MARIN

Challenging wind and waves

Linking hydrodynamic research to the maritime industry

Analysis of the Velocities in the Wake of an Azimuthing Thruster, using PIV Measurements and CFD Calculations

Hans Cozijn (MARIN)

Rink Hallmann, Arjen Koop

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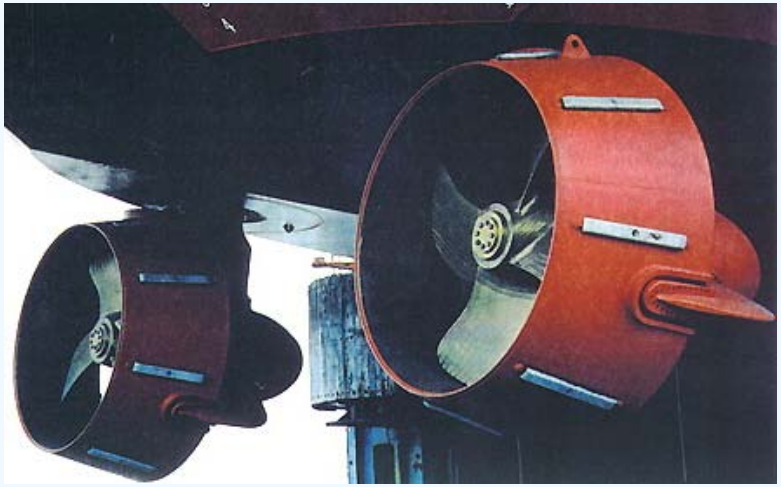
Presentation Outline

- Background and Objectives
- Case Description
  - Thruster in Open Water Conditions
  - Thruster under a Barge
- Model Tests
- PIV Measurements
- CFD Calculations
- Comparison of Results
- Conclusions and Recommendations

Background

- Thrust degradation effects
  - Thruster-hull
  - Thruster-thruster
  - Thruster-current interaction
  - Thruster ventilation



"During DP operations the effective force generated by the thrusters can be significantly smaller than what would be expected based on the thrusters' open water characteristics."

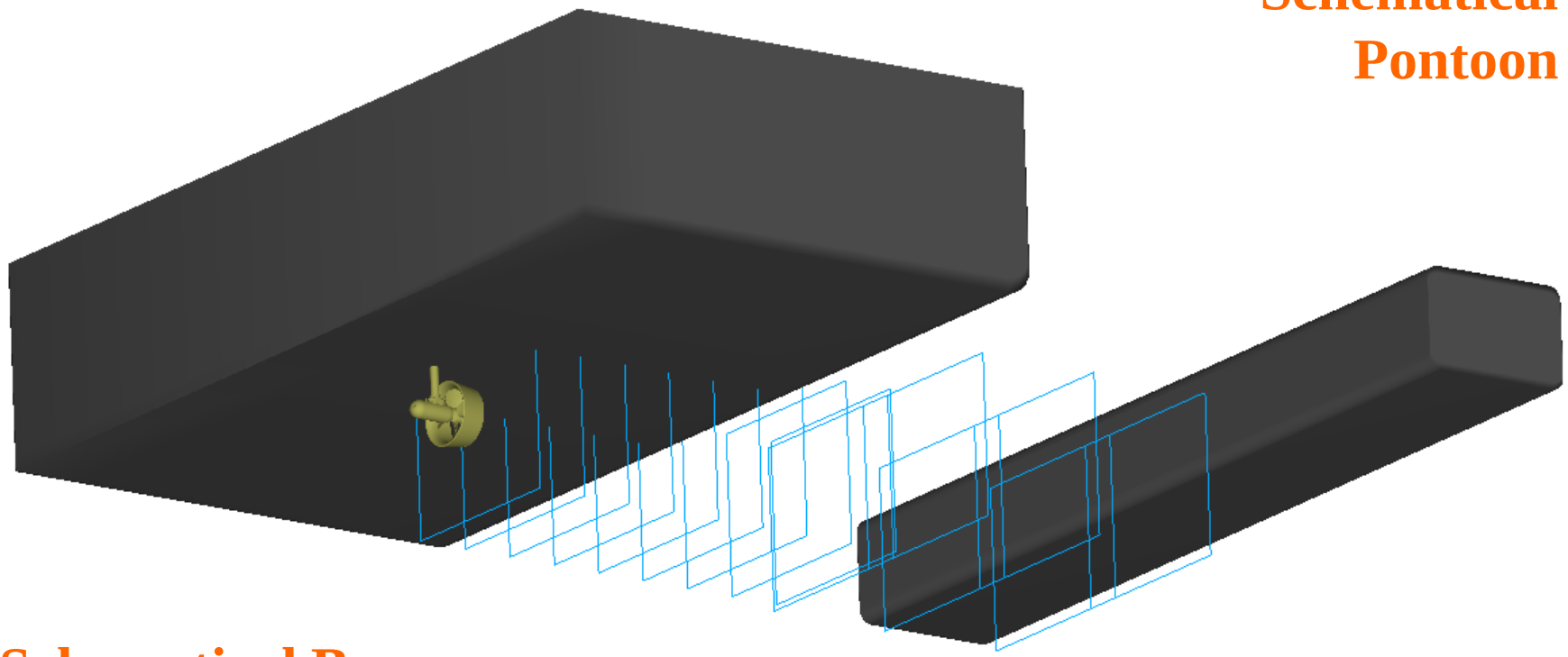
Objectives of the Present Work

- Improve understanding of the physics related to thruster-interaction (thrust degredation) effects
- Investigate applicability of PIV measurements for measurement of thruster wake velocities
- Comparisson of measurements, CFD calculations, and empirical models
  - Thruster in Open Water
  - Thruster under a Barge
- Validation of CFD calculations

Case Description

- Case 1 - Thruster in Open Water
  - Propeller + nozzle
  - Bollard pull conditions
- Case 2 - Thruster under Barge
  - Schematical barge shape
  - Rounded bilge
- (Case 3 - Thruster under Barge with Pontoon)
  - (Schematical pontoon added)

Model Test Set-up Deepwater Towing Tank

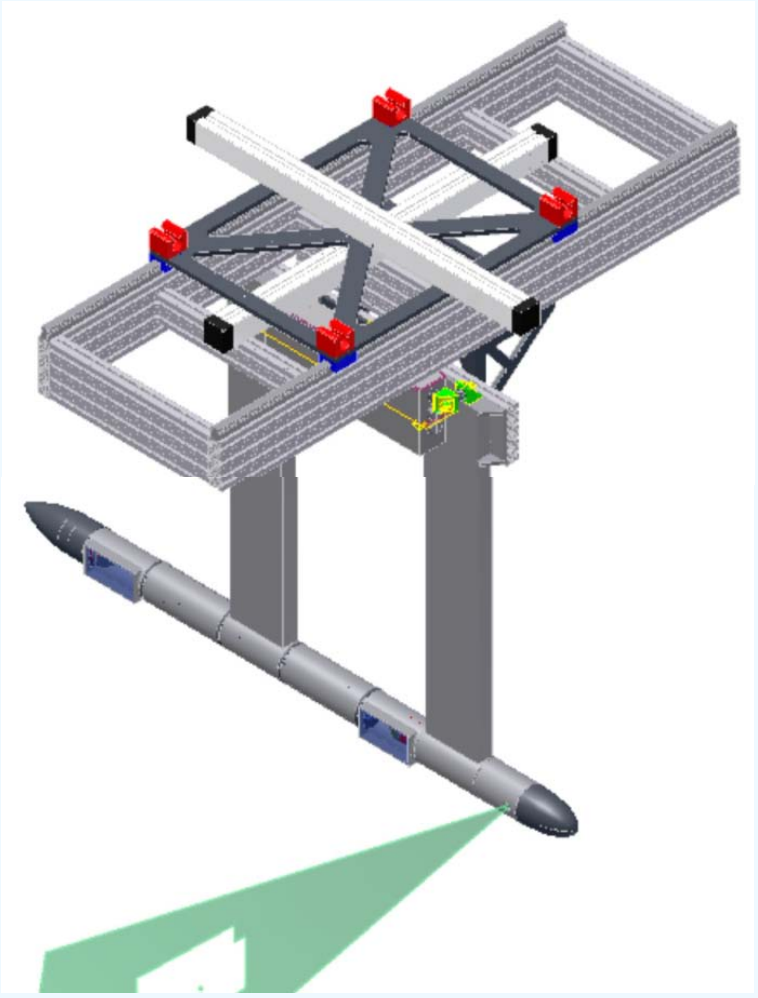


Model Tests - Measured Quantities

- Propeller Thrust and Torque
- (Nozzle Thrust)
- Total Thrust Force
- Total Force on Barge
- Total Force on Schematical Pontoon
- Velocity Measurements
  at x = 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12.5 and 15 x D

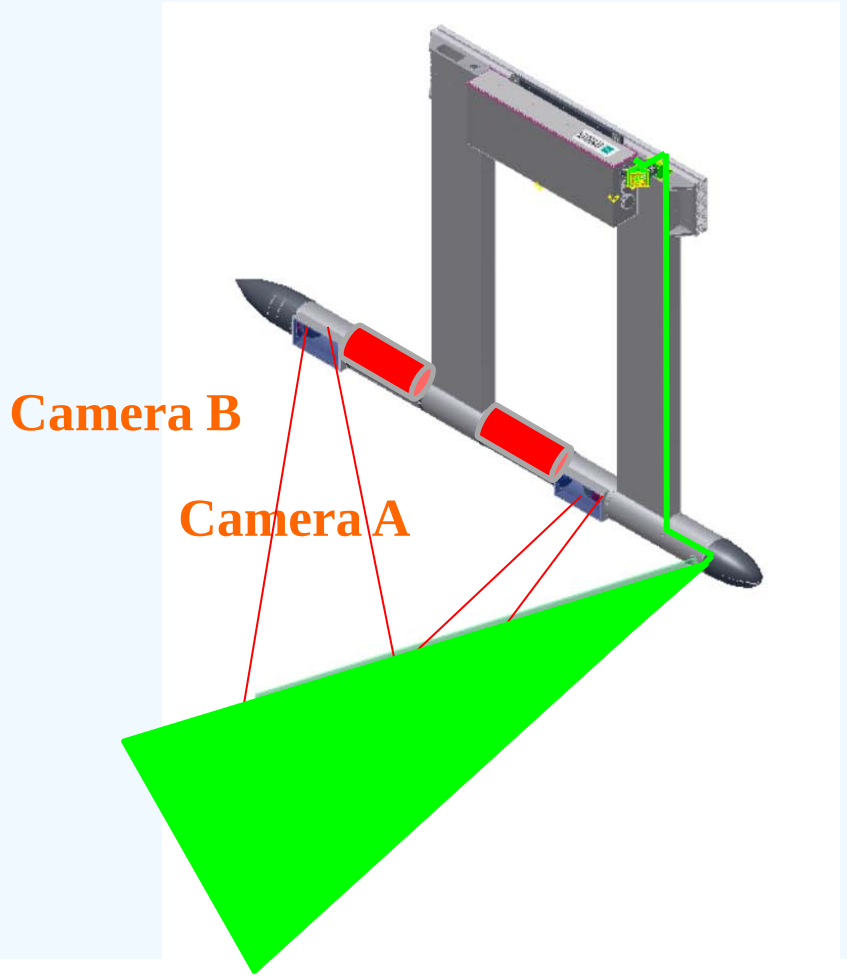
PIV Measurements

- PIV concept
  - Particles in water ("seeding")
  - Illumination by laser sheet
  - Cameras (2)
  - Image capturing + data analysis
- MARIN new PIV system (2009)
  - 3D PIV measurements
  - Measuring area ~ 24 x 36 cm
  - Class 4 laser
  - Traverse system x-y-z
  - Laser + cameras in single housing

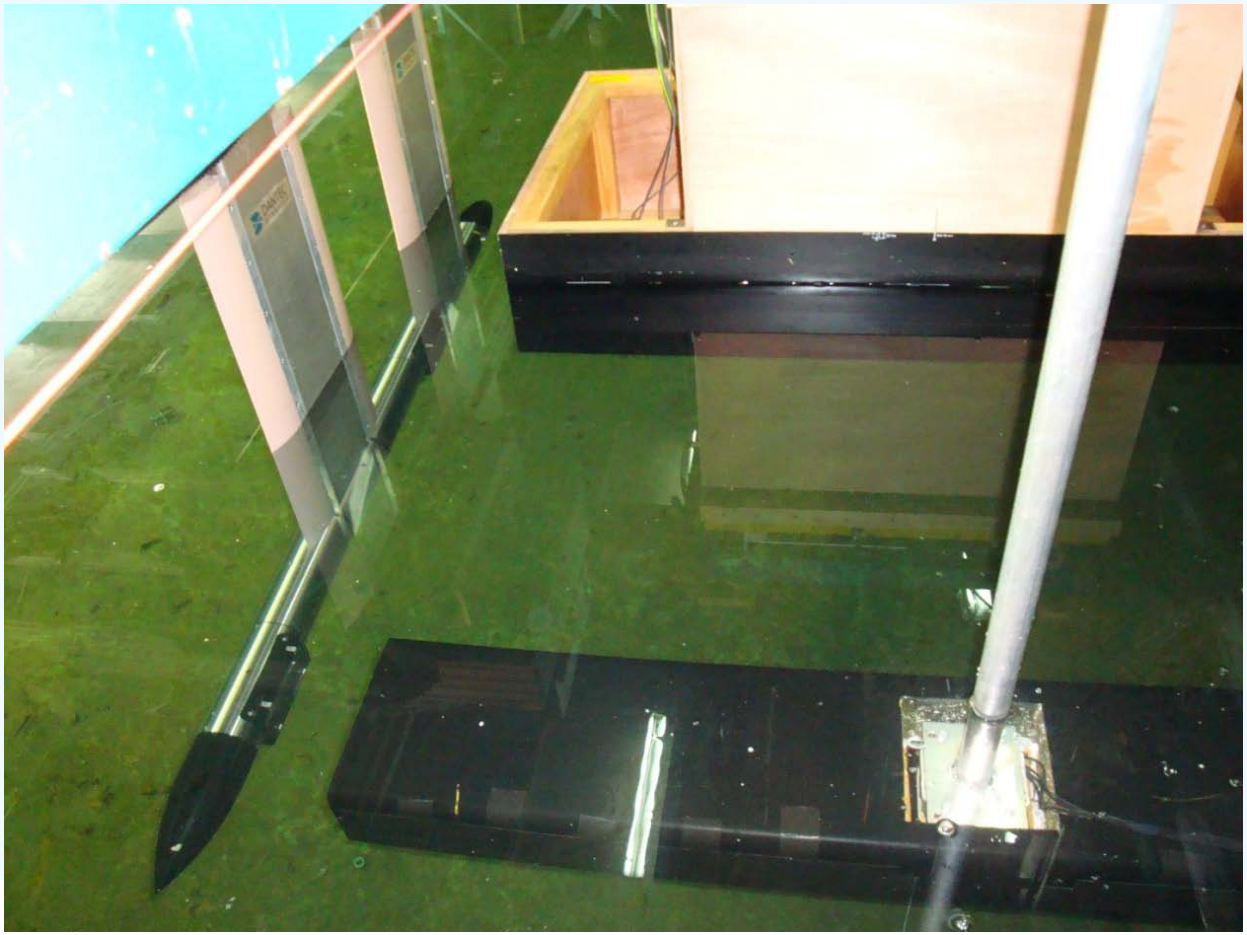


Main Principles of PIV

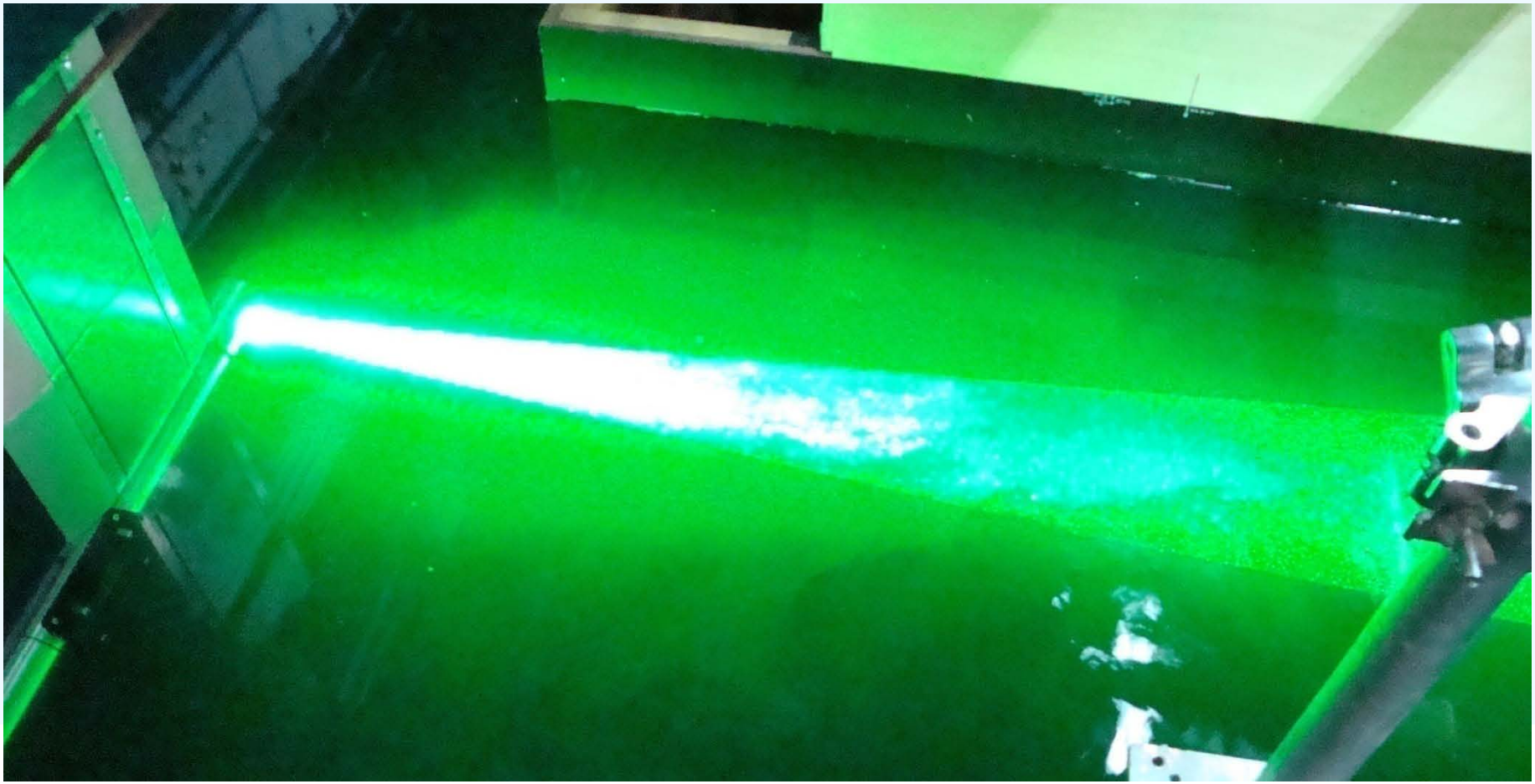
- PIV is a method for determining ‘instant’ velocity vector maps.
- A thin light sheet is generated and the movement of particles inside this light sheet is observed with (one or more) digital cameras



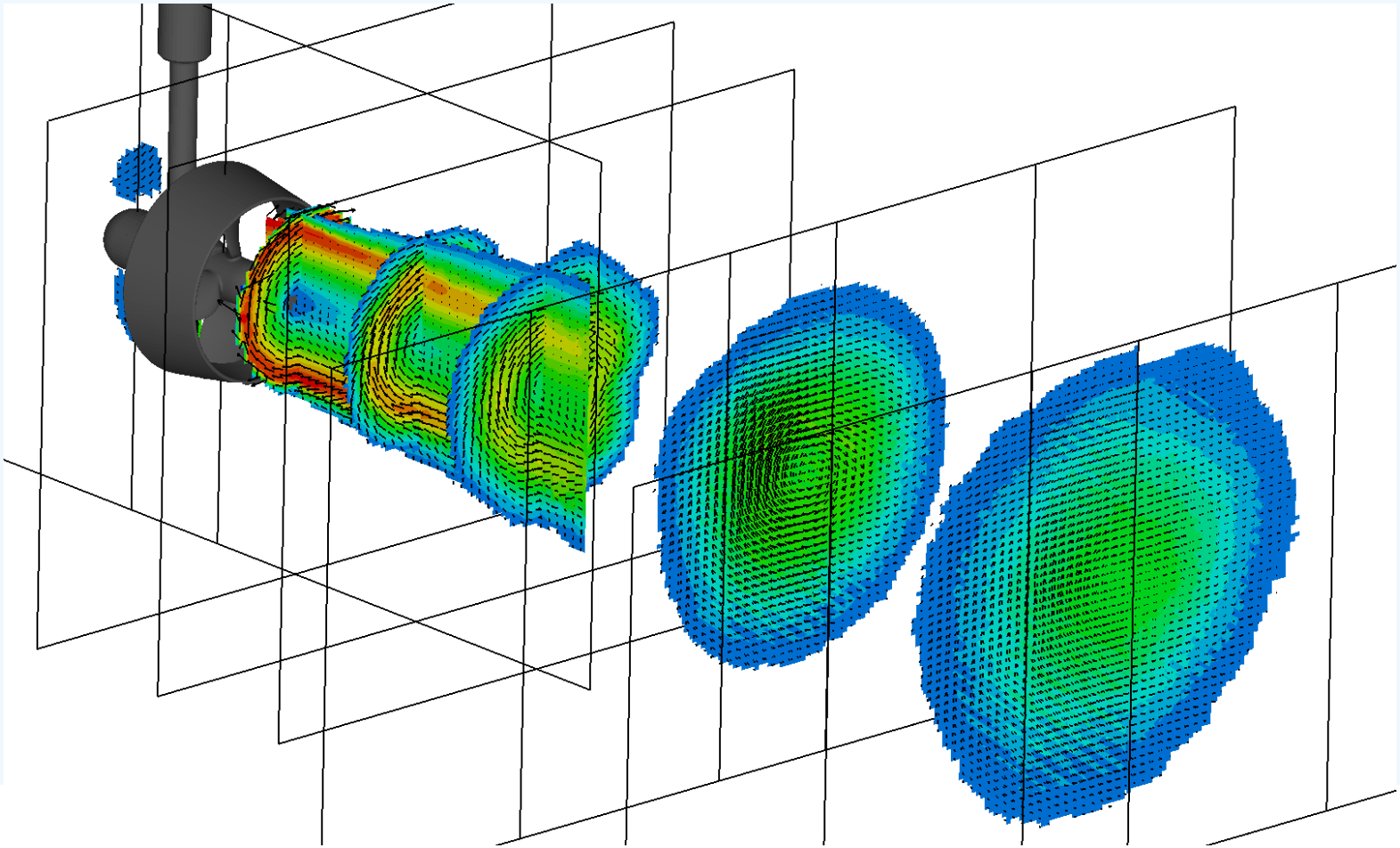
PIV System in MARIN's Deepwater Towing Tank



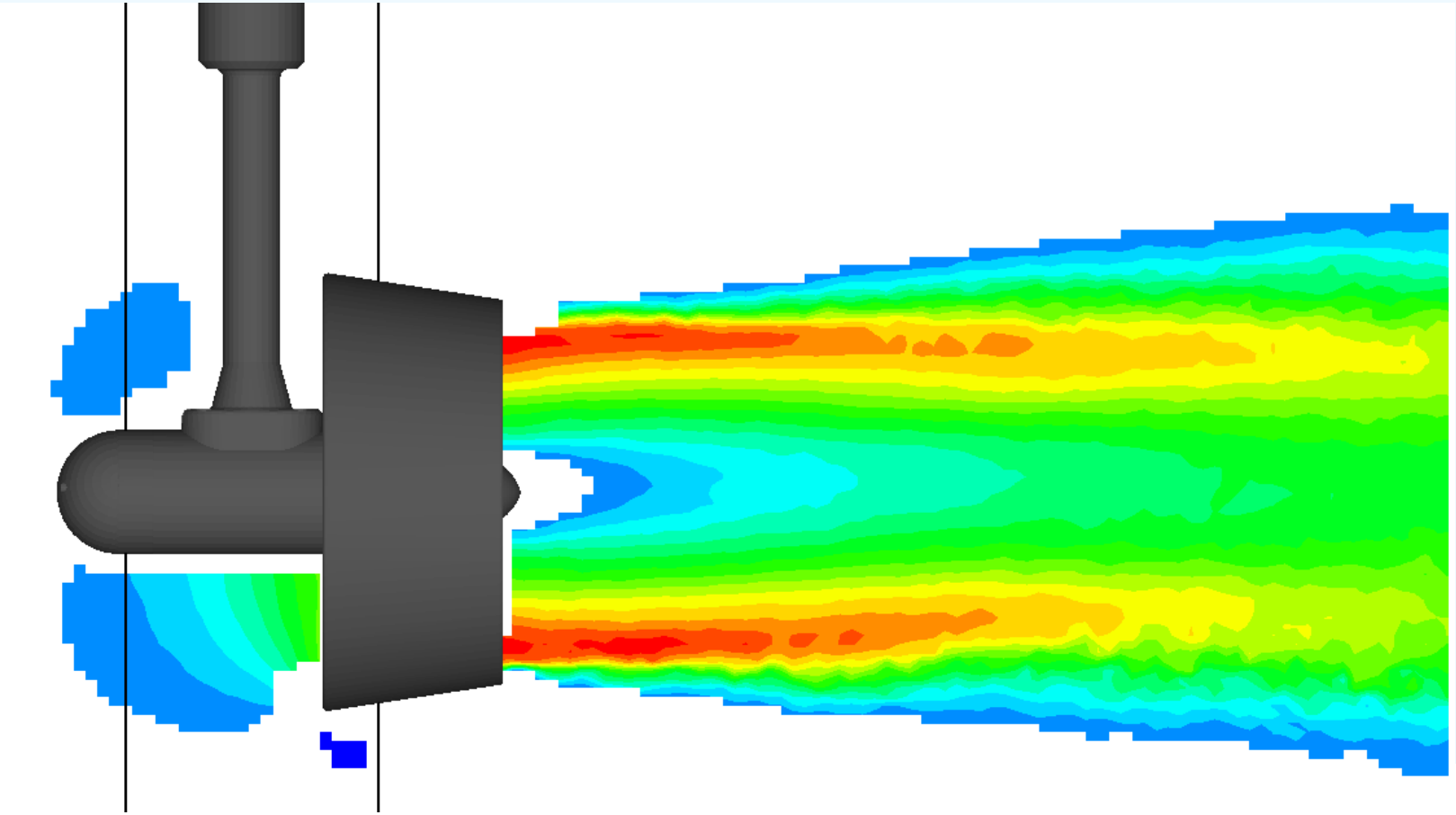
PIV System in MARIN's Deepwater Towing Tank



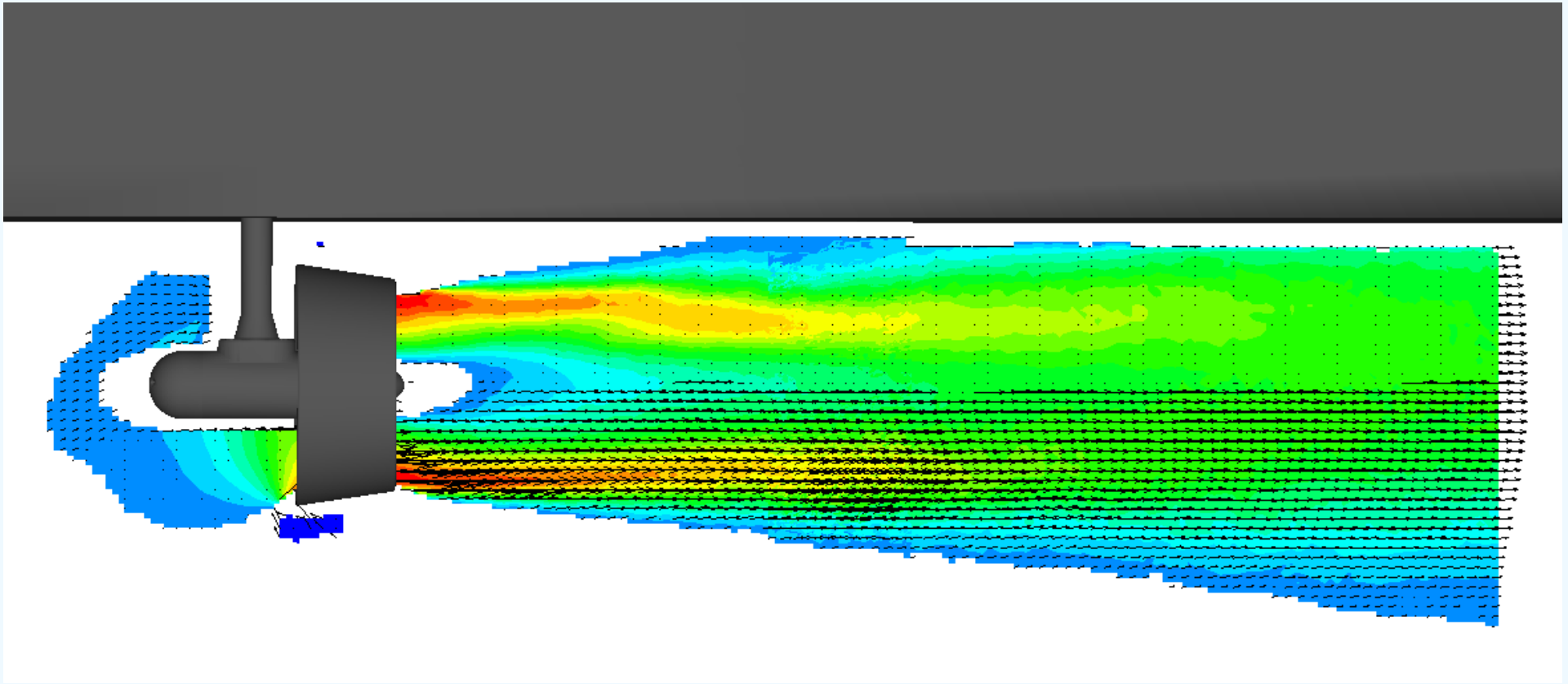
Example PIV Measurements - Open Water



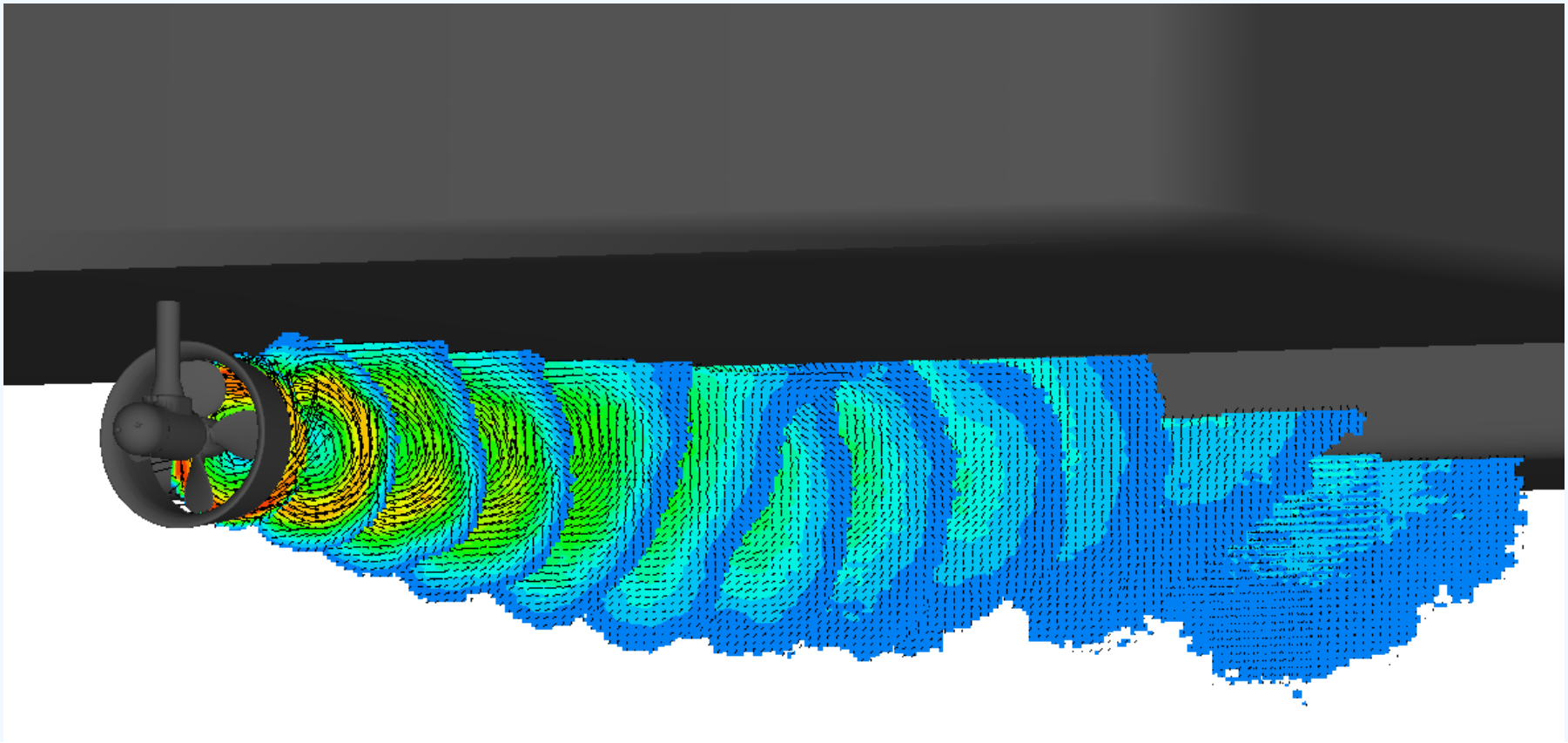
Results PIV Measurements - Open Water



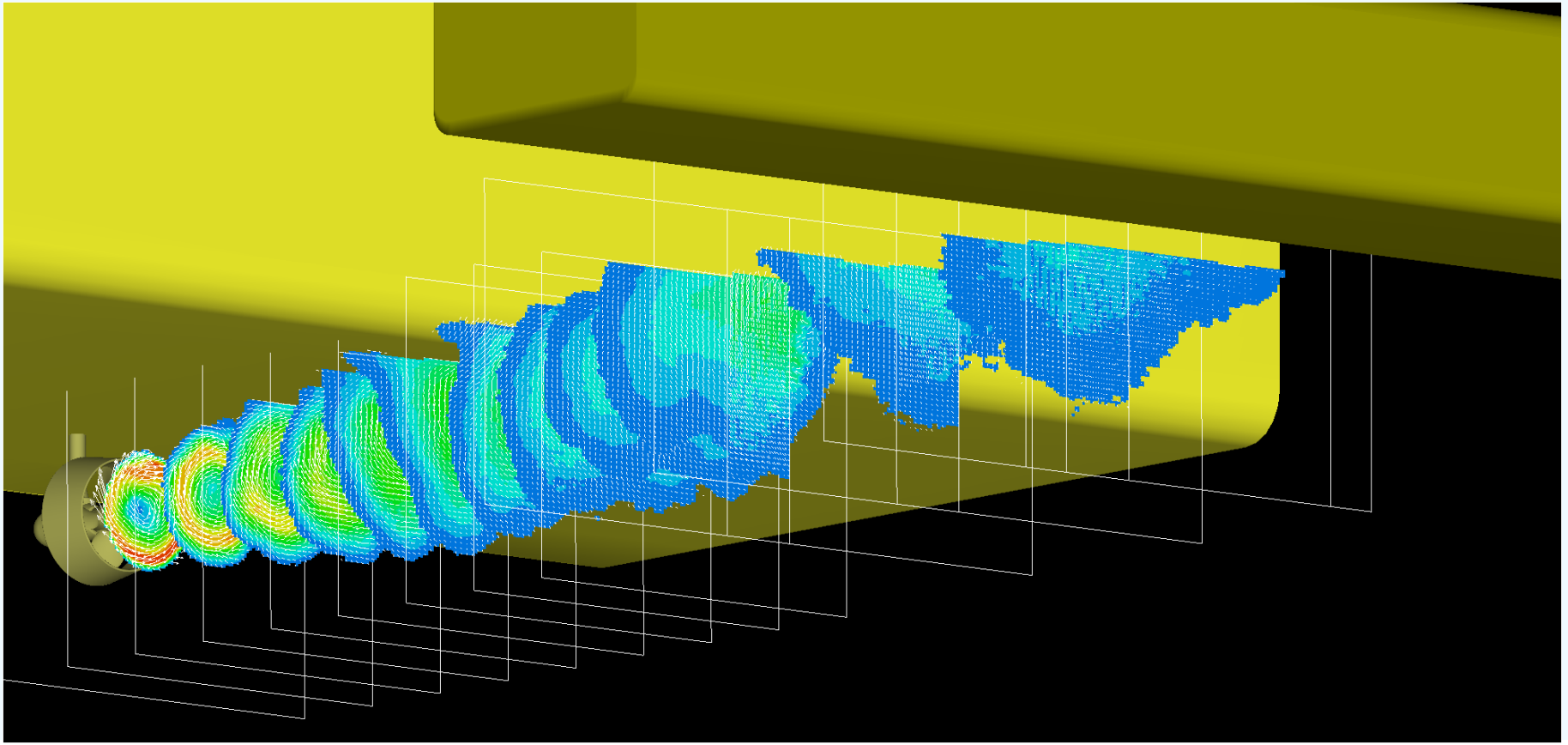
Results PIV Measurements - Under Barge



Results PIV Measurements - Under Barge



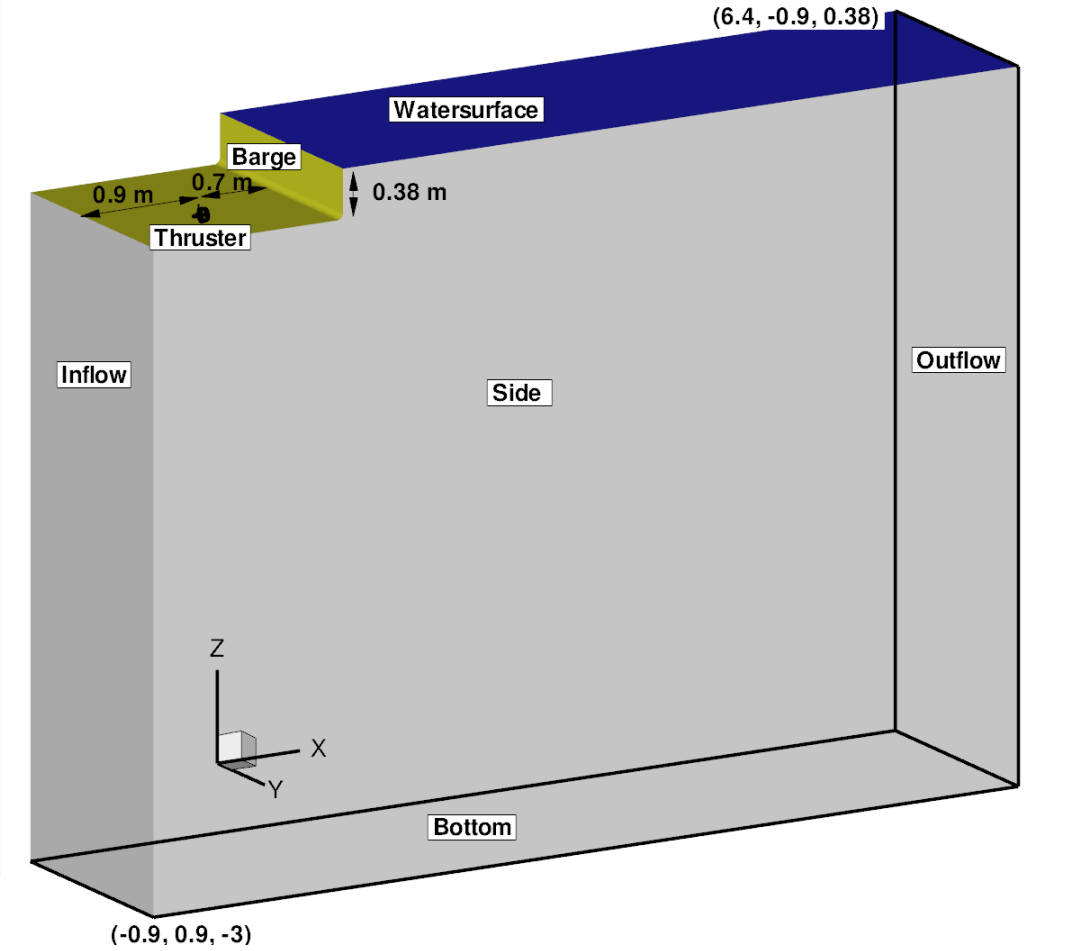
Results PIV Measurements - Under Barge



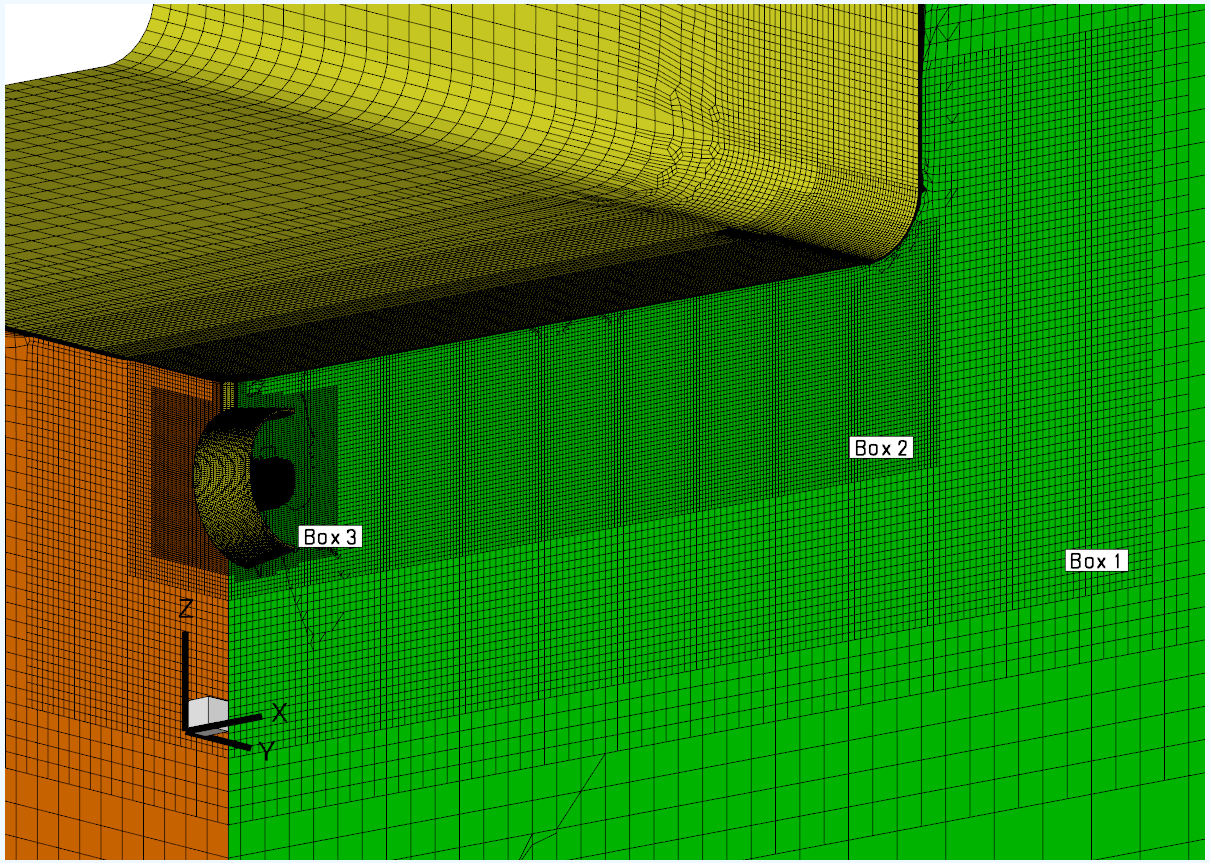
CFD Calculations

- MARIN in-house ReFRESCO code
  - Reynolds Averaged Navier-Stokes (RANS)
  - Turbulence models
  - Finite volume method, allowing use of arbitray grid types
  - Parallelized code
- Calculation Hardware
  - Linux cluster 3 (1,184 processors)
  - Cluster 1 (12 processors), Cluster 2 (256 processors)

Computation Domain

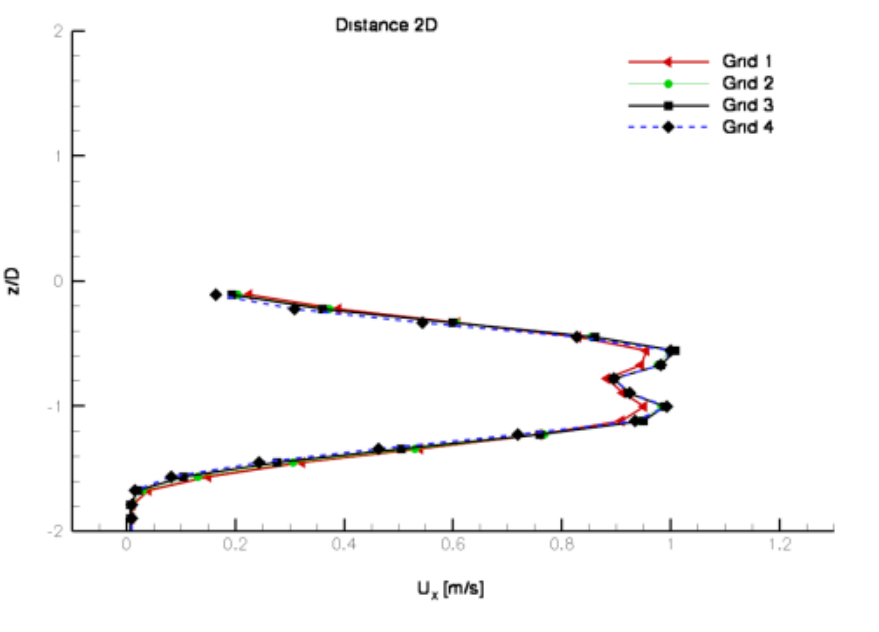


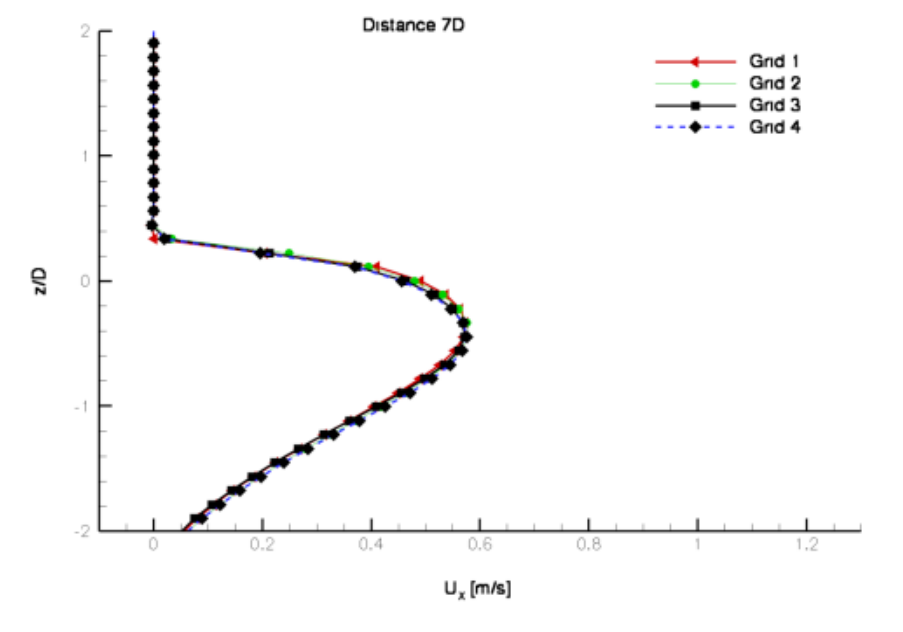
Computation Grids



- Grid 1 - 2.7M cells
- Grid 2 - 4.6M cells
- Grid 3 - 8.5M cells
- Grid 4 - 15.7M cells

Computation Grids

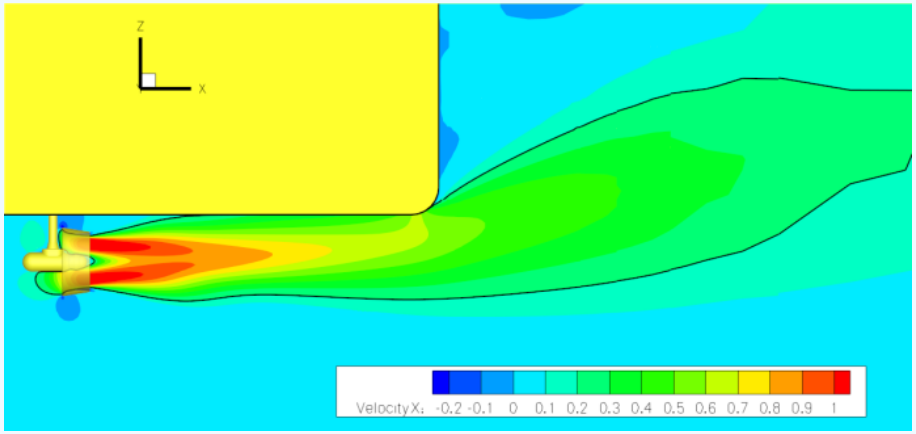




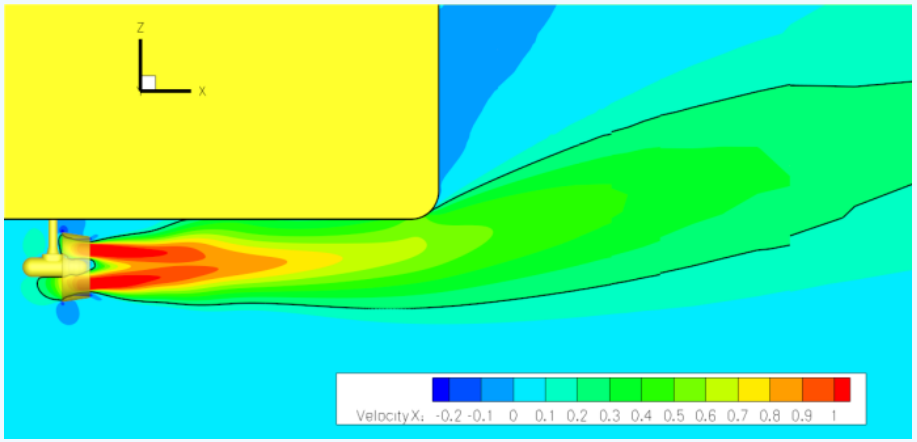
x/D = 2

x/D = 7

Computation Grids



Grid 1 (2.7M cells)

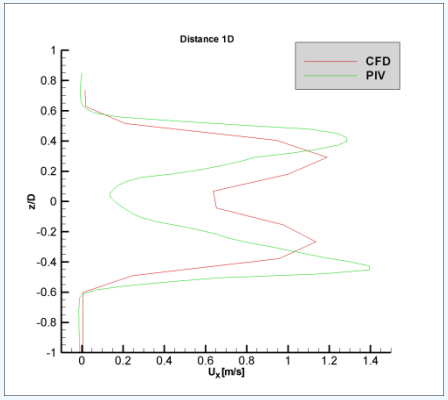


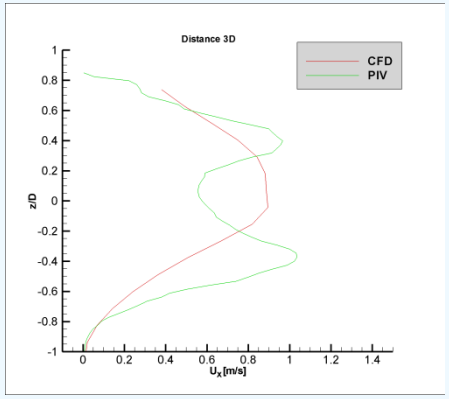
Grid 4 (15.7M cells)

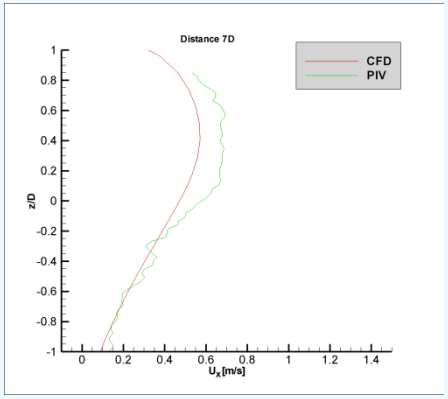
Comparison of Results

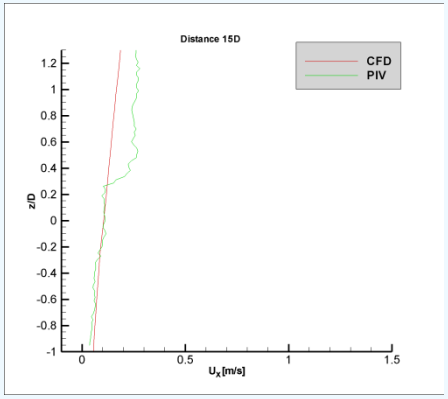
- Open Water Conditions
  - PIV measurements
  - Nienhuis emperical model
- Thruster under a Barge
  - PIV measurements
  - CFD calculations

CFD Calculations vs. PIV Measurements





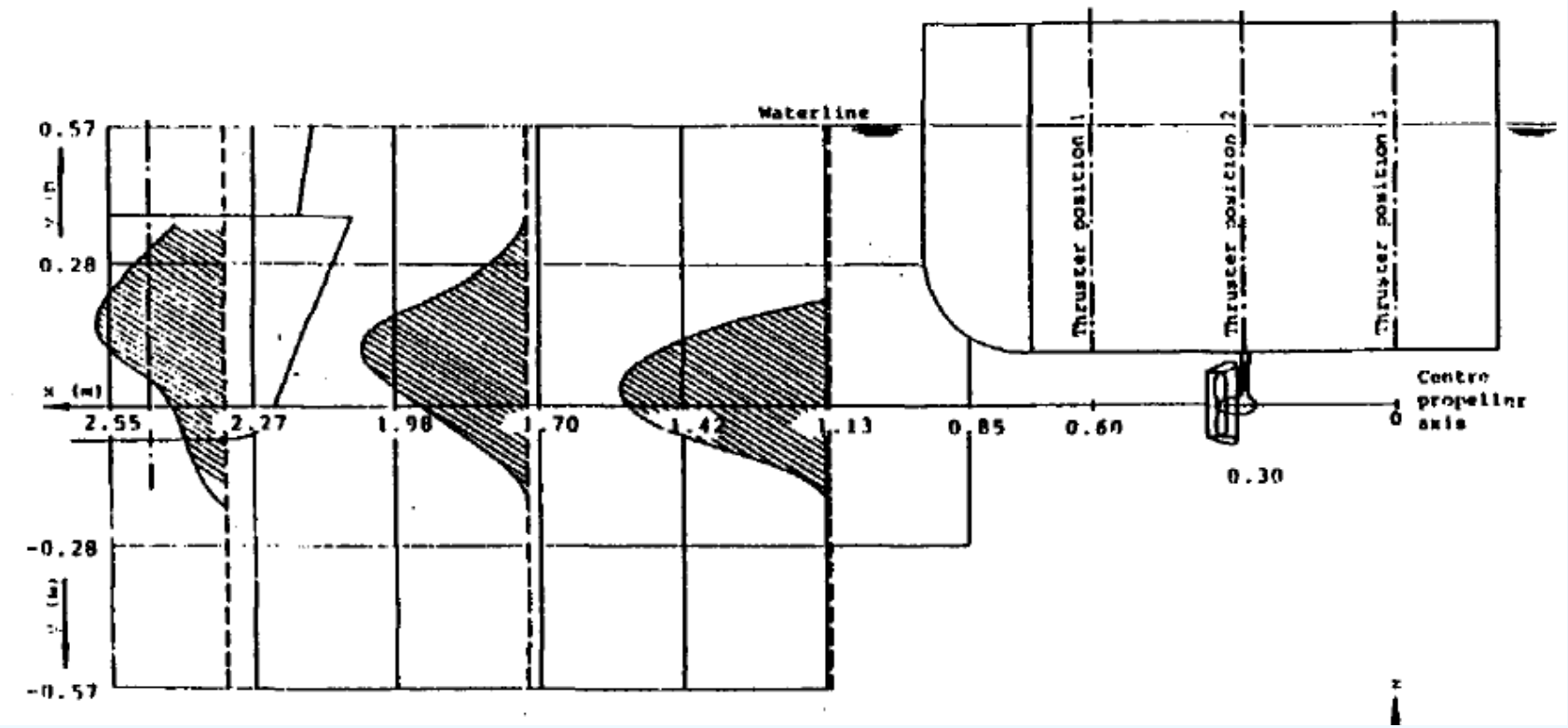




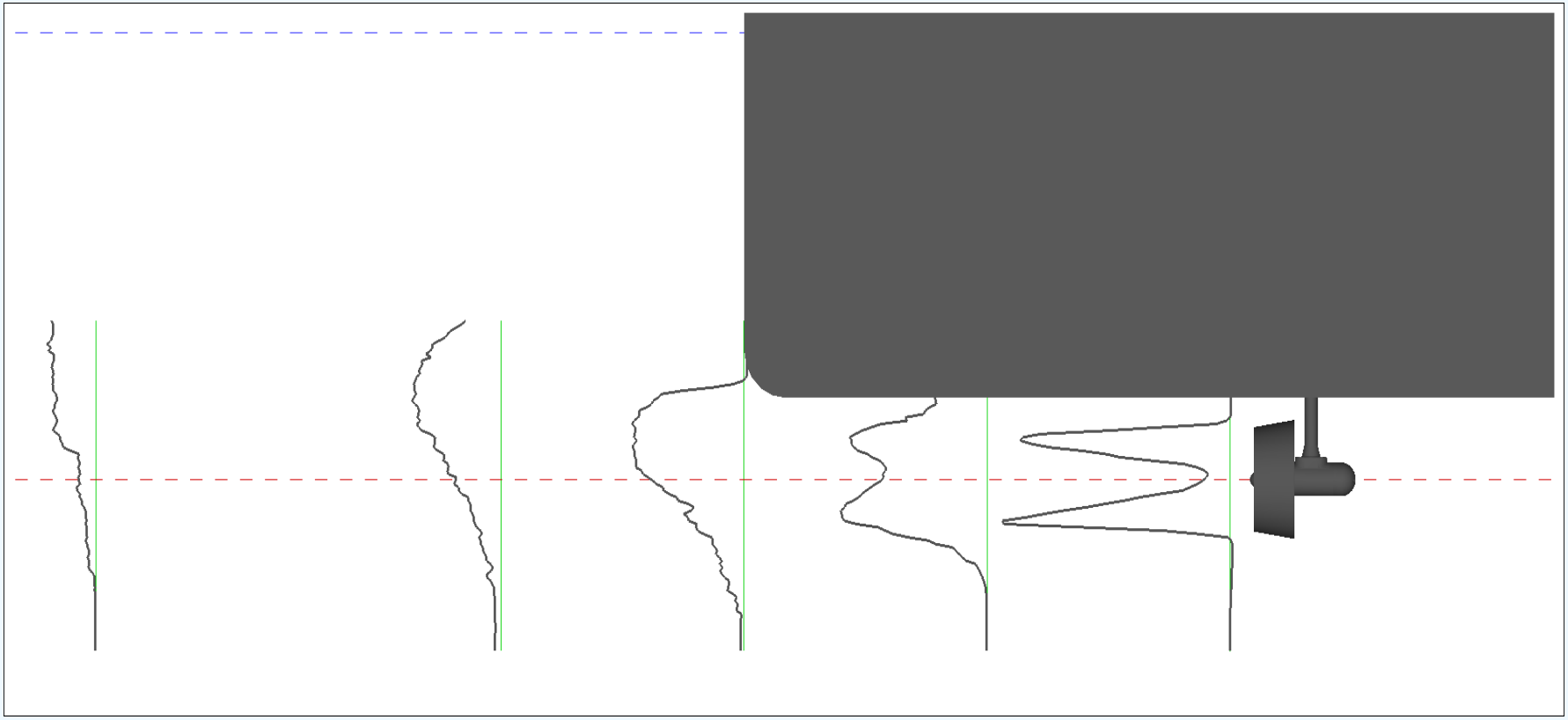
x/D = 1 **x/D = 3** **x/D = 7** **x/D = 15**

- Differences observed near thruster (x/D = 1 - 5)
  - Correspondence may be improved by adjustment of radial thrust distribution
- Better accuracy further down-stream (x/D = 7 - 15)
  - No numerical dissipation is observed

Model Tests by Nienhuis (LDV measurements)



Present Model Tests (PIV measurements)



x/D = 15 x/D = 10 x/D = 7 x/D = 3 x/D = 1

Conclusions and Recommendations

- Conclusions
  - PIV measurements can capture the wake flow behind a thruster, including wake development and Coanda effect.
  - CFD results represent the observed physics in the wake flow. Better accuracy can be achieved by improved modelling of the radial thrust distribution.
- Recommendations for Further Research
  - Investigate effect of radial thrust distribution
  - Investigate effect of rotation and divergence modelling
  - Investigate effect of nozzle shape
  - Analysis of more complex configurations

Thank you for your attention !!

Hans Cozijn

J.L.Cozijn@MARIN.nl

+31 317 493 272