2022

FRIENDSHIP UM 2022 – NUMECA Ingenieurbüro – Thomas Hildebrandt

Optimisation of an Electric Cat in the Early Design Stage

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The Electric Cat

The Electric Cat

Motivation

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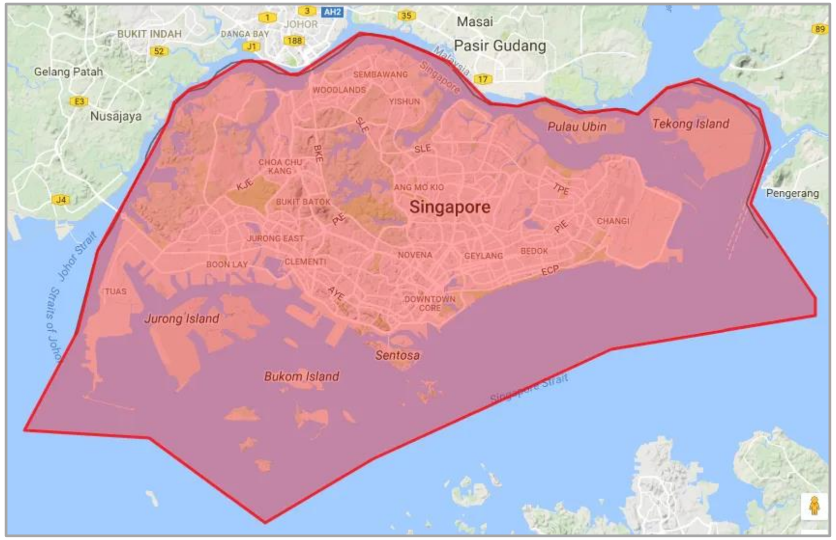
- Singapore Port is a major international crew change hub for ships.
- Singapore Port Authority is seeking to electrify all harbour craft.
- There is a need for an efficient outer port limits (OPL) crew transfer vessel.



The Electric Cat

Challenge

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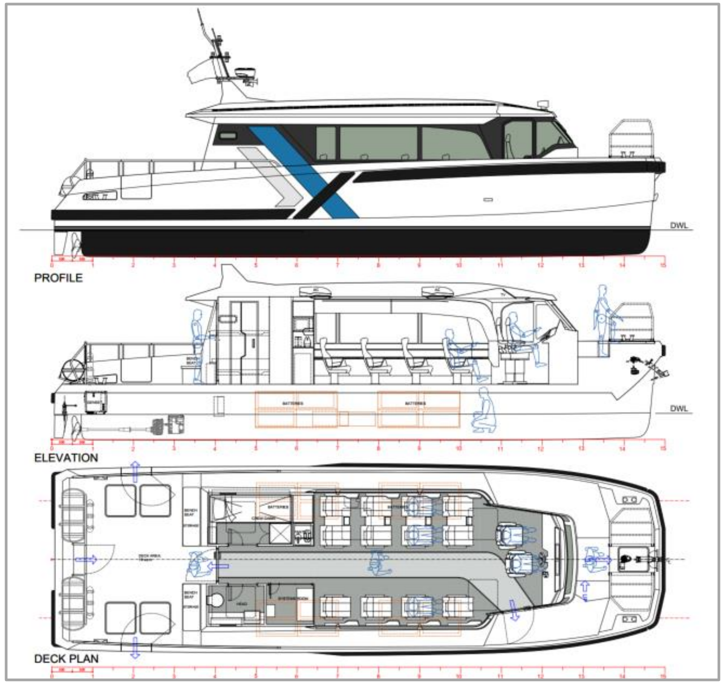
- Design of a fully electric harbour craft.
- Performance ≥ existing conventional craft.

- Batteries are heavy; capacity limited.
- Boat range limited.

=> Optimisation: Range↗ and Performance↗

The Team:

- Icarus Marine
- Friendship Systems
- NUMECA Ingenieurbüro



The Electric Cat

Why canoe stern design?

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- Experience shows very low resistance.
- When comparing with best conventional hulls.
- Advantage: reduced appendage drag.
  - No exposed shafts & brackets.

2 Partially Parametric Modelling

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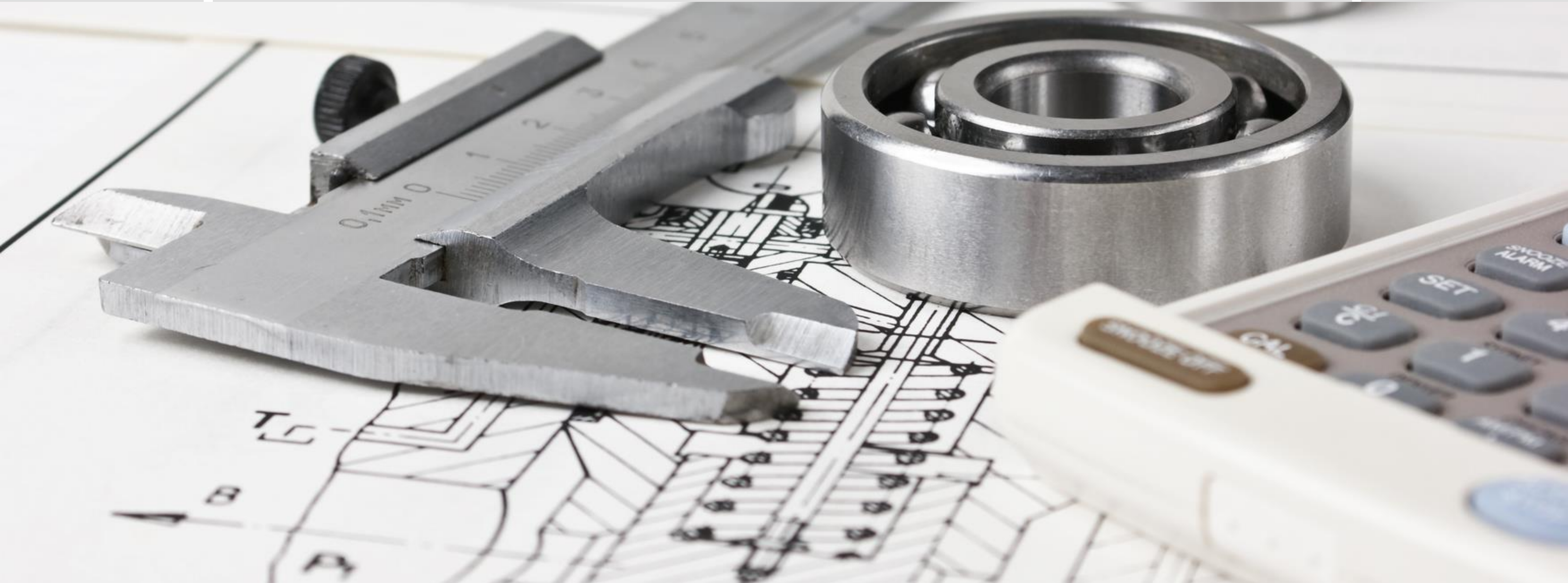

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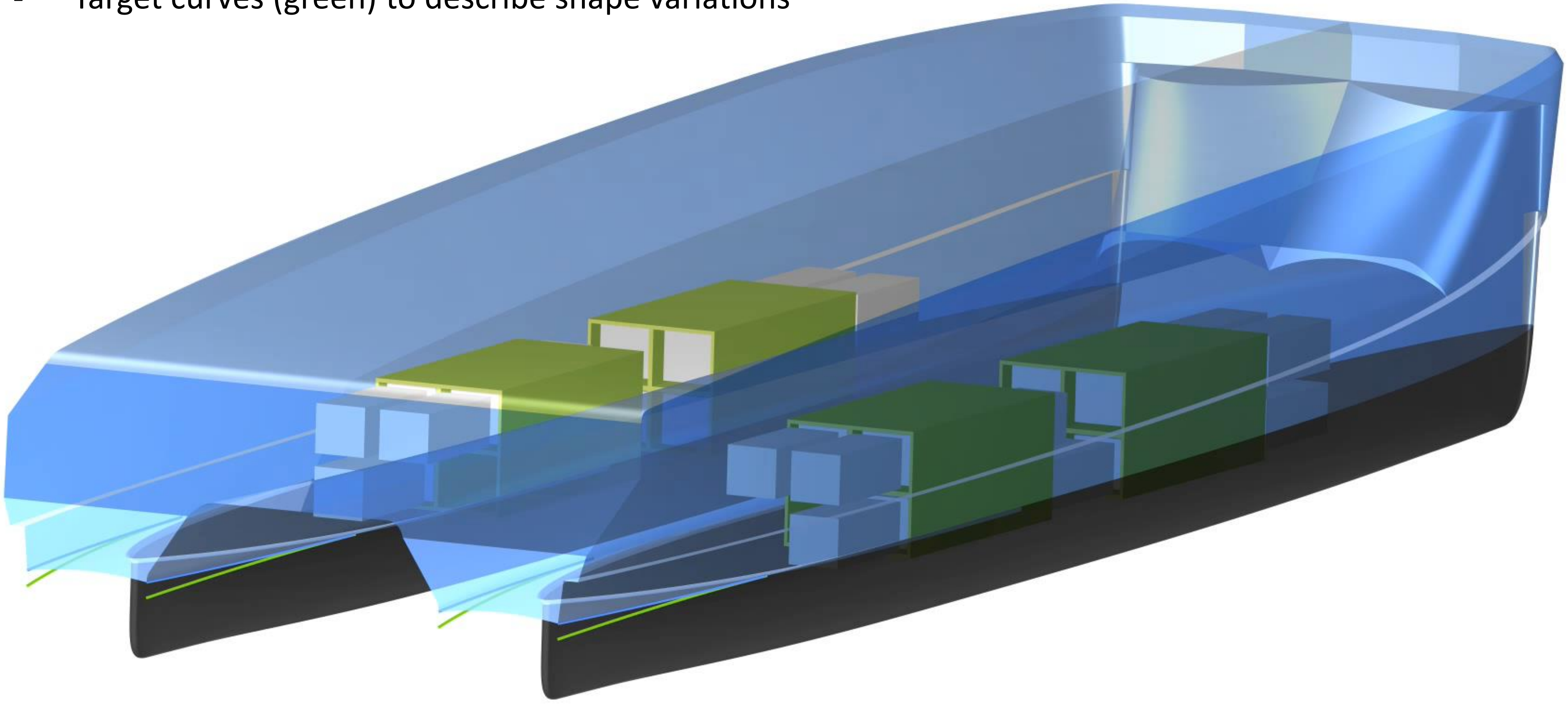
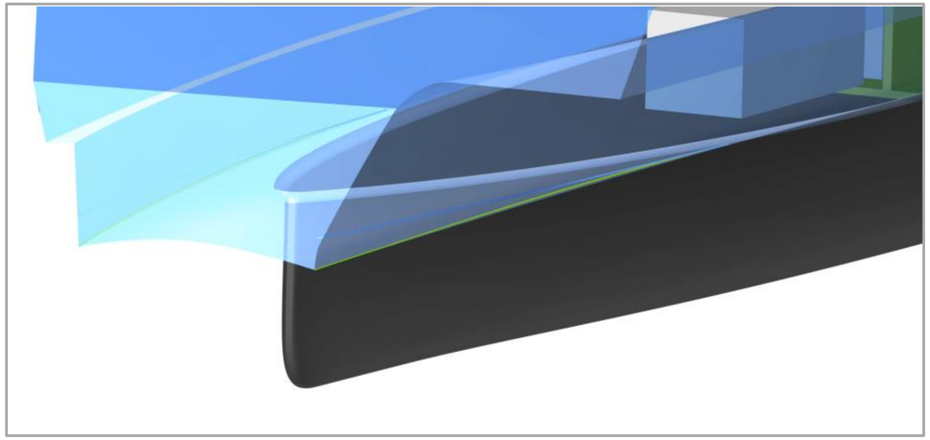
Technique I: BRep Morphing

- Source curves (blue) on initial geometry
- Target curves (green) to describe shape variations

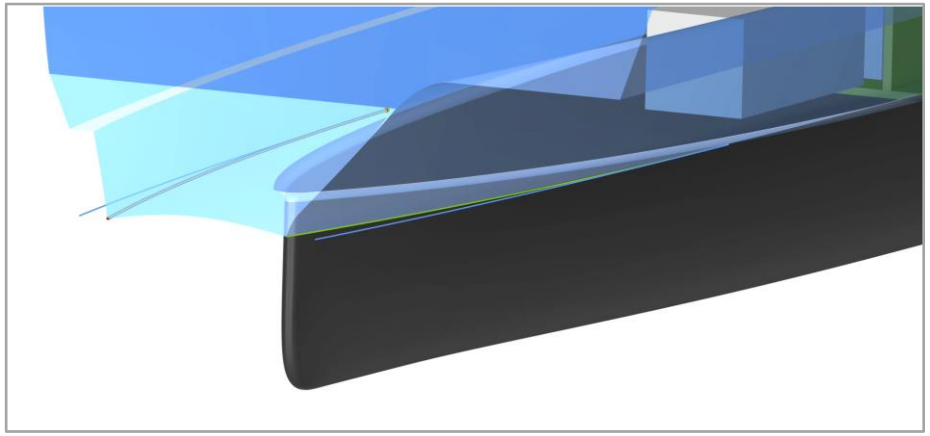


Technique I: BRep Morphing

- Source curves (blue) on initial geometry
- Target curves (green) to describe shape variations
- Selected geometry follows closely while maintaining smooth shape
- Powerful shape variation to adjust transom immersion, lift (trim), anti-ventilation, propeller inflow, pressure recovery, etc…



DZ transom knuckle



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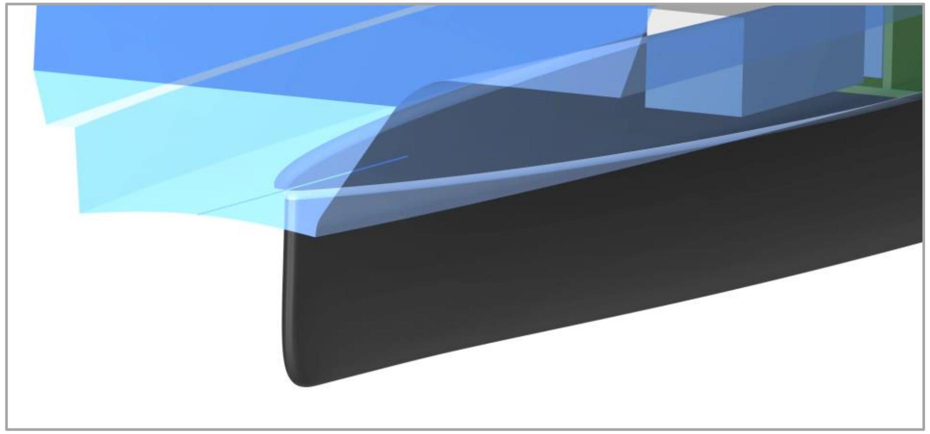
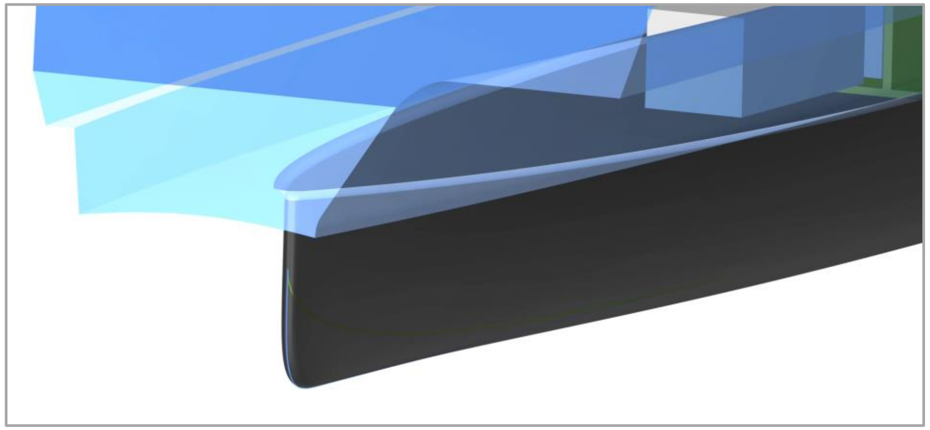


DZ tunnel



Push stern in

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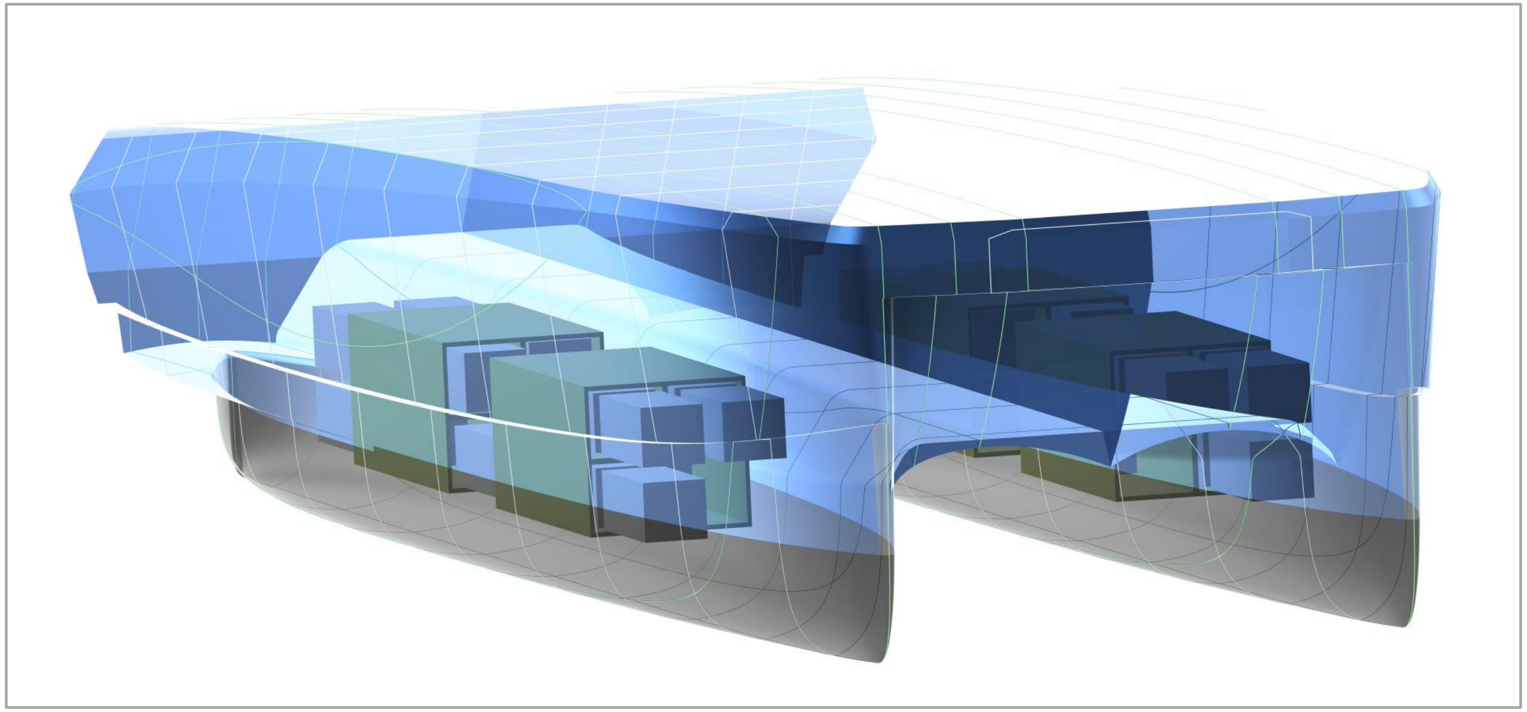

Asymmetry

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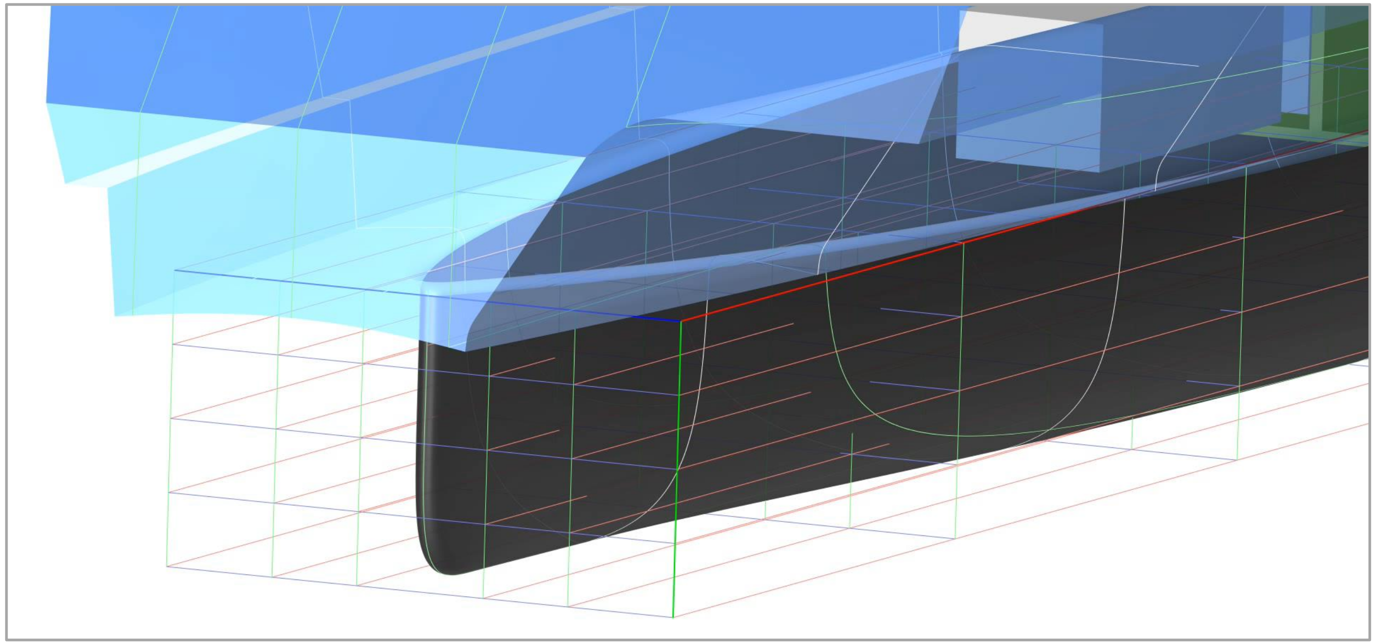
Technique II: Free Form Deformation

- Transforming control points of a B-Spline volume
- Contained geometry follows smoothly surrounding deformation
- Flexible and easy to control variation to adjust hull for improved propeller inflow, pressure recovery, battery accommodation, wave piercing, motions, etc…



Taper aftbody

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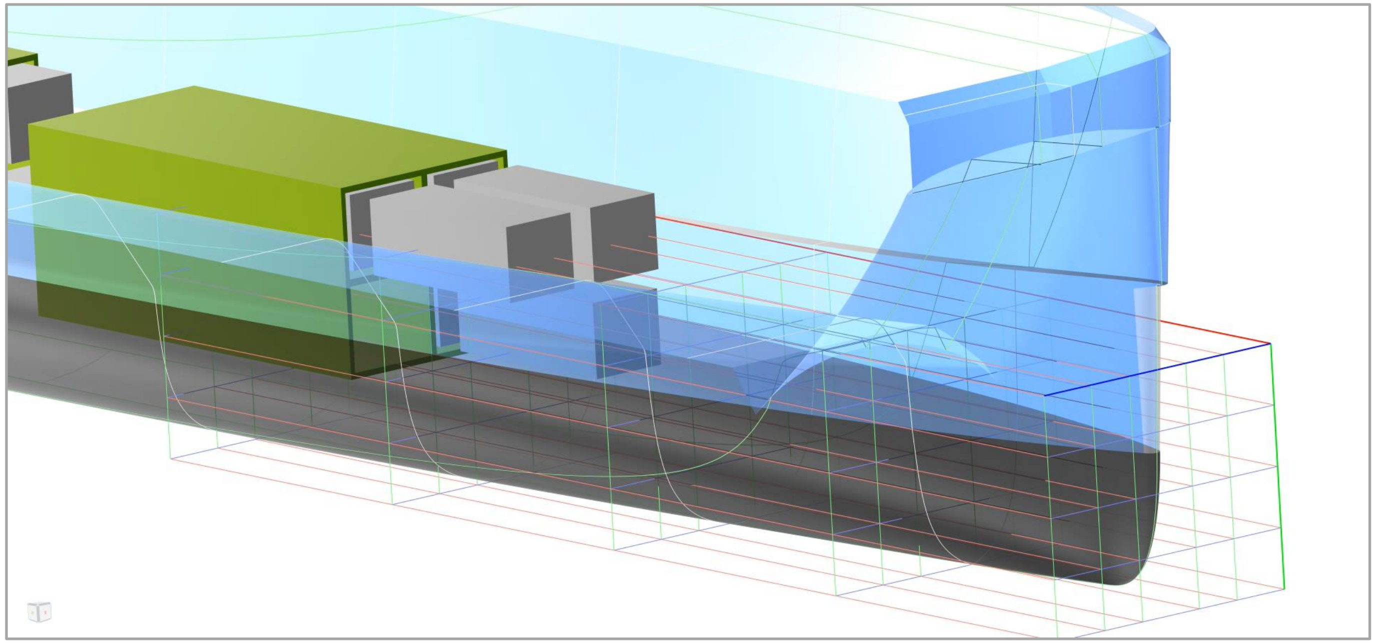

Taper forebody

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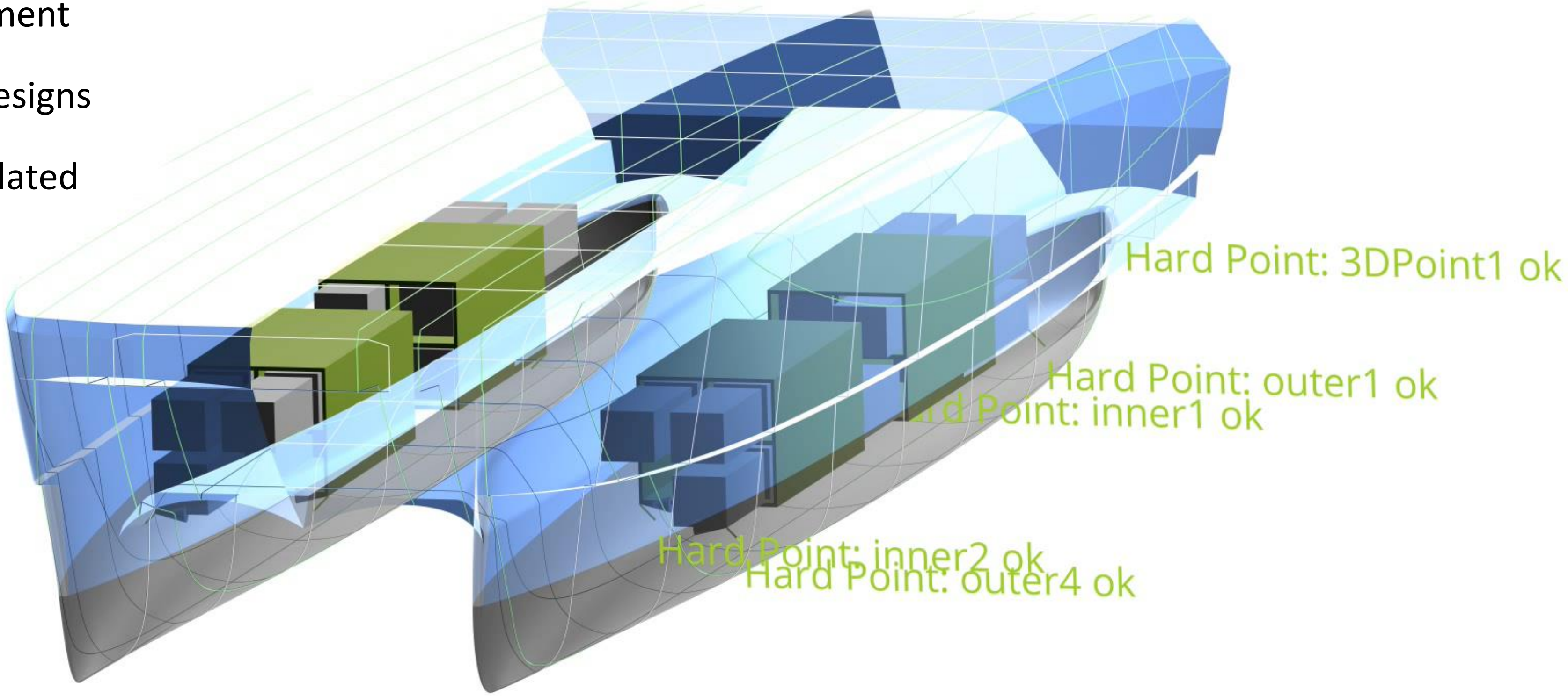
Lackenby Transformation

- Last transformation applied to the model before sending it to CFD.
- Shifting of sections in longitudinal direction to simultaneously:
  - ✓ Adjust overall displacement of the vessel exactly to target value
  - ✓ Set distinct LCB (to match LCG for any given battery position)
  - ✓ Shift mid frame (free design variable)

Check of the model

Design of Experiments (Sobol)

- 10 Designs for visualization
- 13 free Design Variables
- Constant displacement
- LCB = LCG for all designs
- No hard points violated



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Optimisation

Operating Conditions in Optimisation

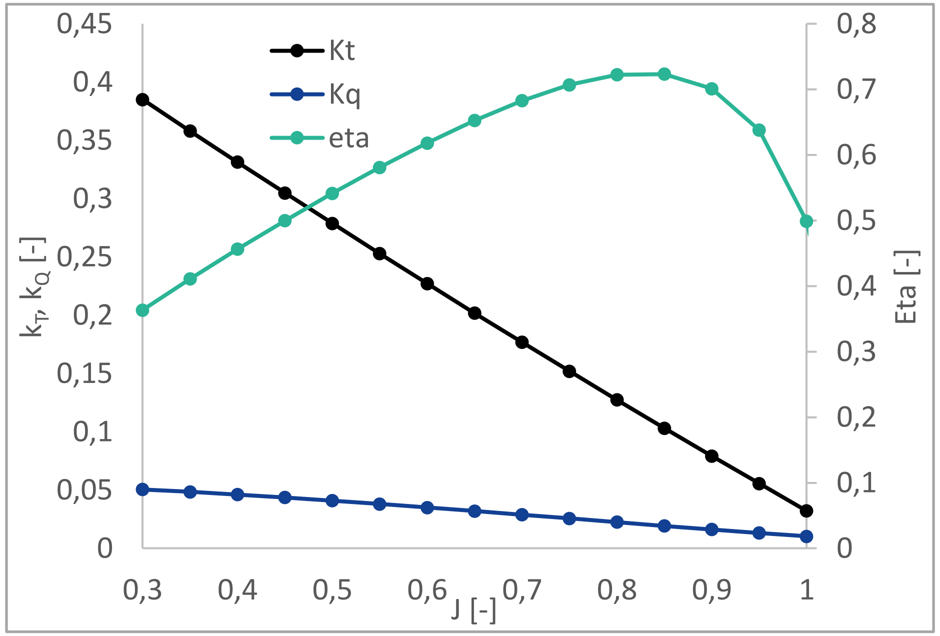
Case Setup:

- Classical resistance simulation
- Half model
- Actuator disc as propulsor
- Enriched with open water data

- Vessel speed: 12kn
- Displacement: 19.5t (fully loaded condition)

- Mesh size: ~610k cells
- High-Re with y+ of 80
- Free surface via AGR (+150k cells)

- 3,5h on 2 cores per design



Propeller data

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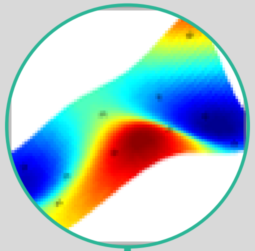
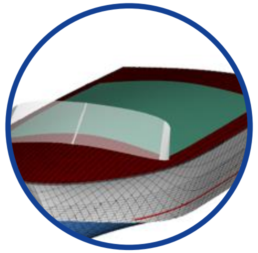


Optimise

- FINE™/Design3D
- Surrogate Models
- Genetic Algorithms
- Data Mining tools

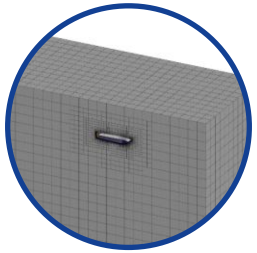
Python (API)



CAD

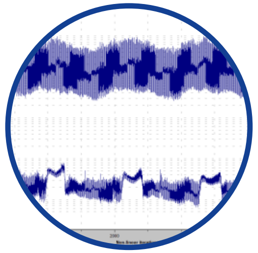
- CAESES®
- Efficient parametrisation
- High geometric variability
- Robust

STL



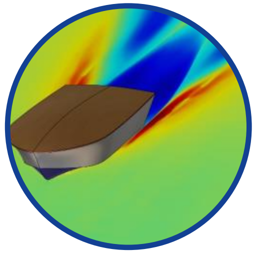
MESH

- HEXPRESS™
- Fully hexahedral
- Anisotropic
- Quality viscous layers



SOLVE

- FINE™/Marine
- Dedicated tool
- Very scalable
- Adaptive grid refinement



POST

- CFView™
- Qualitative & quantitative results

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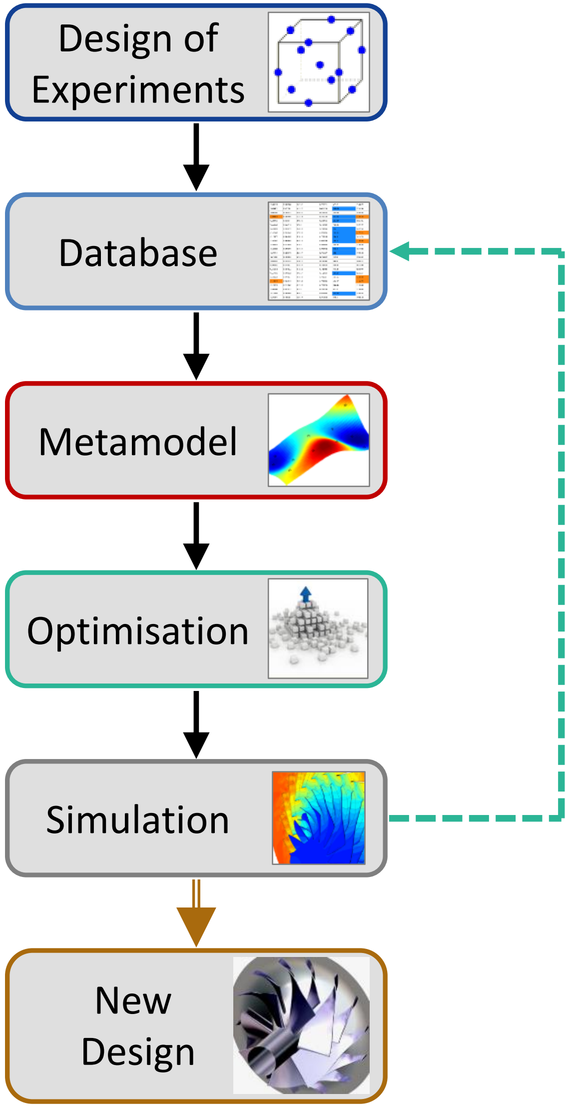
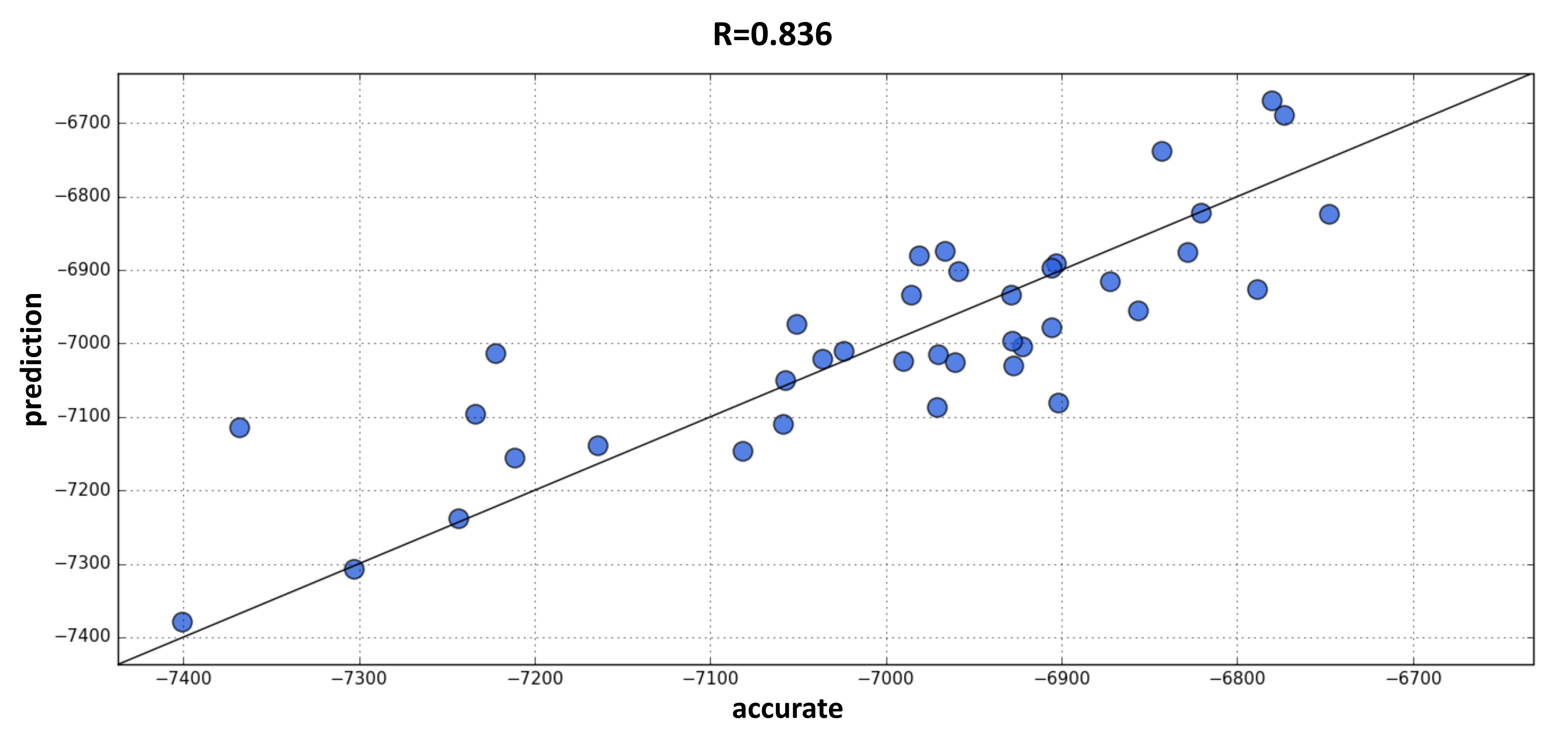
Online SBO:

- **Generation of initial database**
- **Surrogate model based on DoE points**
- **Optimisation on surrogate**
  - Mono-objective EA
  - Multi-objective EA
  - Generate Pareto fronts
  - Constraints and penalties
- Accurate simulation of optimal result(s)
- Enrichment of database
- Repeat until convergence

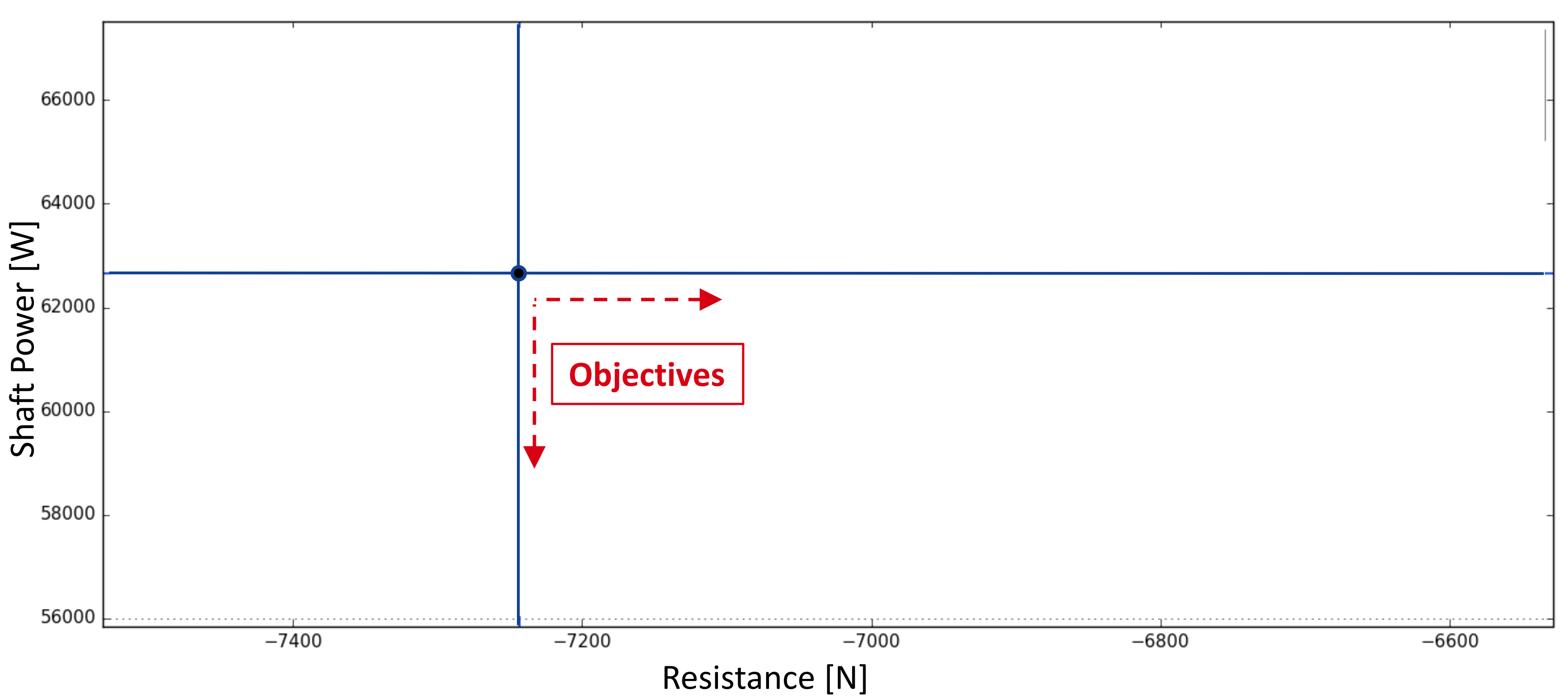


Results: Surrogate Model Correlation



Correlation: Surrogate model over CFD

Results: Scatter Plot



Shaft power over total resistance (12kn, 19.5t)

Optimisation

Results: Analysis of Variance (ANOVA)

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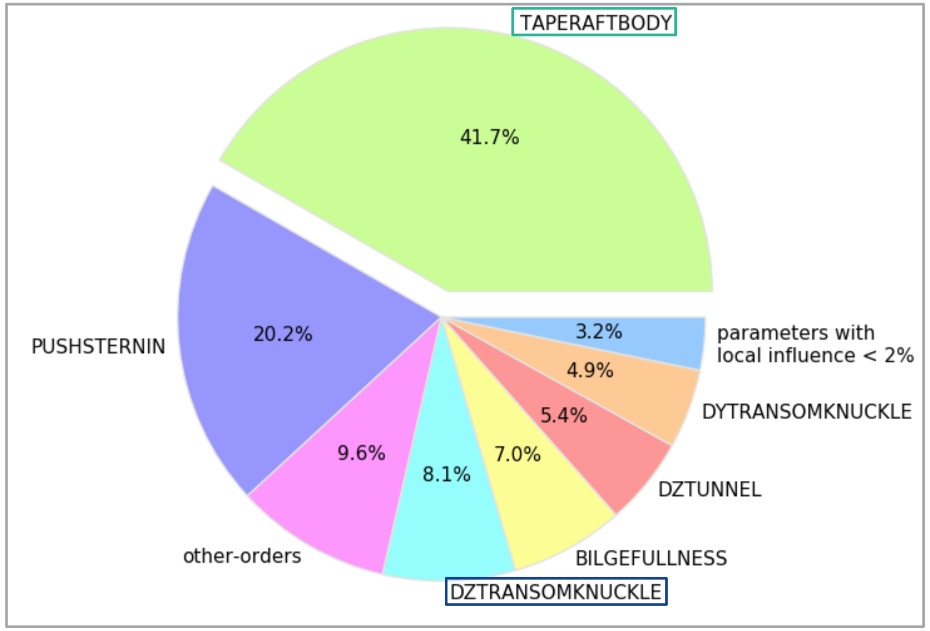
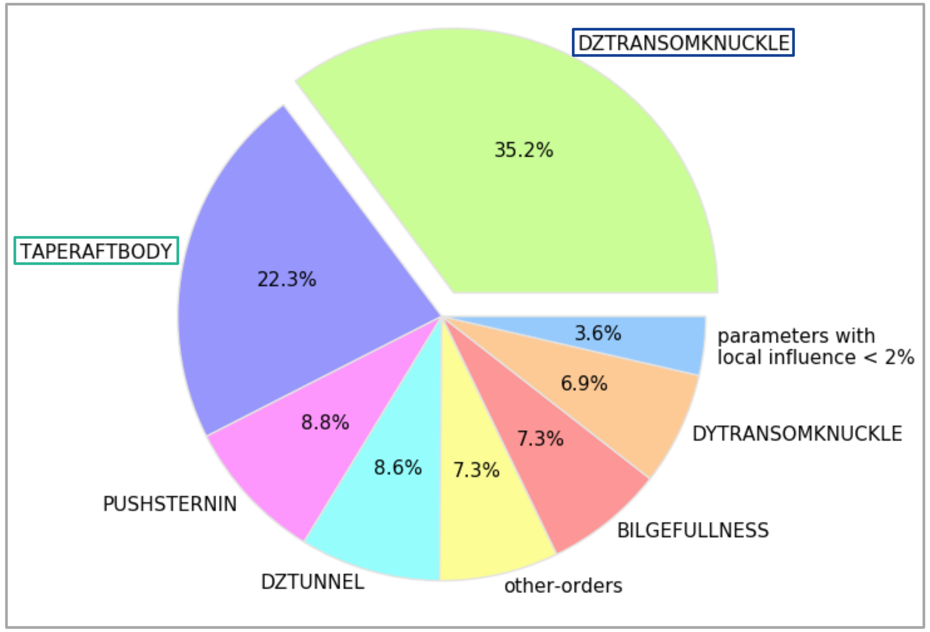
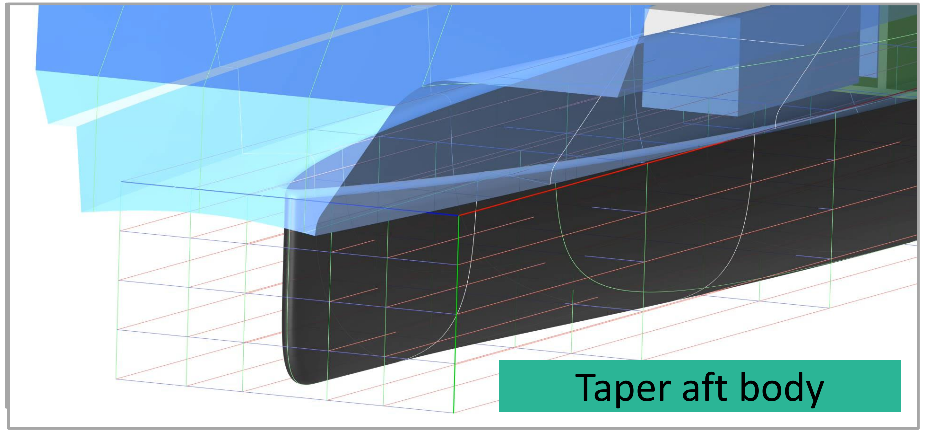
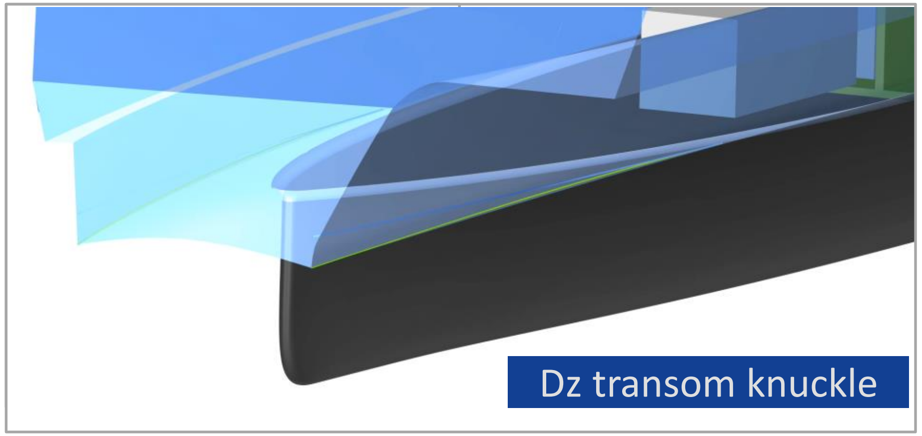


Parameter impact on total resistance



Parameter impact on shaft power





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Intermediate results

- We have a better design
- Optimised for one operating point

- How about the whole operating range?
- Is there room for improvement?

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Next Design Iteration

Next Design Iteration

Observations on current designs

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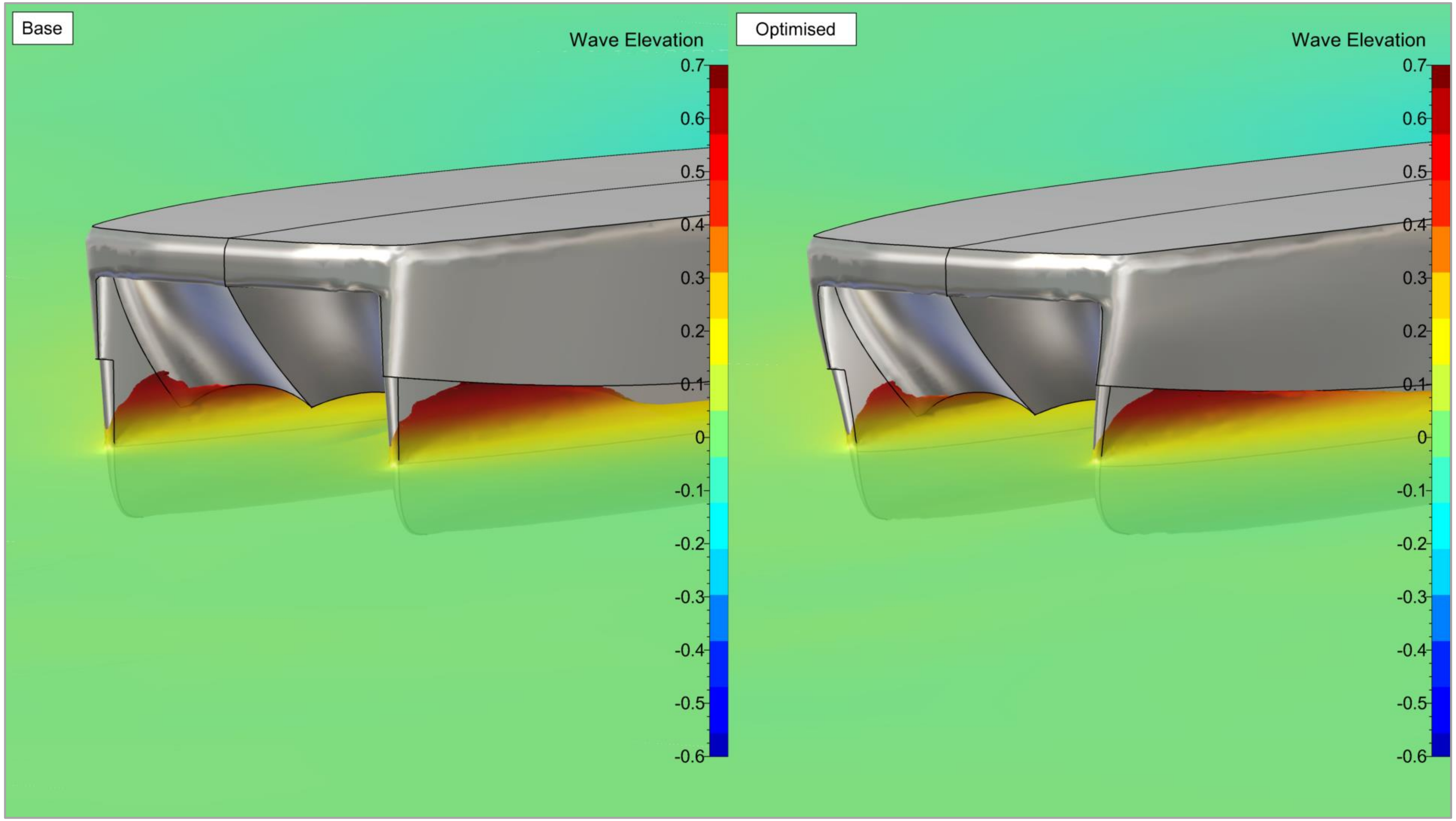
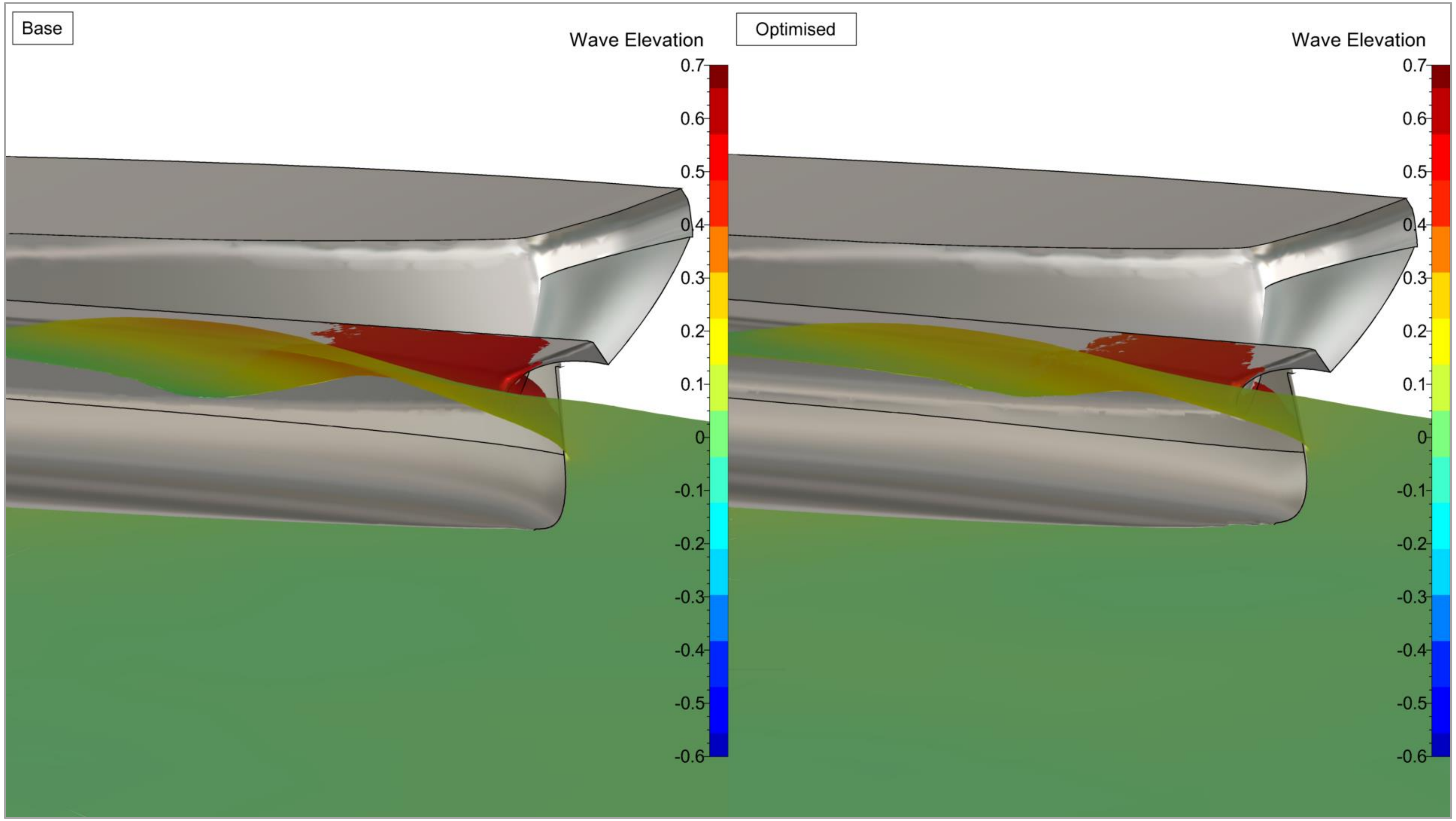


Bow spray hits tunnel in both Base and Opt design (12kn, 19.5t)

Next Design Iteration

Observations on current designs



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Next Design Iteration

Observations on current designs

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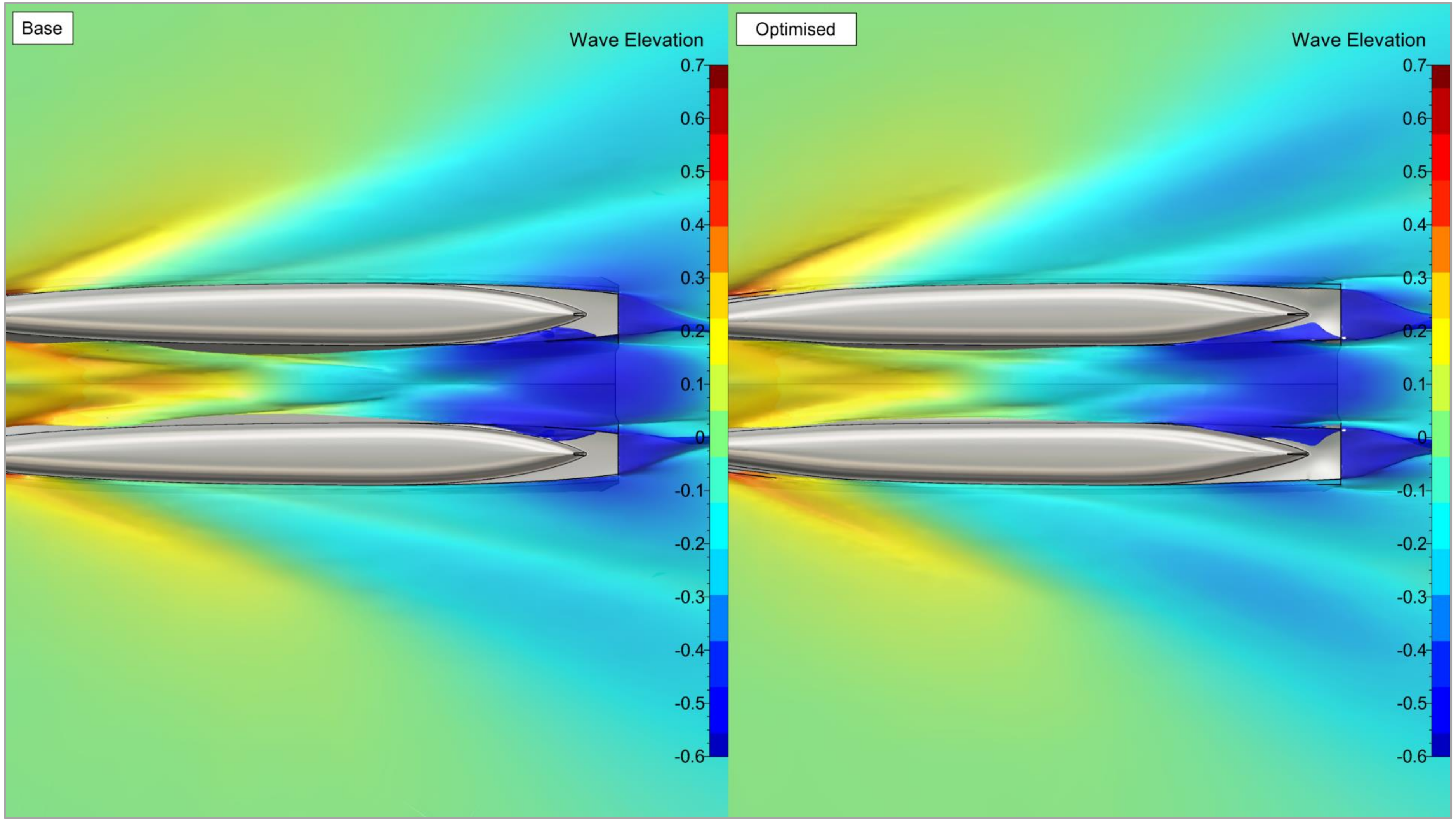

Ventilation in both Base and Opt design (12kn, 19.5t)

Next Design Iteration

Inspired design

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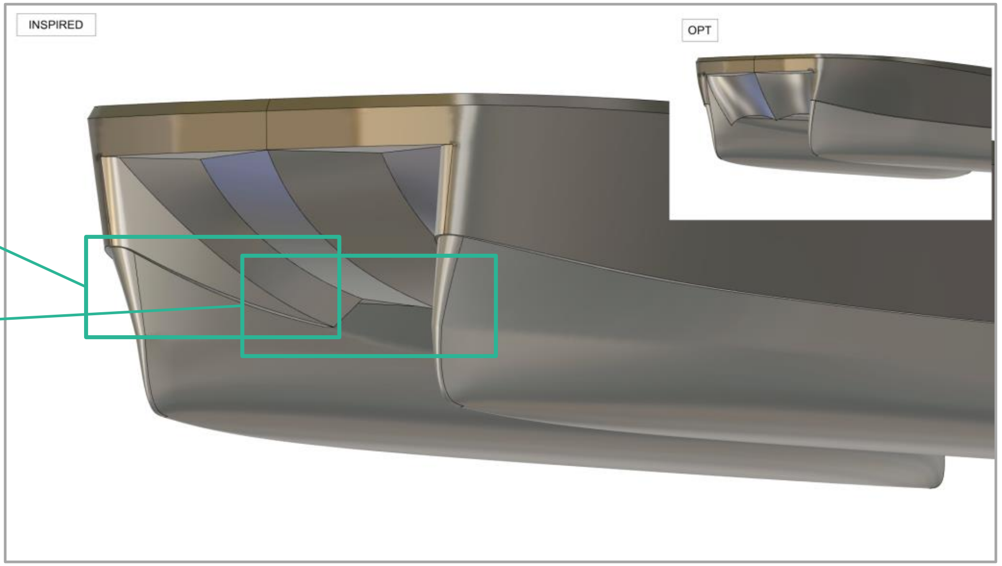
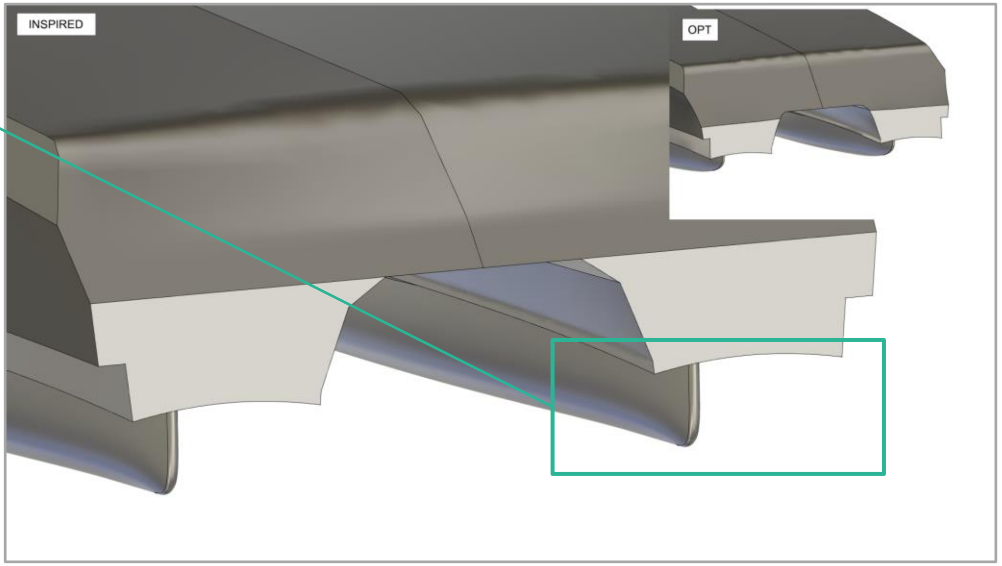
Changes to the Opt design:

- Implementation of an inner spray rail
- Move tunnel upwards
- Move tunnel backwards
- Slight modification to the stern (the sensitive part!)





Final Case Setup:

- Base, Opt, Inspired design
- Half model

- Vessel speed: 8 to 14kn
- Displacement: 17.5 & 19.5t

- Mesh size: 2.3M cells
- High-Re with y+ of 50
- Free surface via AGR (up to 1M extra cells)

- Meshing done in FIDELITY™
- Using Family Tree Option

Next Design Iteration

Meshing in FIDELITY™

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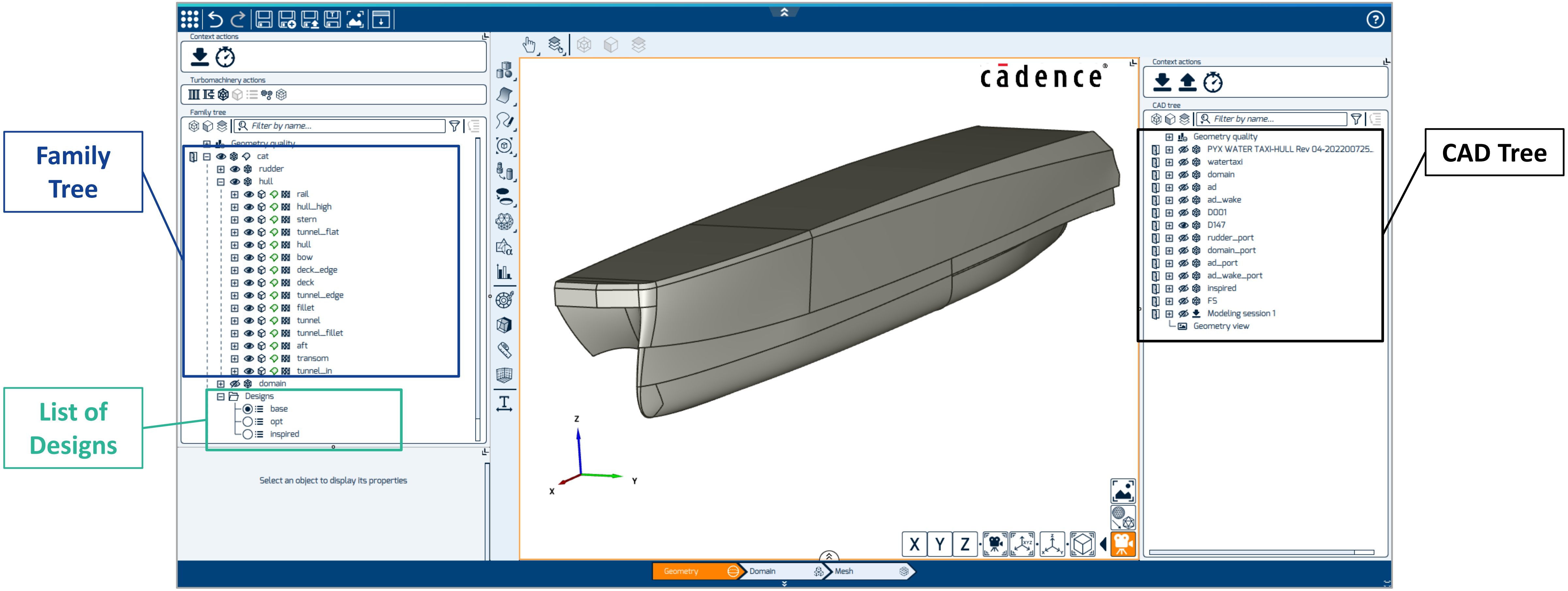

FIDELITY™ Interface in Geometry Context

Next Design Iteration

Meshing in FIDELITY™

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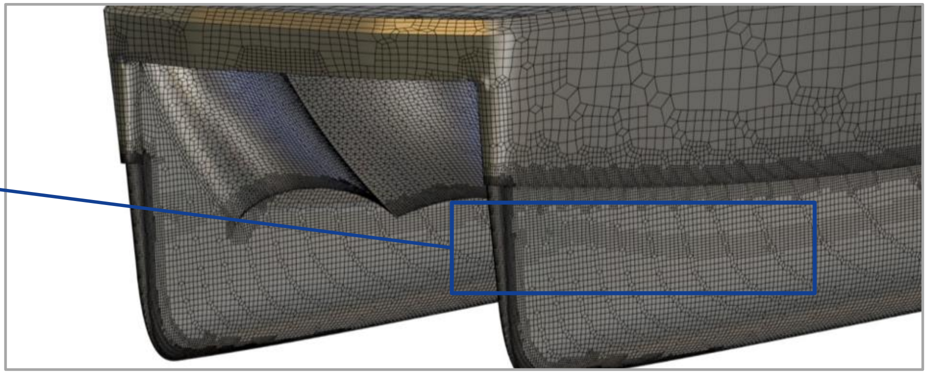
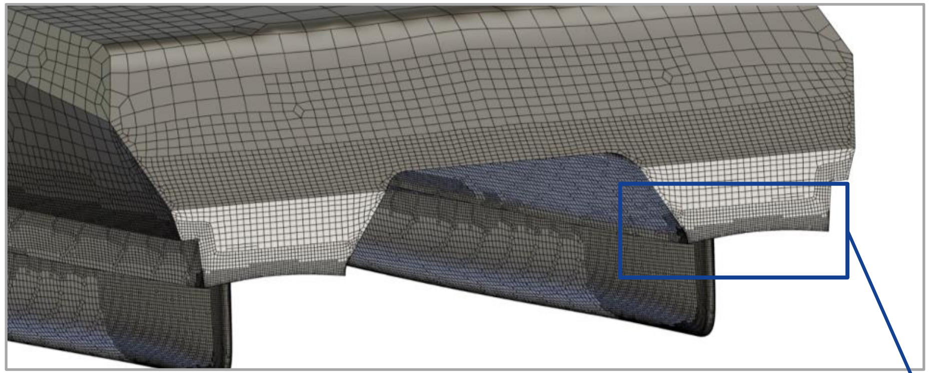
AGR

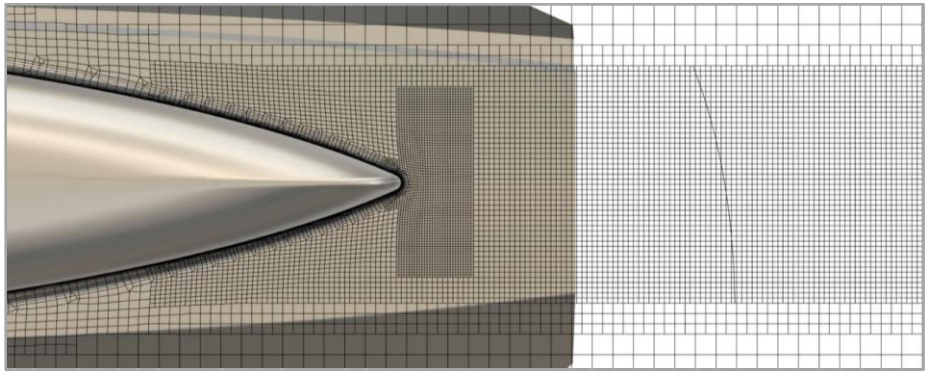


Mesh at bow

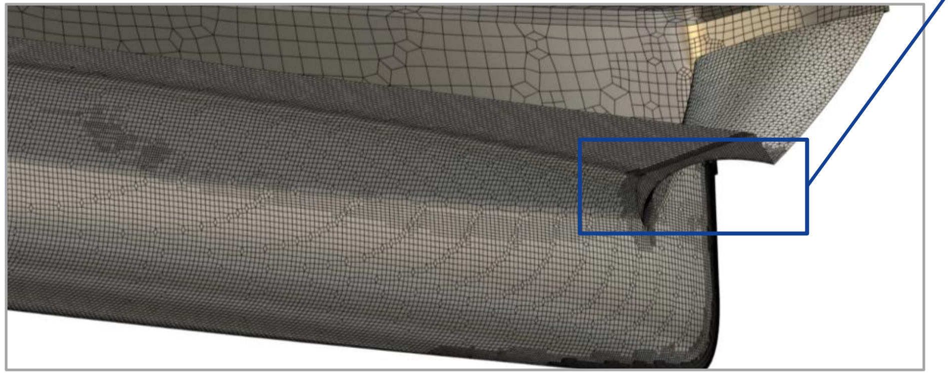


Mesh at stern

Separation zones



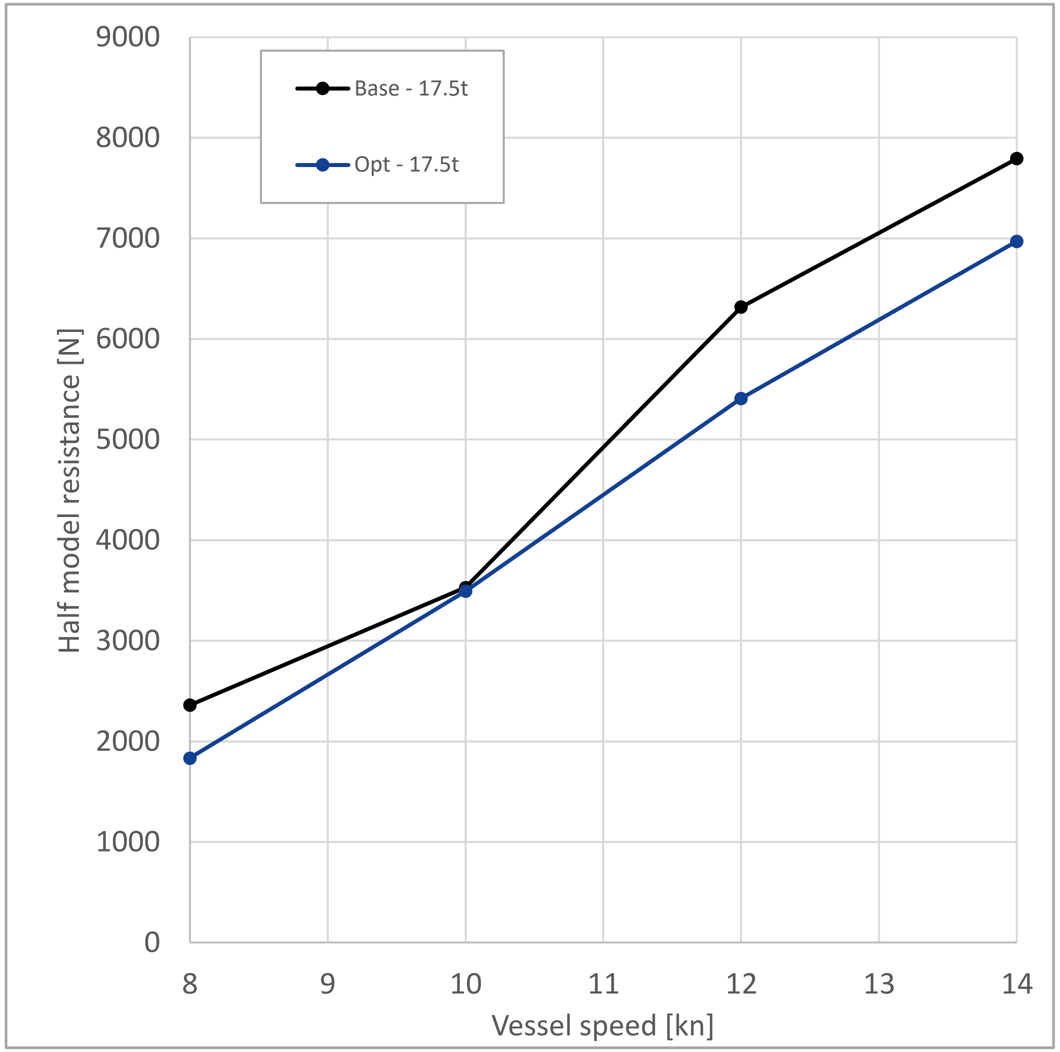
Cut view actuator disc incl. in- & outflow



Tunnel edge

Opt design:

- Optimisation was done at 12kn only
- Improvements kept except at 10kn
- 10kn: Start of the ‘hump’ (Fn 0.43)
- Some uncertainty in the data due to very strong flow unsteadiness



Resistance at 17.5t

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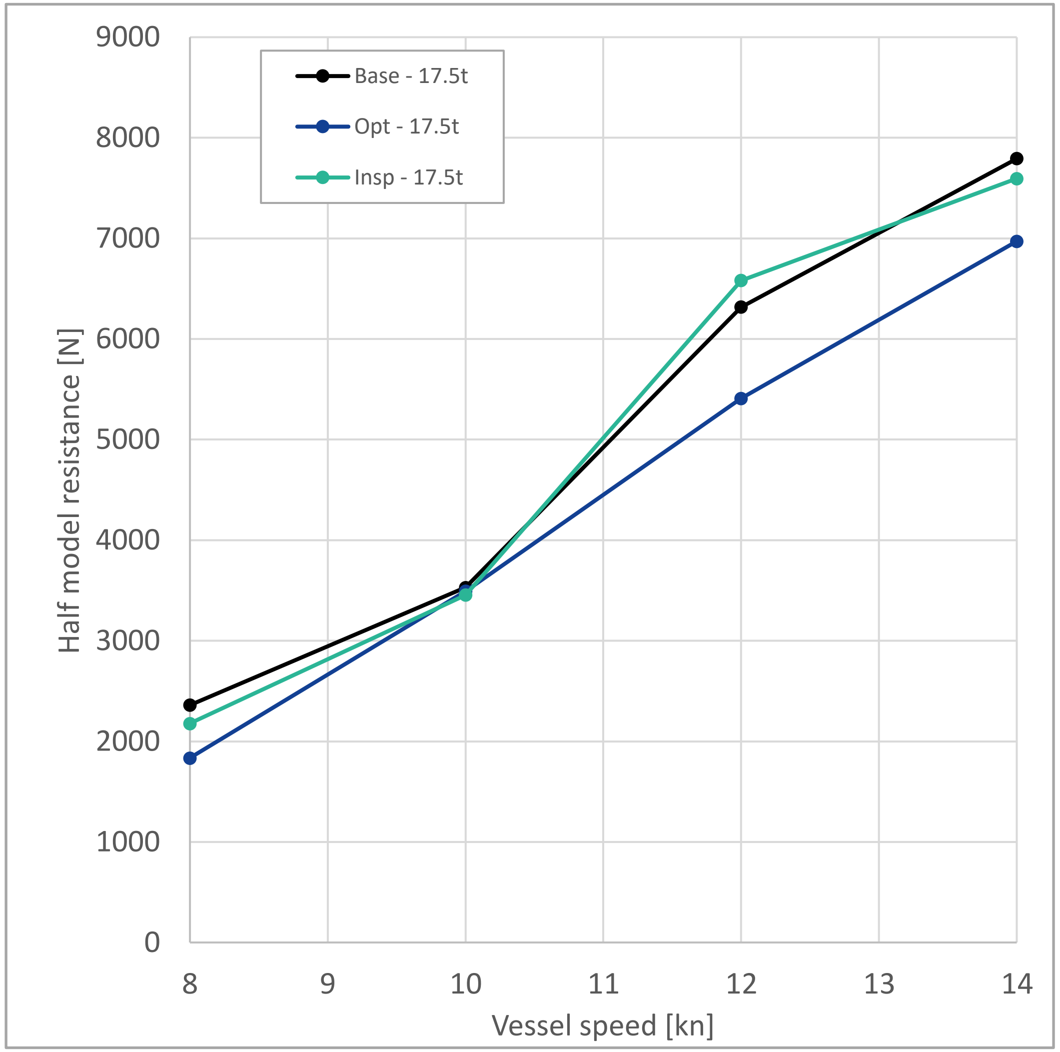
Inspired design:

- Improvements mostly lost
- Results similar at 19.5t



Resistance at 17.5t

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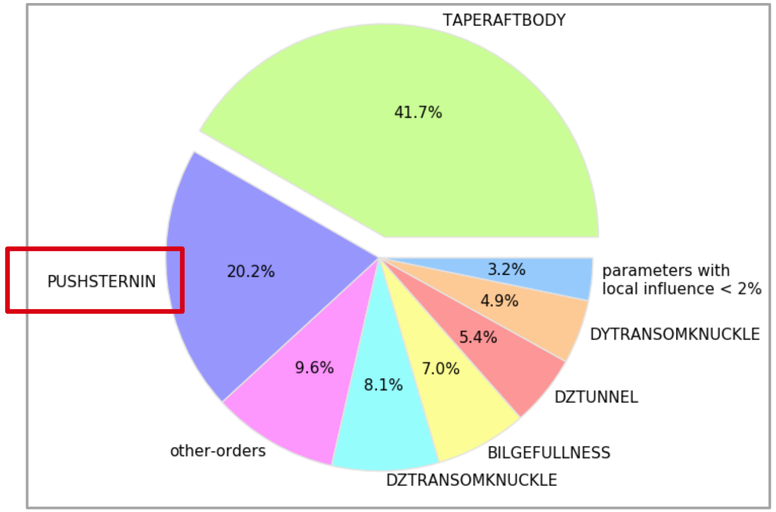
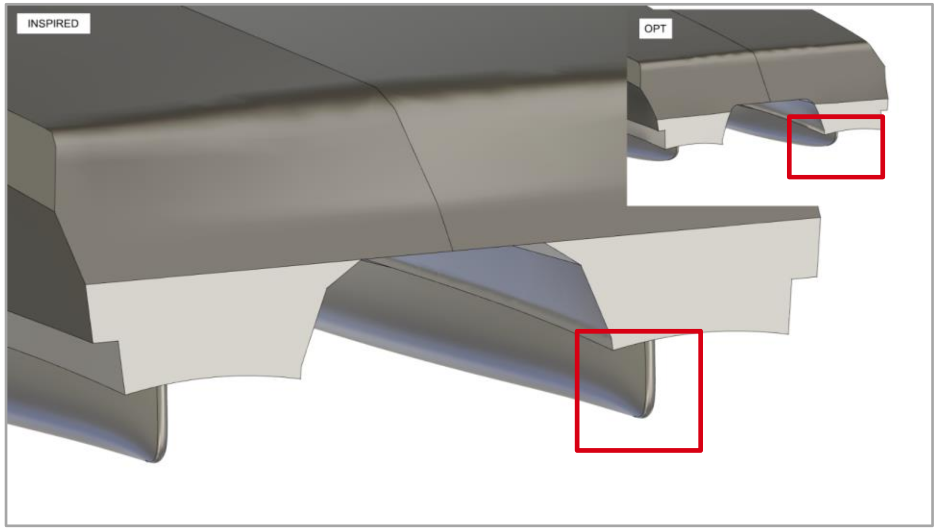
Inspired design:

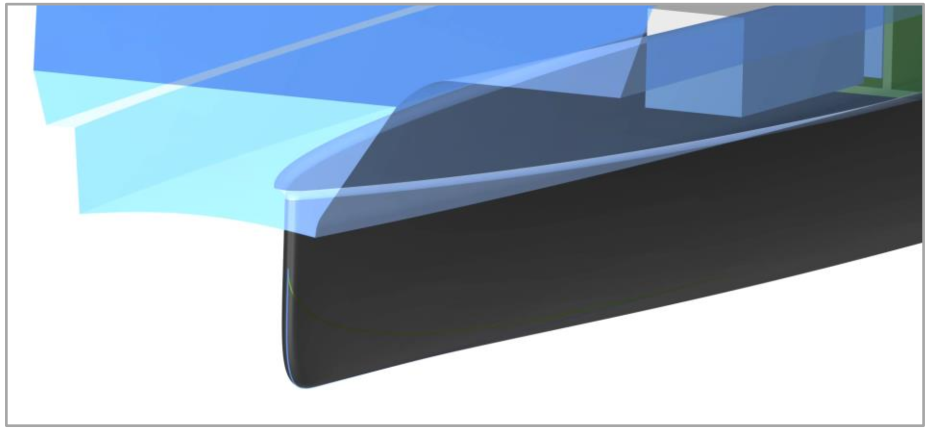
- Remember this?
- The importance of data mining!
- Next iteration will surely fix this!



Parameter impact on total resistance



Push stern in



Push stern in

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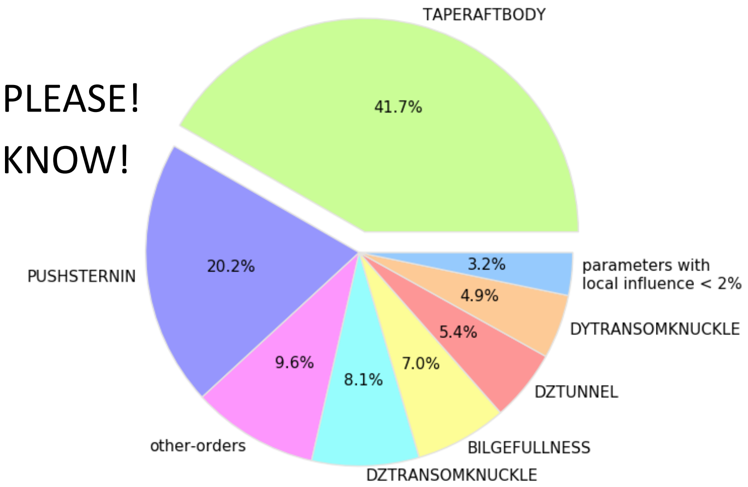
Conclusions:

- An electric Cat in a very early design stage has been improved: -10% power consumption.
- Partially parametric modelling is time efficient – once it is created.
- Modest Hardware Req.: CFD & Optimization – 80 samples over a weekend (32 cores machine).
- Important insights gained into critical parts of the Cat.

Lessons Learned:

- Naval Architects: DO NOT TOUCH AN OPTIMZED DESIGN – PLEASE!
- CFD Engineers: TELL THE NAVAL ARCHITECTS WHAT YOU KNOW!



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End of Presentation

Thank you for your attention