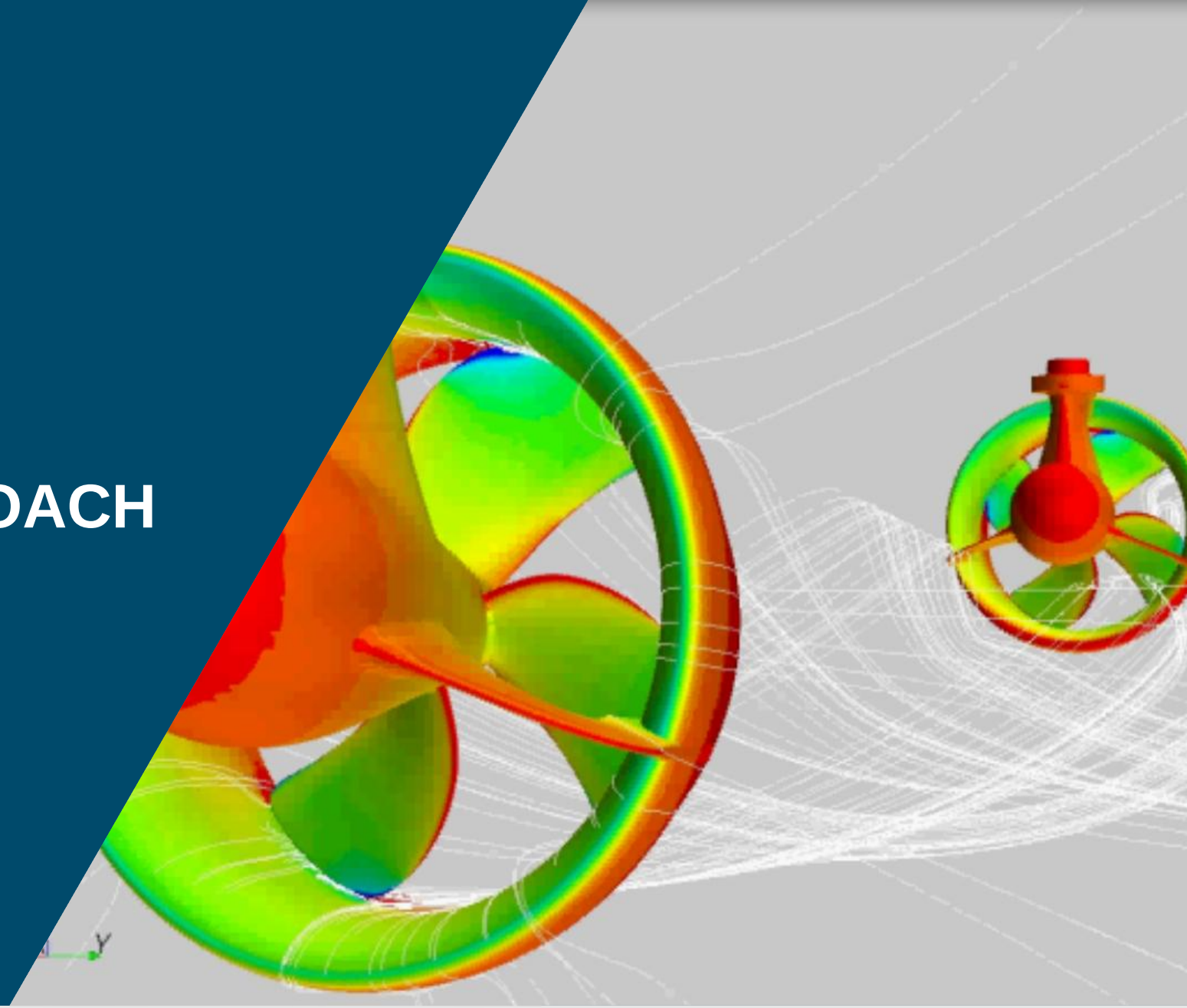

Optimum thrust is the angle at which the losses due to turning the upstream thruster together with the losses due to thruster-thruster interaction are minimized.

$$T_{total} = T_{upstr} + T_{downstr} = T_0\left(\cos\alpha + \tau_\alpha\right)$$

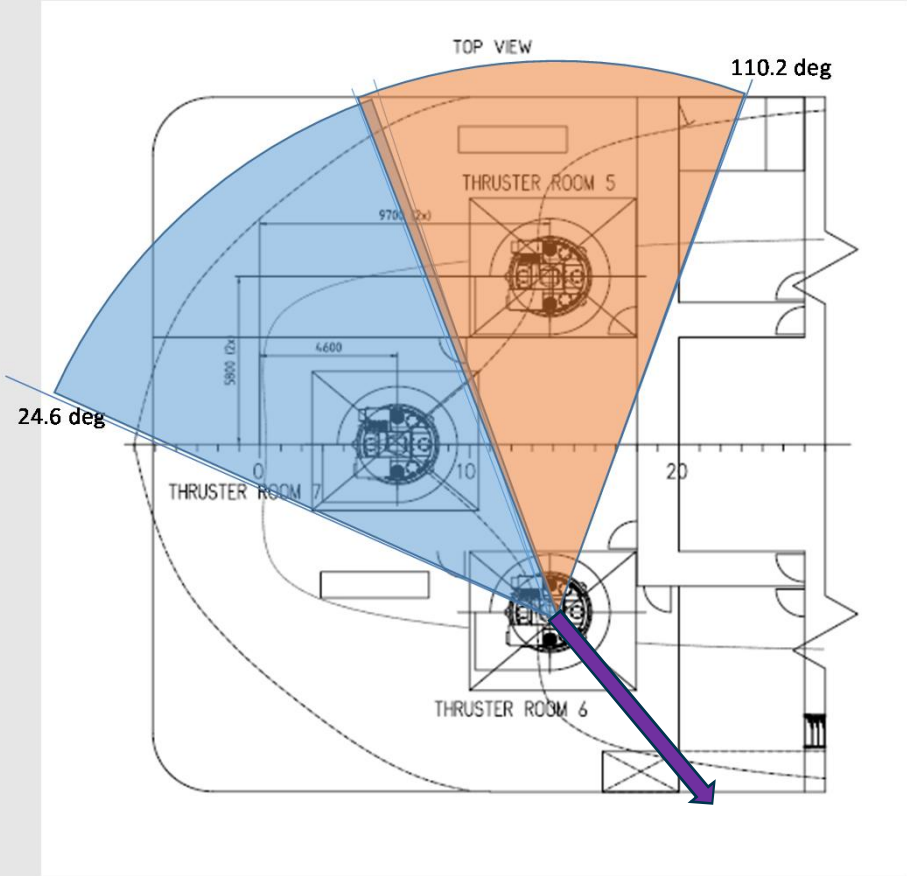



The zone within the optimum angle is denoted as **forbidden zone**, due to thruster-thruster interaction.

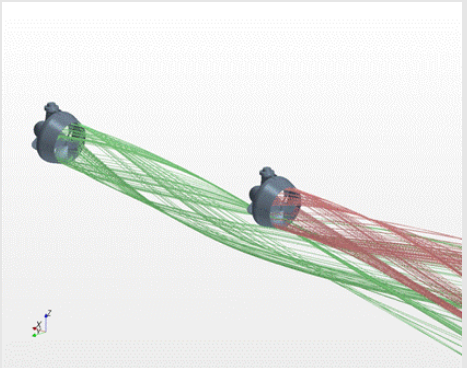
# CORRIDOR APPROACH



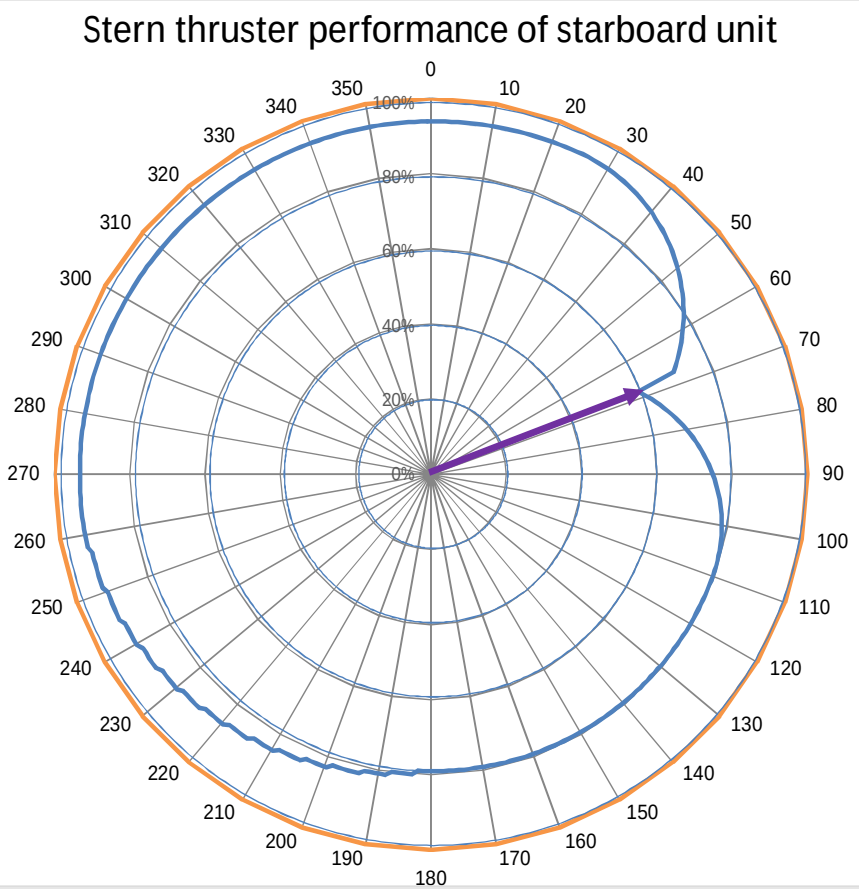
# Drill ship – thruster-thruster-thruster interaction




- The interaction between the **three units in the stern** of a drill ship can lead to an interesting phenomenon.
- Depending on the location of the thruster units, the **two forbidden zones can overlap**.
- This results in one single large forbidden zone for the steerable thruster.

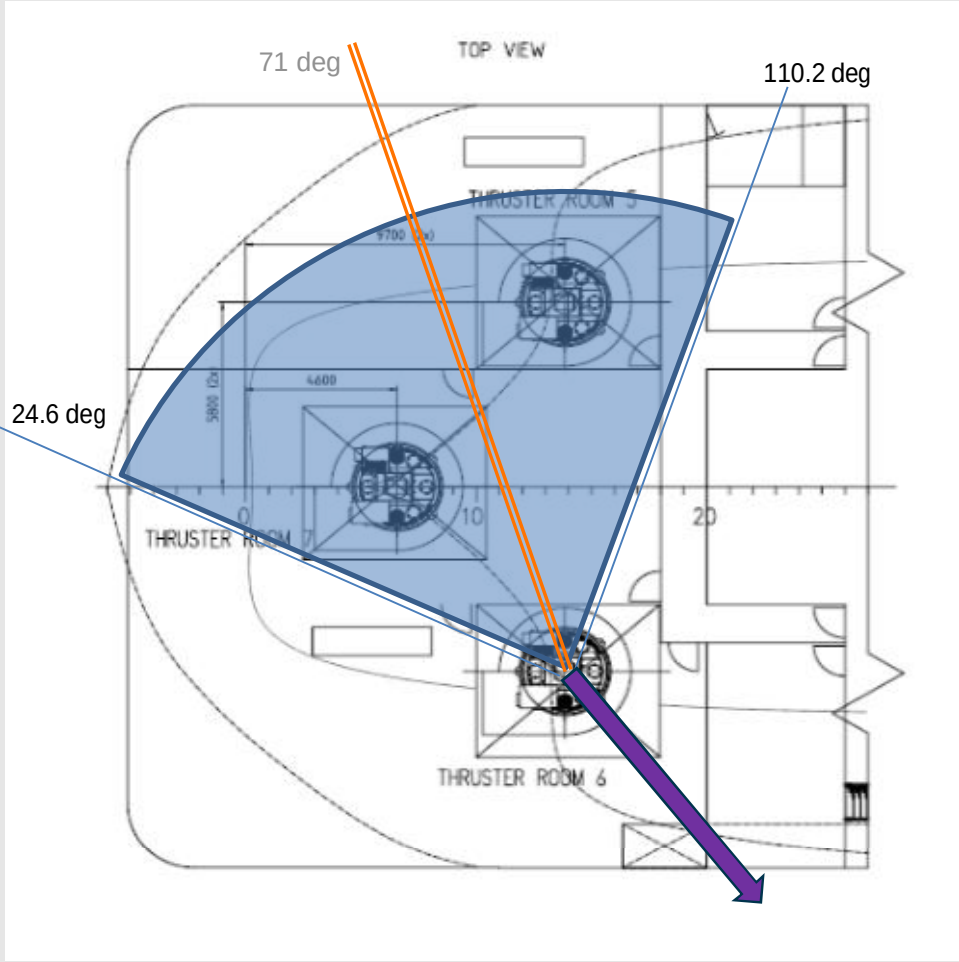


# Polar plot of thruster performance




- The available thrust of the unit is shown for the complete 360° circumference.
- The interaction losses with the hull and due to the forbidden zones are taken into account.
- At approx. 70° about 60% thrust is available in this configuration.
- *Note: this analysis has been made for a conventional, straight thruster unit.*

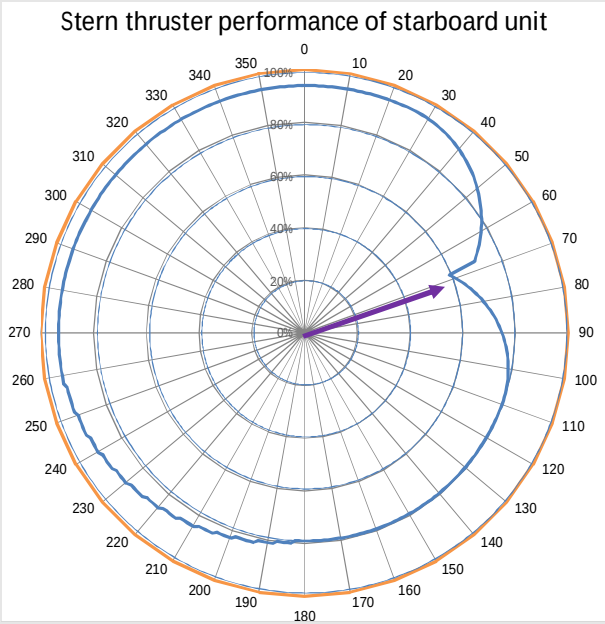
# Drill ship – Corridor Approach

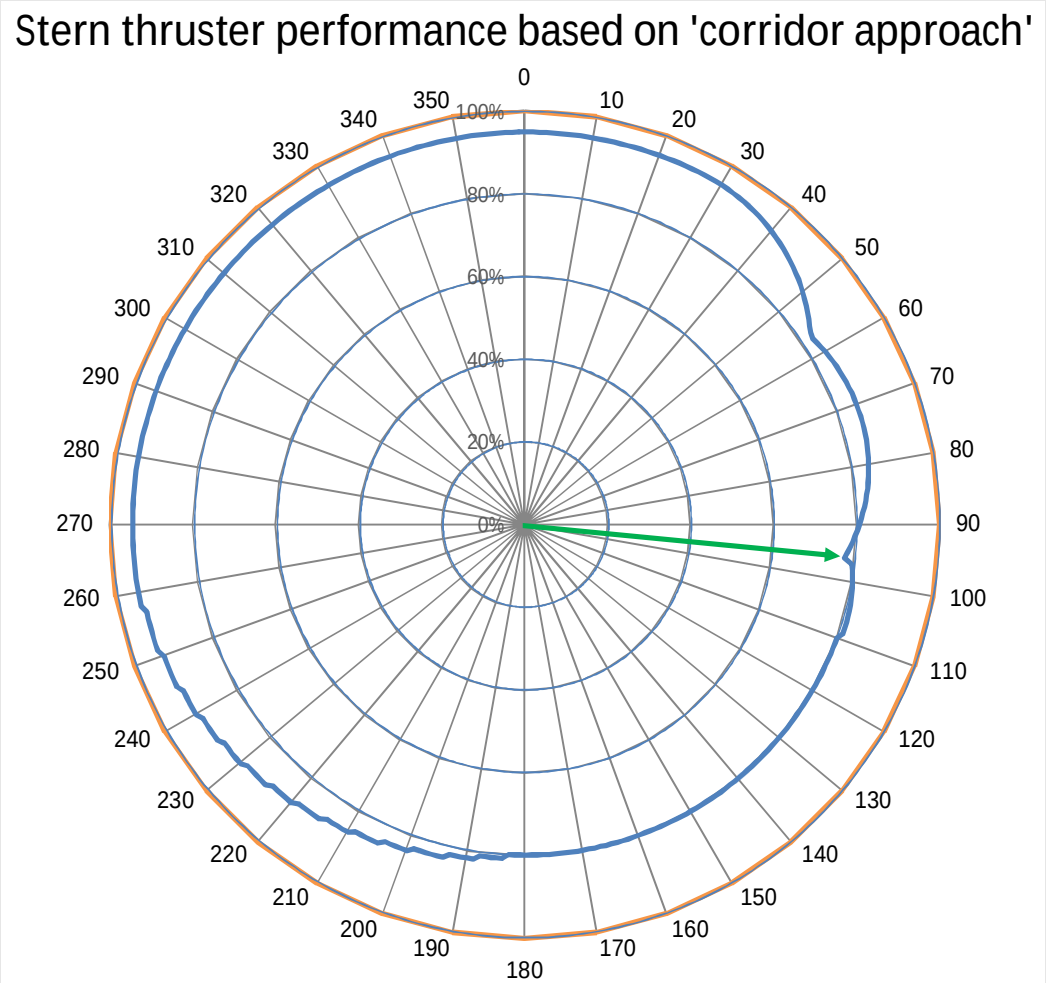



- In order to improve the thrust availability around 70° region, a **Corridor Approach** is implemented in which operation at given steering angle is allowed.
- In this case the corridor is set at 71°.
- This Corridor Approach is a good example of Smart Controls Systems.

# Impact of Smart Controls Approach

- With the **Smart Controls** the minimum available thrust is increased from 60% to 77%.
- This is a clear example of the benefits on Smart Controls systems on the overall performance of the vessel.



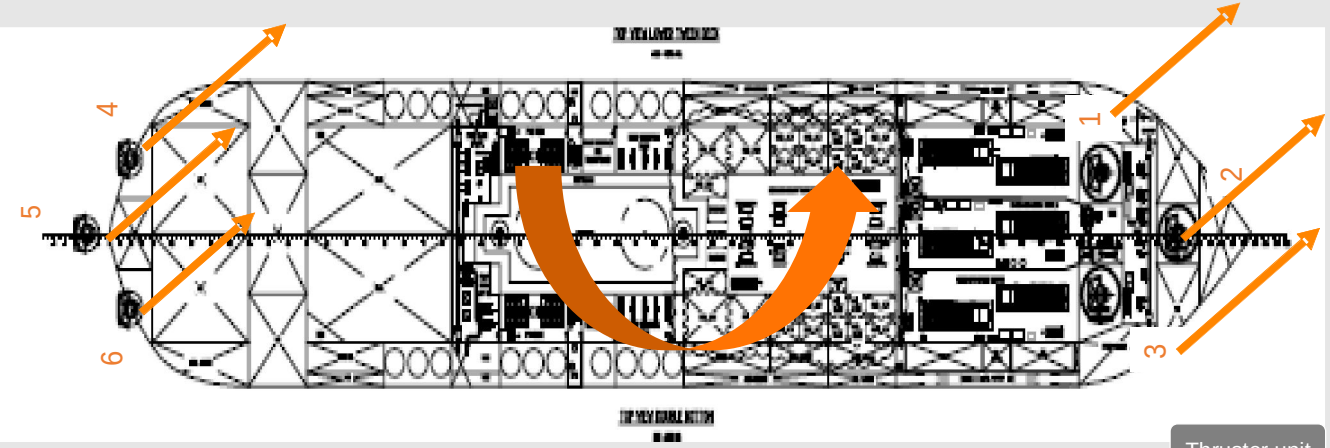



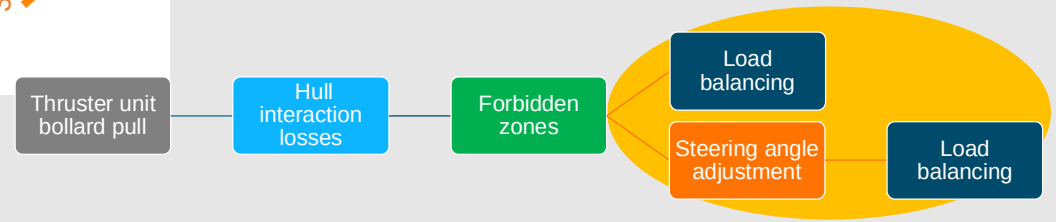
# THRUST ALLOCATION ON DRILL SHIP

# Drill ship performance

- The overall DP-capability of a drill ship is based on the performance of the 6 thrusters together.

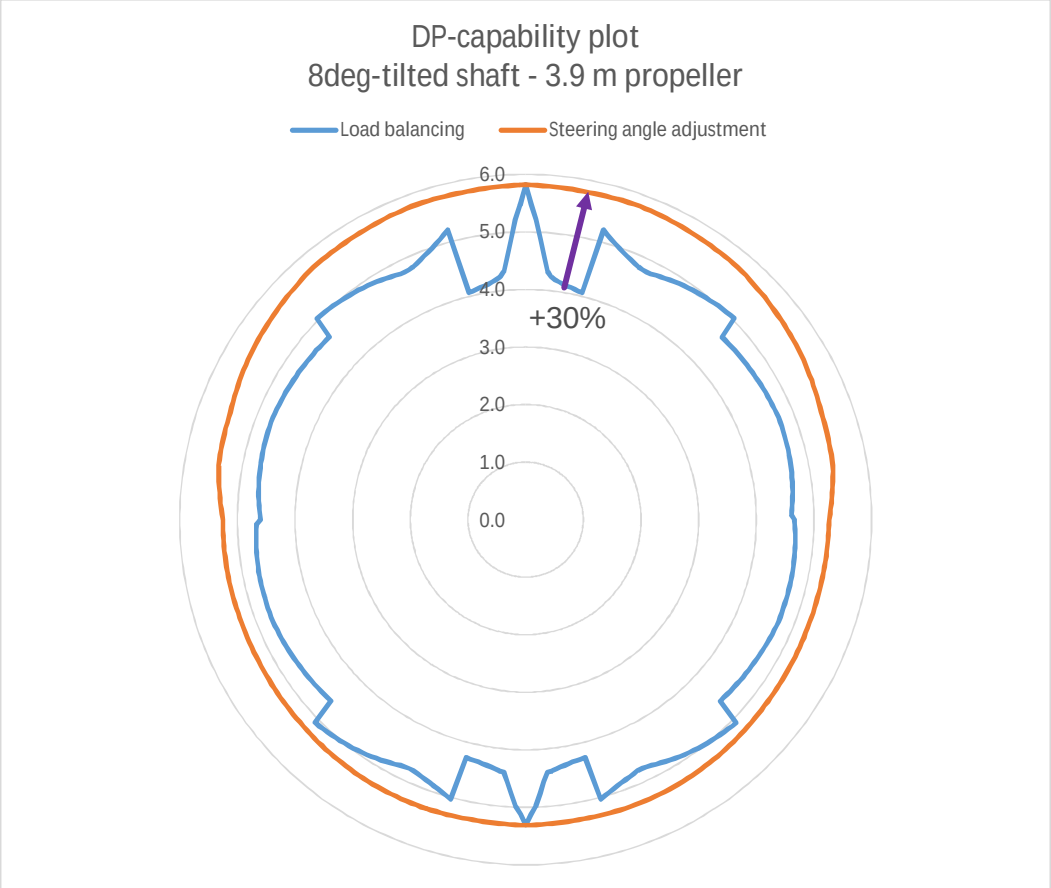
- In order to eliminate the yaw moment around the vessel center-point, the input loads of all thrusters have to be balanced. This can be achieved by:
  - Balancing of the magnitude of the thrust factor (**load balancing**)
  - **Adjustment of steering angles** to modify the torque-arm



# Comparison of thrust load balancing and angle adjustment

- In the polar plot the results are shown for:
  - Thrust load balancing (blue)
  - Angle adjustment  & thrust balancing (orange)
- The gains in overall performance are obviously in favor for the angle adjustment methodology: **15% over 360° averaged**.
- The most critical condition of minimum thrust can be improved with 30%.
- Note: *this angle adjustment methodology will be used for further comparisons.*

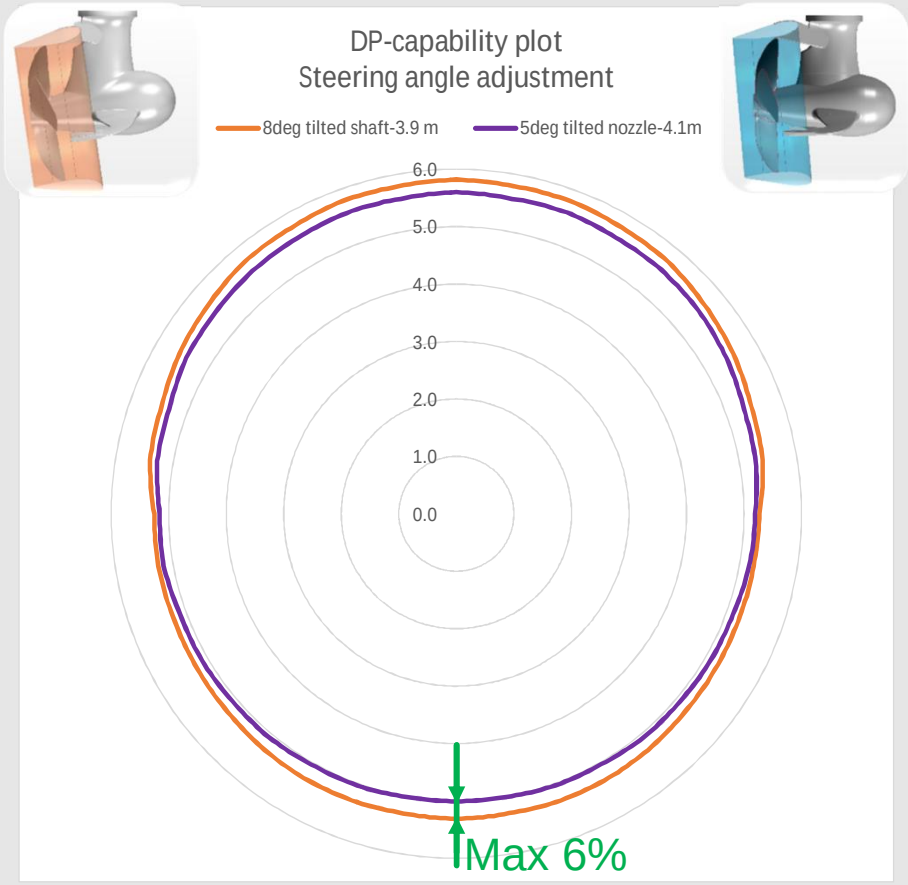


# Dynamic Positioning thrust polar plot

- In the polar plot the normalized available thrust results are shown for:
  - Reference unit – 4.1 m - 5°-nozzle (purple)
  - WST-55 – 3.9 m - 8°-shaft (orange)

- The WST-55U has on average over the 360° circumference 3.5% more thrust for the same installed power.
- The maximum difference in DP-thrust is 6%.

| Type | Diameter [mm] | BP unit thrust | DP-capability (6 units) |
|---|---|---|---|
| WST-55U | 3900 | 98.9% | 103.5% |
| Reference unit | 4100 | 100.0% | 100.0% |



# CONCLUSIONS

# Conclusions

- The hydrodynamic performance of thrusters with 8°-tilted shaft outperforms the industry reference design with 5°-tilted nozzle on:
  - Open water performance / bollard pull performance due to the alignment of propeller and nozzle
  - Thruster-hull interaction losses (thrust-deduction) due to better downward deflection of the wake.
- The difference in performance can be partly covered by larger propeller diameters, which will result in larger overall units.
- The calculated gain in DP-capability performance is 360°-averaged 3.5% and at max 6.0% when the 3.9m WST-55U is compared with the 4.1m reference unit for the same input power.

# Conclusions

- In case two forbidden zones overlap as a result of interaction between 3 thrusters, the introduction of a corridor in the forbidden zones can improve the overall DP-performance.

- The thrust allocation algorithm can have a significant impact on the overall DP-capability, depending on the methods to balance the yaw-moment of the vessel.
- The differences between the load-balancing method and the steering angle adjustment is about 15% averaged over 360° and it can go up to 30% for the most critical angle.

- Future DP-systems need therefore be based on the actual net-thruster performance over its 360° azimuth sector.

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