WHEN TRUST MATTERS

Friendship Systems User Conference 2022
Reducing CII with Bulbous Bow Optimization

From Regulations To Efficient Operation

22 September 2022

IMO's measures to reduce CO_2 emissions

CII (annual Carbon Intensity Indicator)

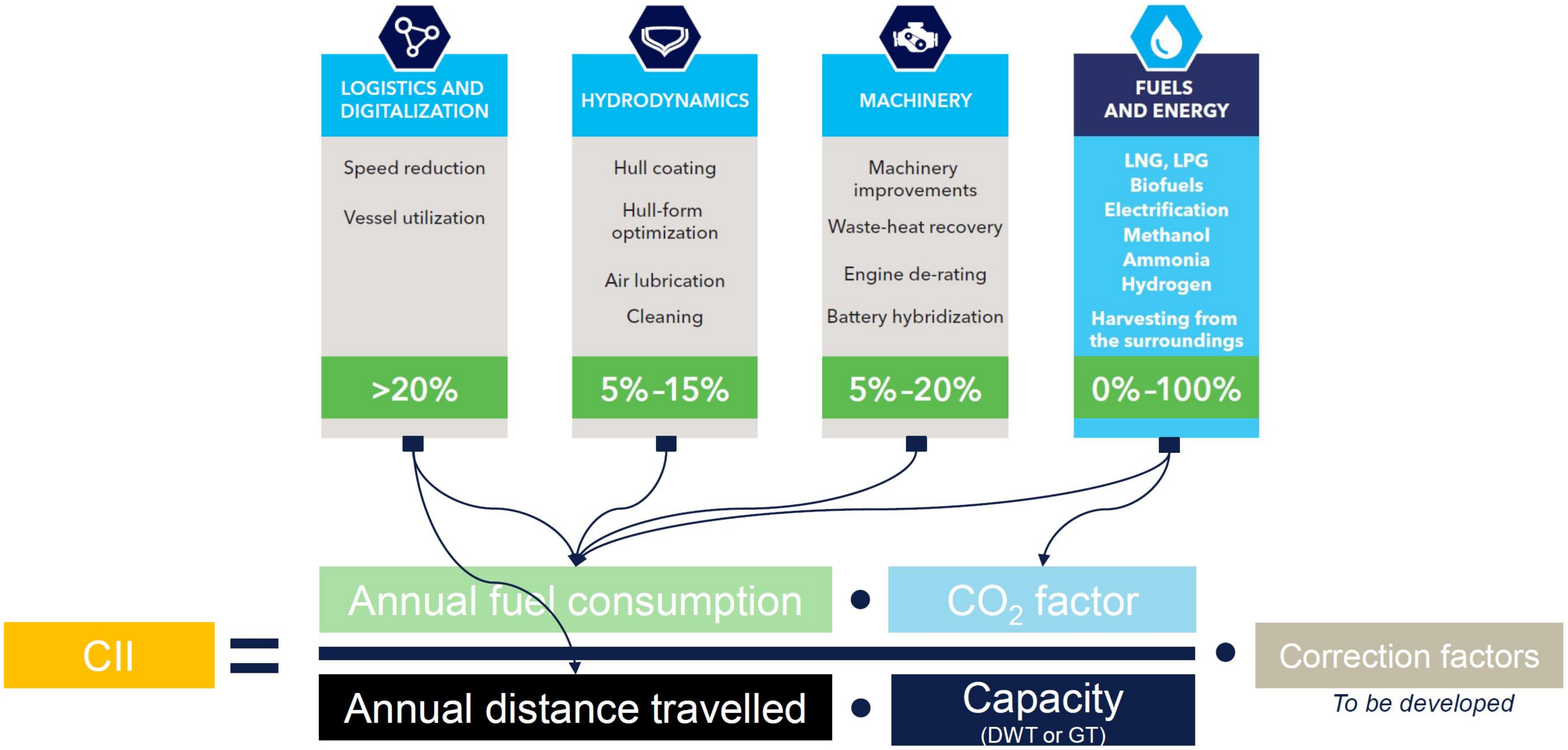
- Effective from next year
- Rating from A – E with annual evaluation
- Corrective plans required after ‘D’ rating for three consecutive years, or a single ‘E’ rating
- Requirements intended to become stricter as 2050 approaches with 40% reduction in 2030 already
- Unlike EEXI, CII is a good representation of the actual operation of the ship
- Every vessel improvement (also design) is considered

Transparency

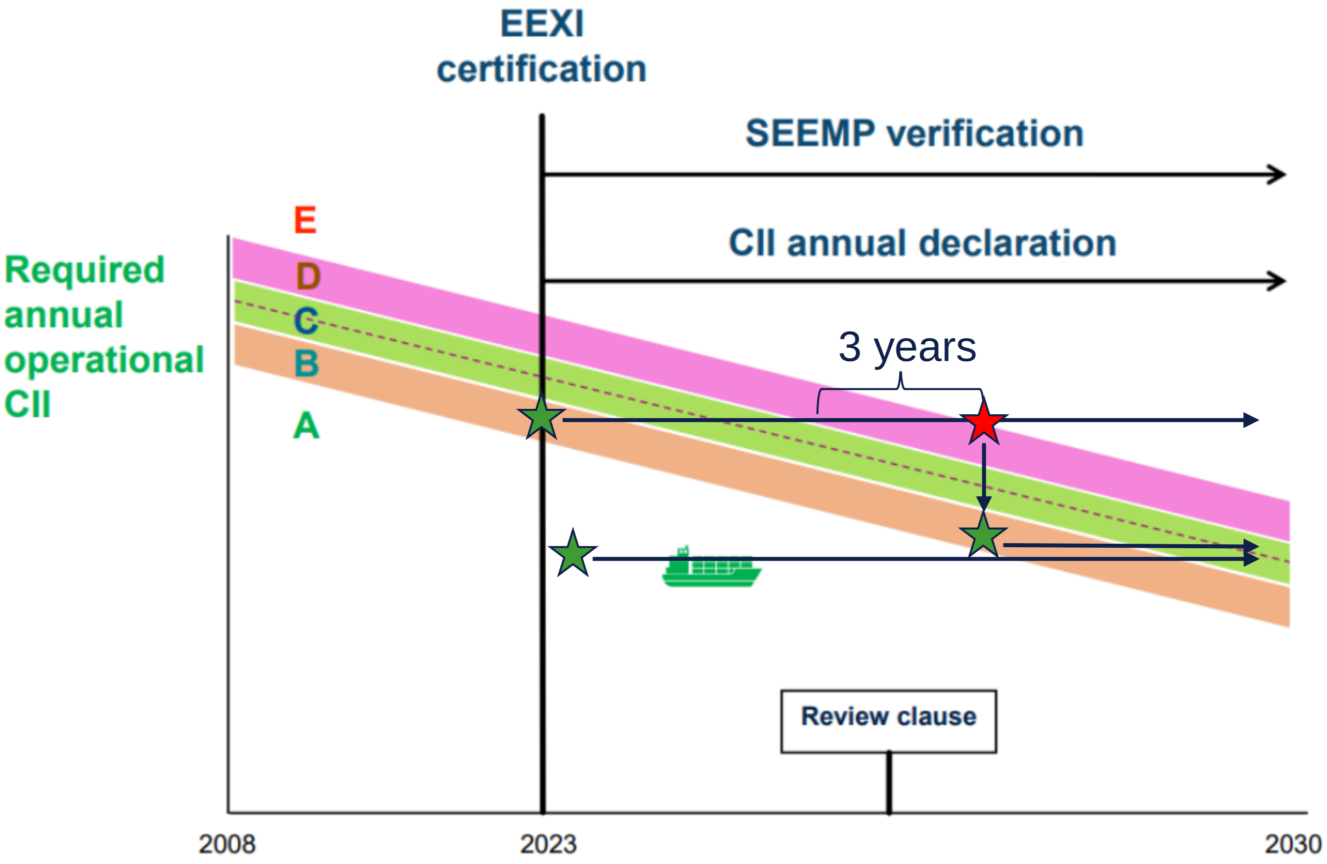
- Efficient vessels are easy to identify
- Pressure on less efficient ships will increase

$$\text{CII} = \frac{\text{Annual } CO_2 \text{ emissions}}{\text{Transport work}} = \frac{\text{Annual fuel consumption} \bullet CO_2 \text{ factor}}{\text{Annual distance travelled} \bullet \text{Deadweight}}$$

How to improve CII



The pathway



* The pathway is represented linearly for ease of presentation.

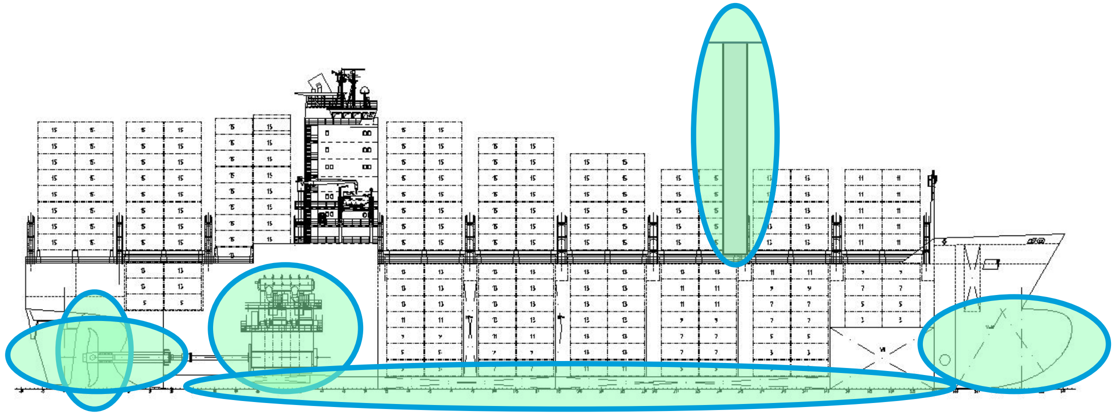
Possible actions to be taken:

- Trim optimization
- Retrofit
  - Bow, Propeller, ESD, WAPS, ALS
- Draft / DWT increase
- Performance management
- Fuel type
- Slower steaming
- Etc.

Retrofitting

Retrofit - Fields of application

- 6 major retrofit measures.
- Every ship type can benefit.
- Achievable savings strongly depend on the
  - Operational profile
  - Ship speed
  - Deck layout
  - ‘Quality’ of the vessel
  - Etc.

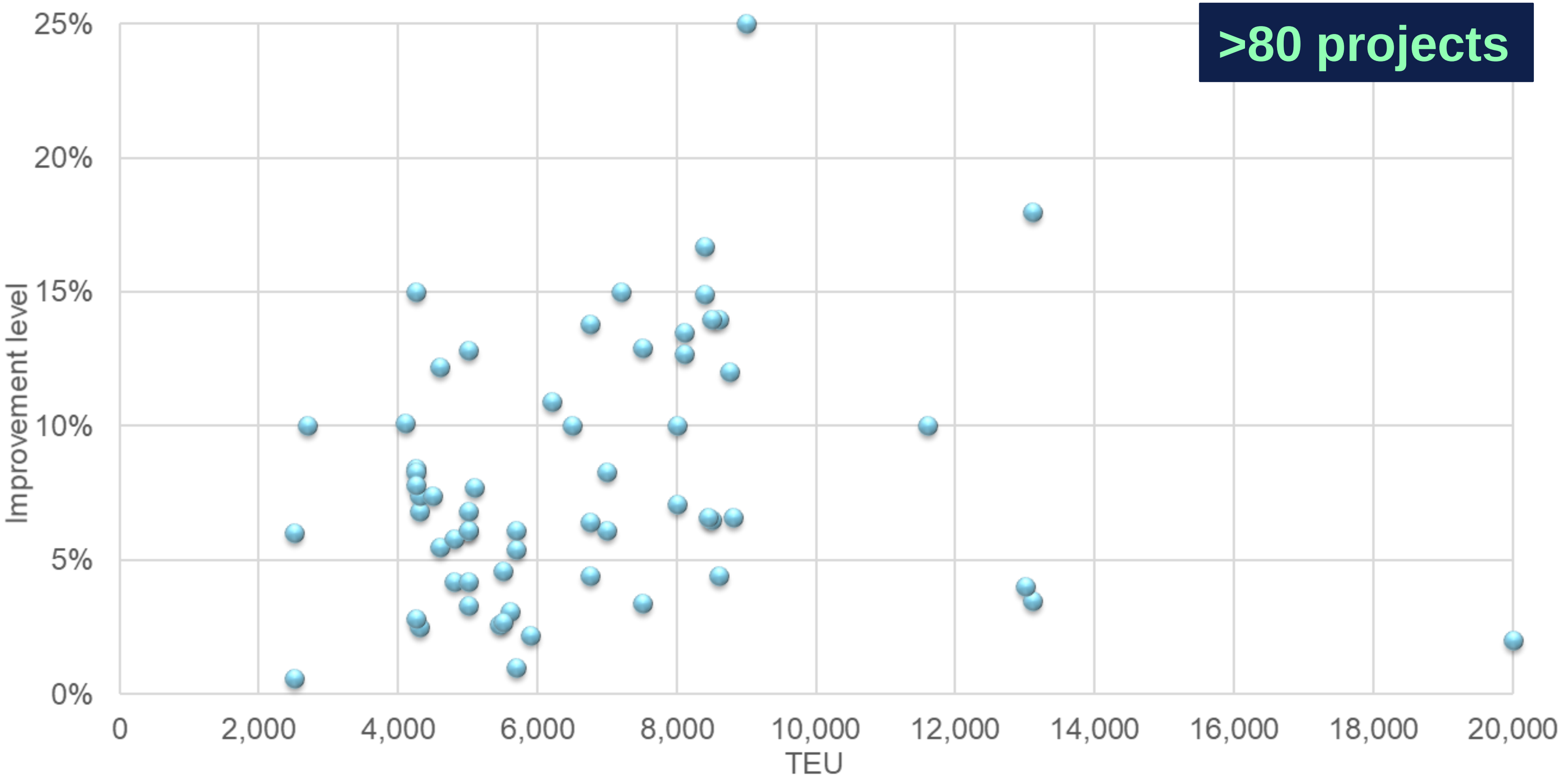


x Primary target

		Applicable ship type						
		Container	MPV	RoRo/PCTC	LNG/LPG	Tanker	Bulker	Other
Retrofit	Bow	X	3-20%	X	X			
	Propeller	X	X	X	X	X	X	X
	Engine Systems	X	X	X	X	X	X	X
	PID				X	X	X	
	WAPS		X			X	X	X
	ALS	X	X	X	X	X	X	

Recent projects

ECO Retrofit Bow - Container vessels improvement



UASC
msc SHIPMANAGEMENT
SCHULTE GROUP
Offen Group
China Shipping
Hapag-Lloyd
HAMBURG SÜD GRUPPE
COSCO
E.R. SCHIFFAHRT
seaspan

Selected ECO Solutions customers ↑

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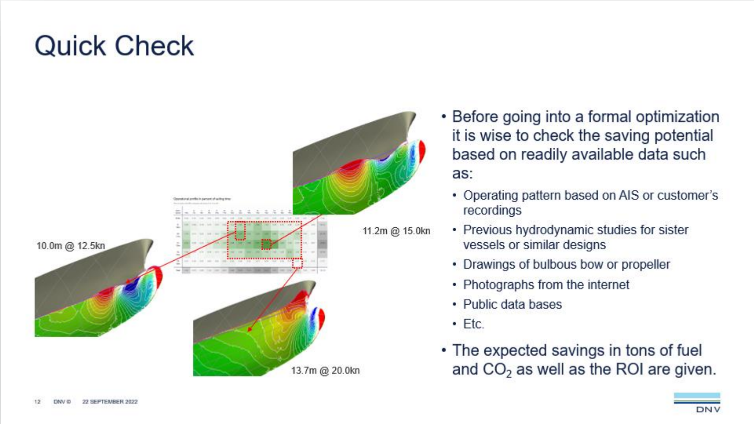
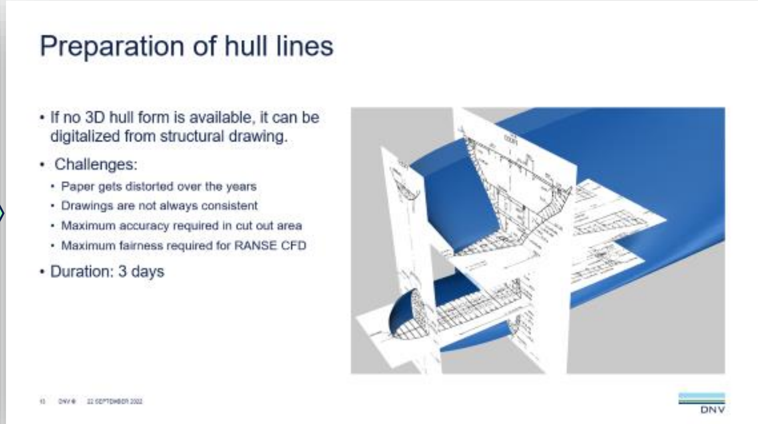
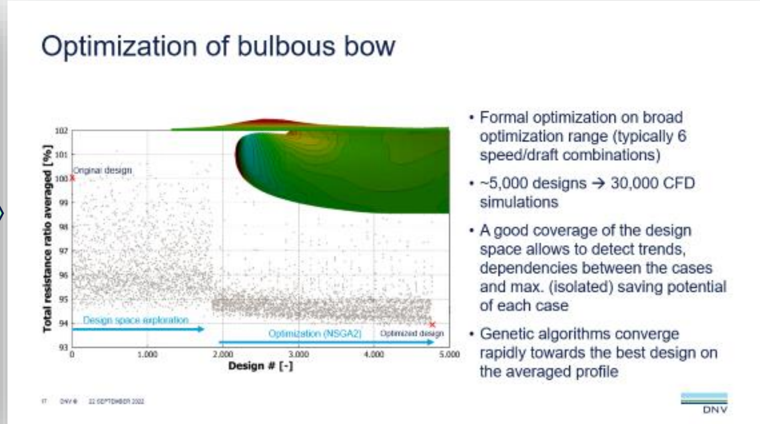
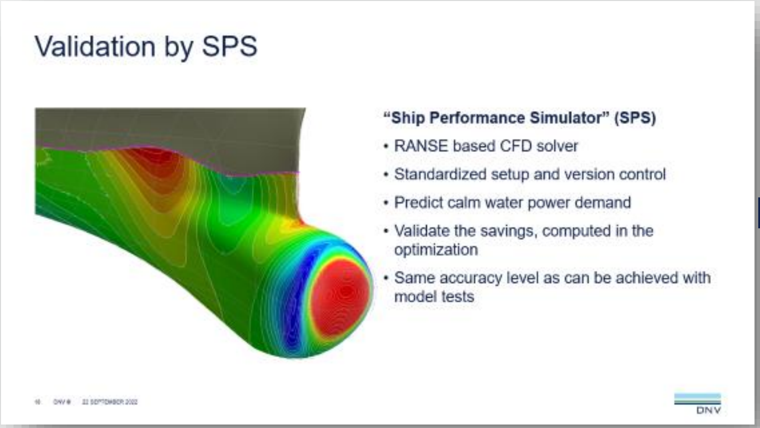
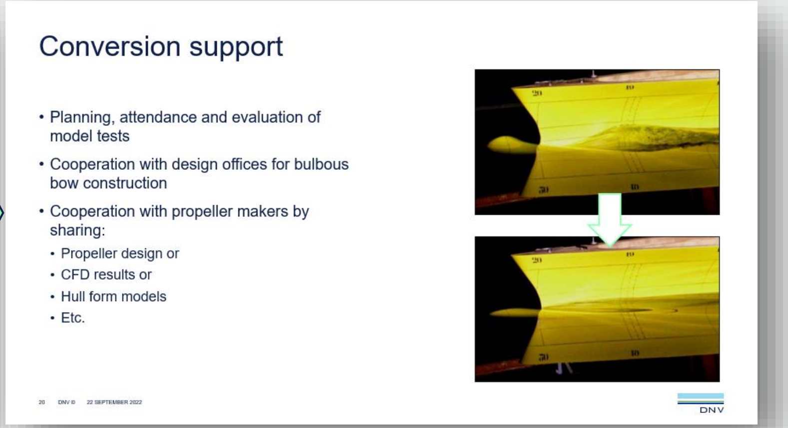
ECO Retrofit - Workflow

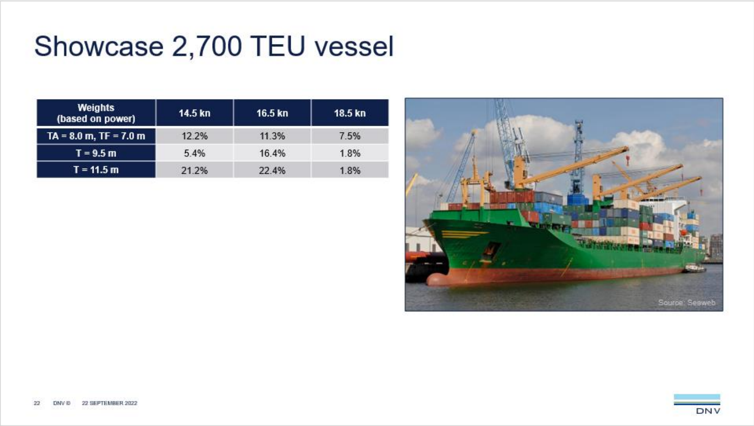












Weights (based on power)	14.5 kn	16.5 kn	18.5 kn
TA = 8.0 m, TF = 7.0 m	12.2%	11.3%	7.5%
T = 9.5 m	5.4%	16.4%	1.8%
T = 11.5 m	21.2%	22.4%	1.8%

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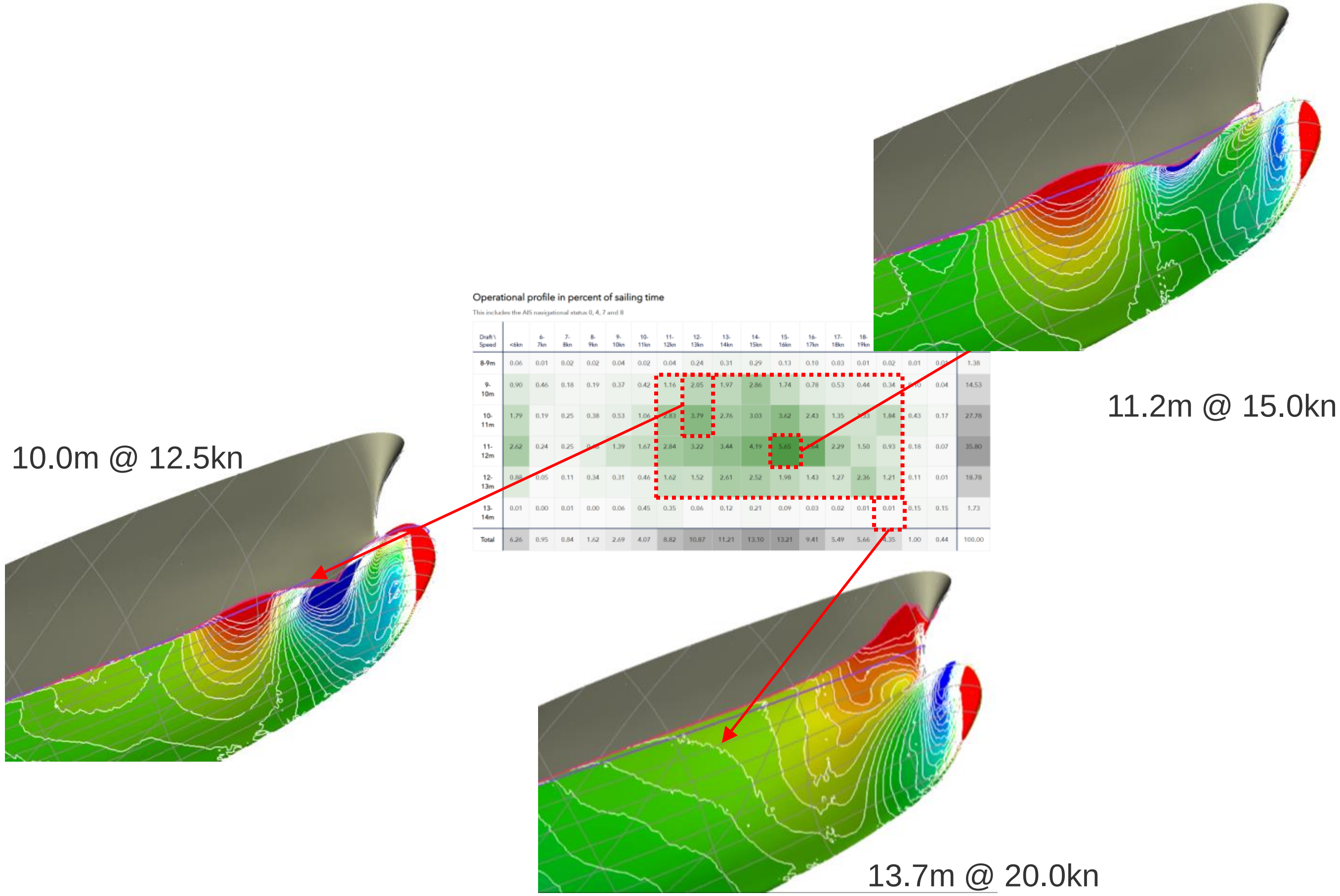
Quick Check

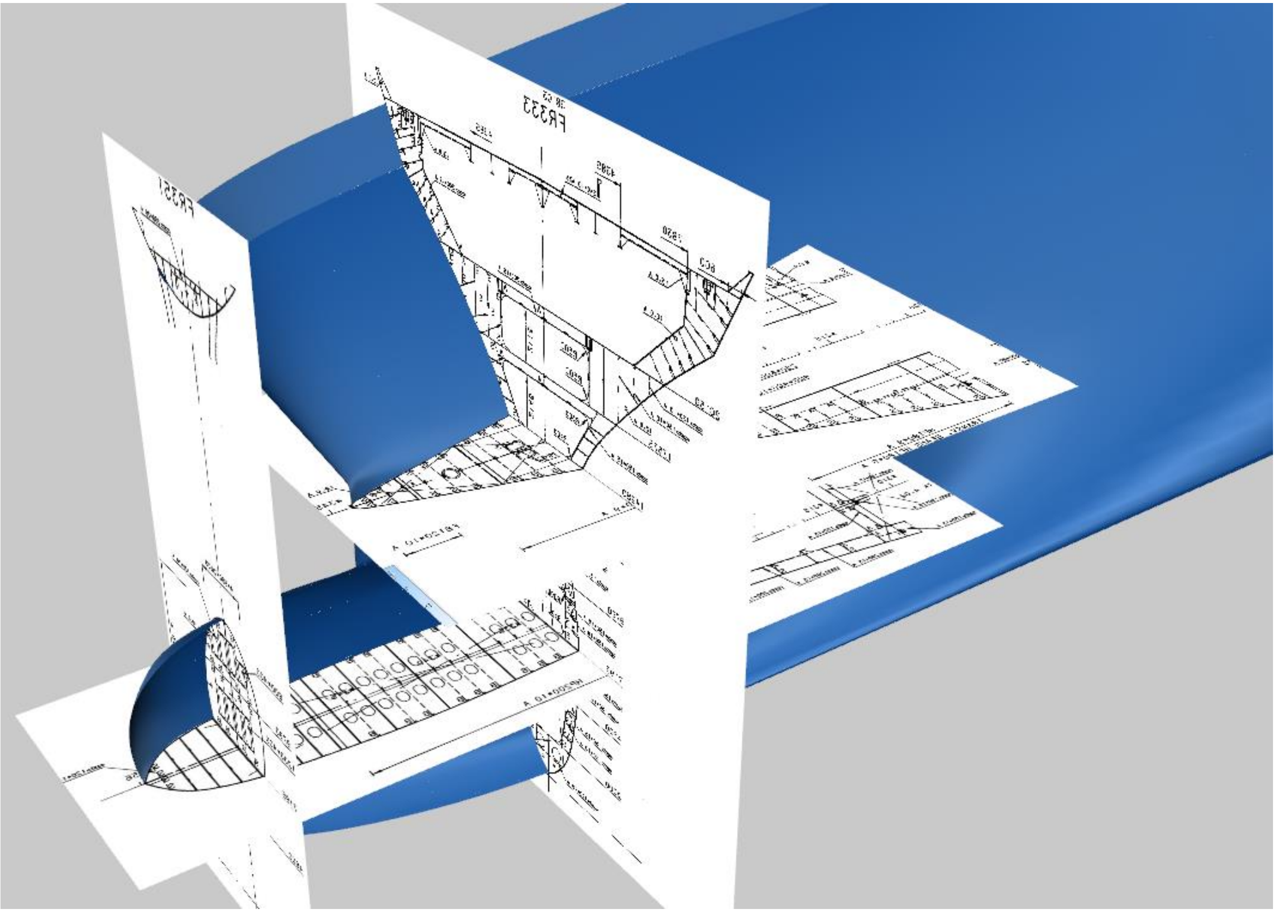


Draft \ Speed	<6kn	6-7kn	7-8kn	8-9kn	9-10kn	10-11kn	11-12kn	12-13kn	13-14kn	14-15kn	15-16kn	16-17kn	17-18kn	18-19kn				
8-9m	0.06	0.01	0.02	0.02	0.04	0.02	0.04	0.24	0.31	0.29	0.13	0.10	0.03	0.01	0.02	0.01	0.01	1.38
9-10m	0.90	0.46	0.18	0.19	0.37	0.42	1.16	2.05	1.97	2.86	1.74	0.78	0.53	0.44	0.34	0.10	0.04	14.53
10-11m	1.79	0.19	0.25	0.38	0.53	1.06	2.83	3.79	2.76	3.03	3.62	2.43	1.35	1.33	1.84	0.43	0.17	27.78
11-12m	2.62	0.24	0.25	[illegible]	1.39	1.67	2.84	3.22	3.44	4.19	5.65	[illegible]	2.29	1.50	0.93	0.18	0.07	35.80
12-13m	0.88	0.05	0.11	0.34	0.31	0.46	1.62	1.52	2.61	2.52	1.98	1.43	1.27	2.36	1.21	0.11	0.01	18.78
13-14m	0.01	0.00	0.01	0.00	0.06	0.45	0.35	0.06	0.12	0.21	0.09	0.03	0.02	0.01	0.01	0.15	0.15	1.73
Total	6.26	0.95	0.84	1.62	2.69	4.07	8.82	10.87	11.21	13.10	13.21	9.41	5.49	5.66	4.35	1.00	0.44	100.00

- Before going into a formal optimization it is wise to check the saving potential based on readily available data such as:
  - Operating pattern based on AIS or customer's recordings
  - Previous hydrodynamic studies for sister vessels or similar designs
  - Drawings of bulbous bow or propeller
  - Photographs from the internet
  - Public data bases
  - Etc.
- The expected savings in tons of fuel and CO_2 as well as the ROI are given.

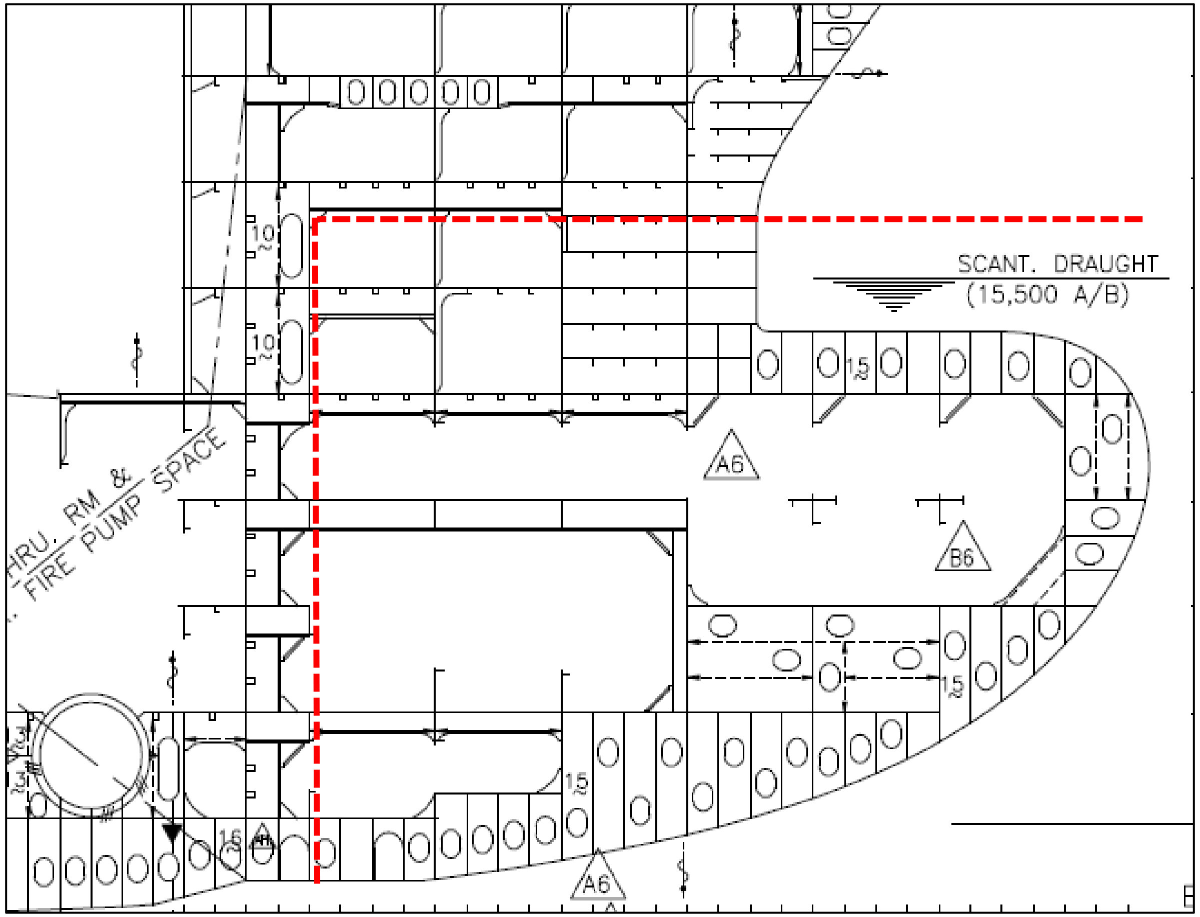
Preparation of hull lines

- If no 3D hull form is available, it can be digitalized from structural drawing.
- Challenges:
  - Paper gets distorted over the years
  - Drawings are not always consistent
  - Maximum accuracy required in cut out area
  - Maximum fairness required for RANSE CFD
- Duration: 3 days



Cut out

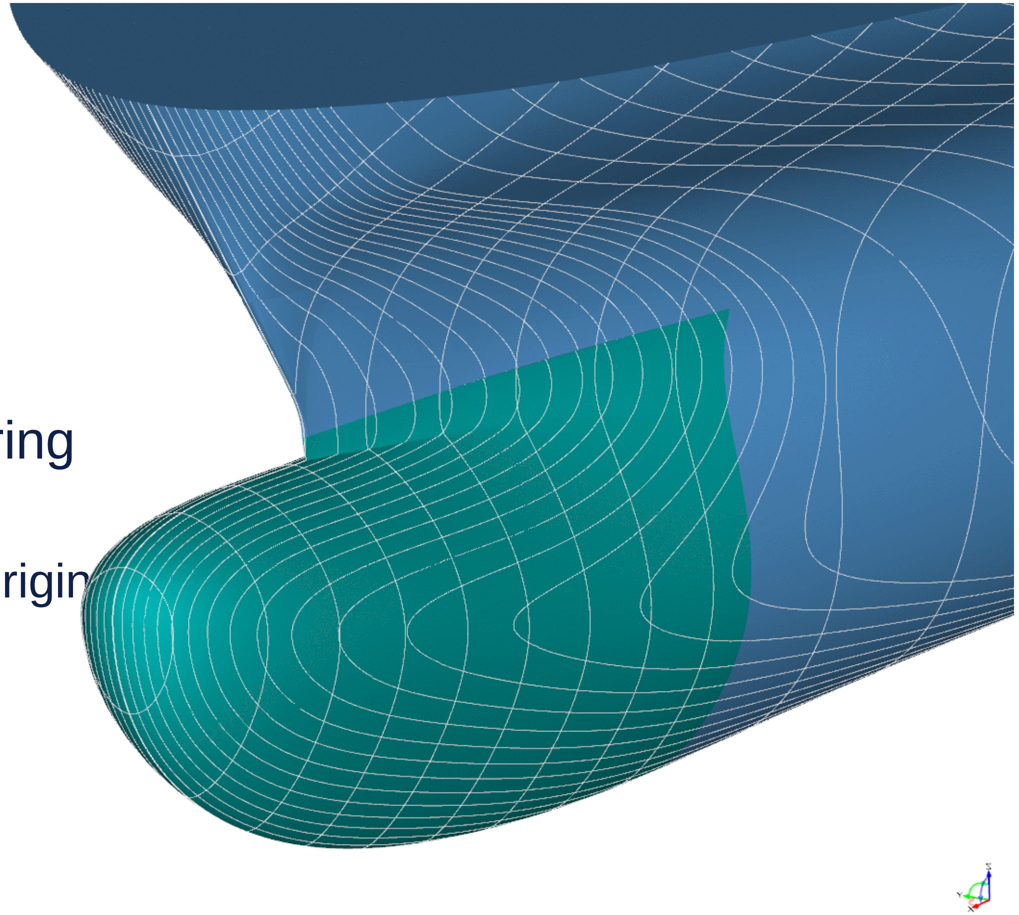
- Cooperation with the involved design office
- Cut typically defined in front of the collision bulkhead



The parametric model

Challenges of the model:

1. It needs to be connected to an existing IGES representation of the original hull form.
   - Varying surface quality
   - Varying surface topology
2. It needs to provide max. shape flexibility while ensuring a smooth result.
   - Optimal hull form might deviate to a large extent from the origin

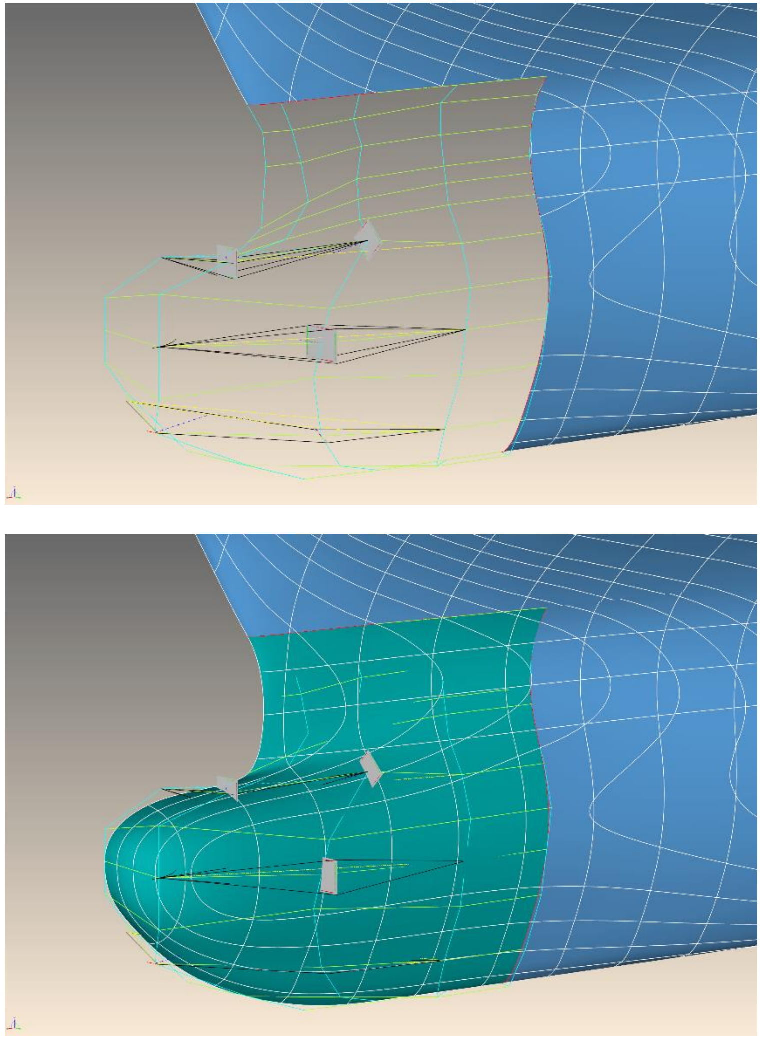


Specs of the model:

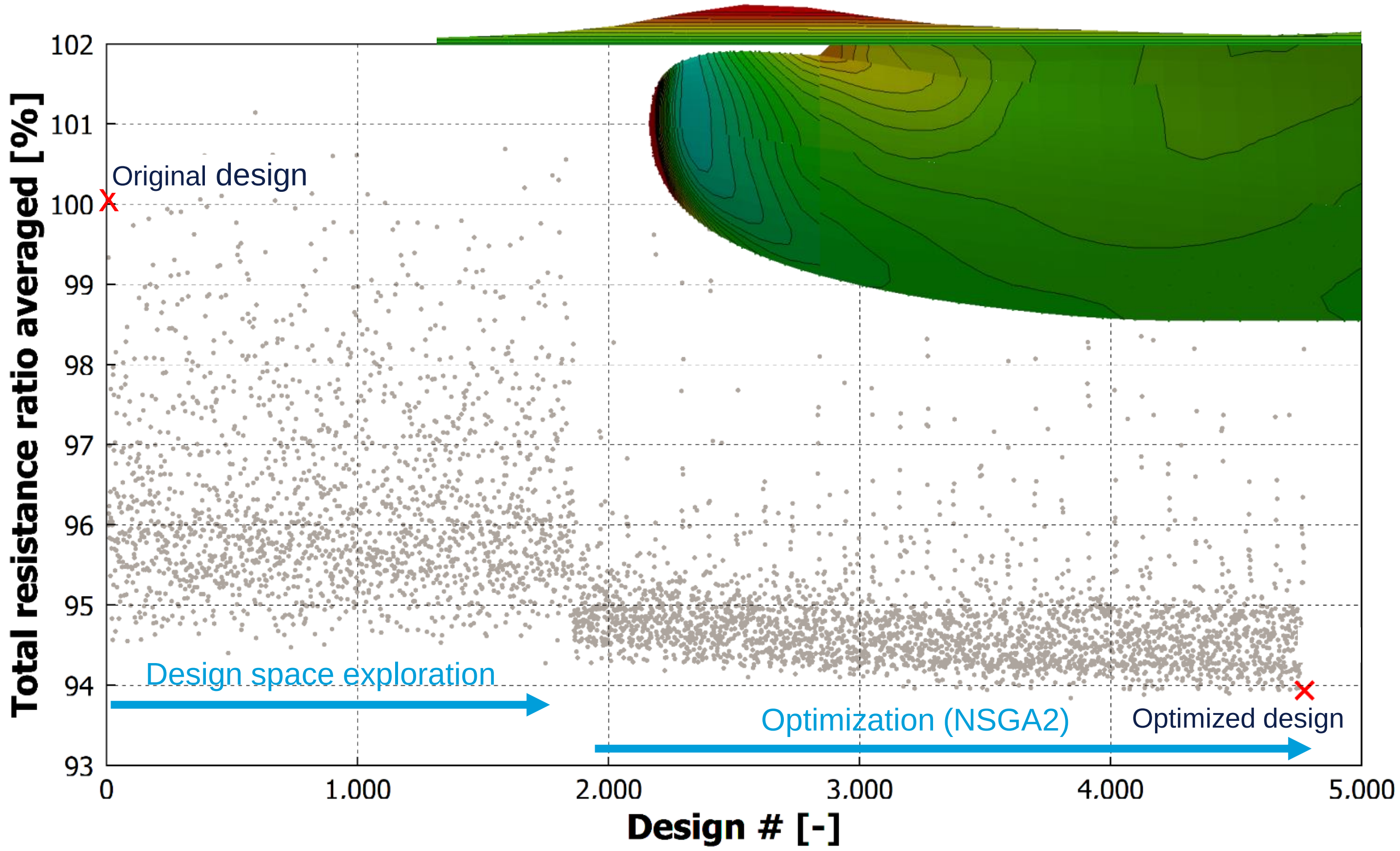
- tangential transition
- 15 free form parameters
- embedded fairing algorithm

Main idea of the model

1. Define cut out line for bow section as well as parametric stem curve
2. Snap 3 stacked B-Spline surfaces to the edges of the bulbous bow section
3. Define relationships between neighbour points (e.g. tangential connection knuckle…)
4. Vary characteristic points at the stem curve (surface polygon will follow)
5. Vary waterline entrance angles (2nd last column of points)
6. Vary internal points by shifts (1D, 2D, rotations…)
7. Refit surface within a given tolerance to match the original hull at cut out.

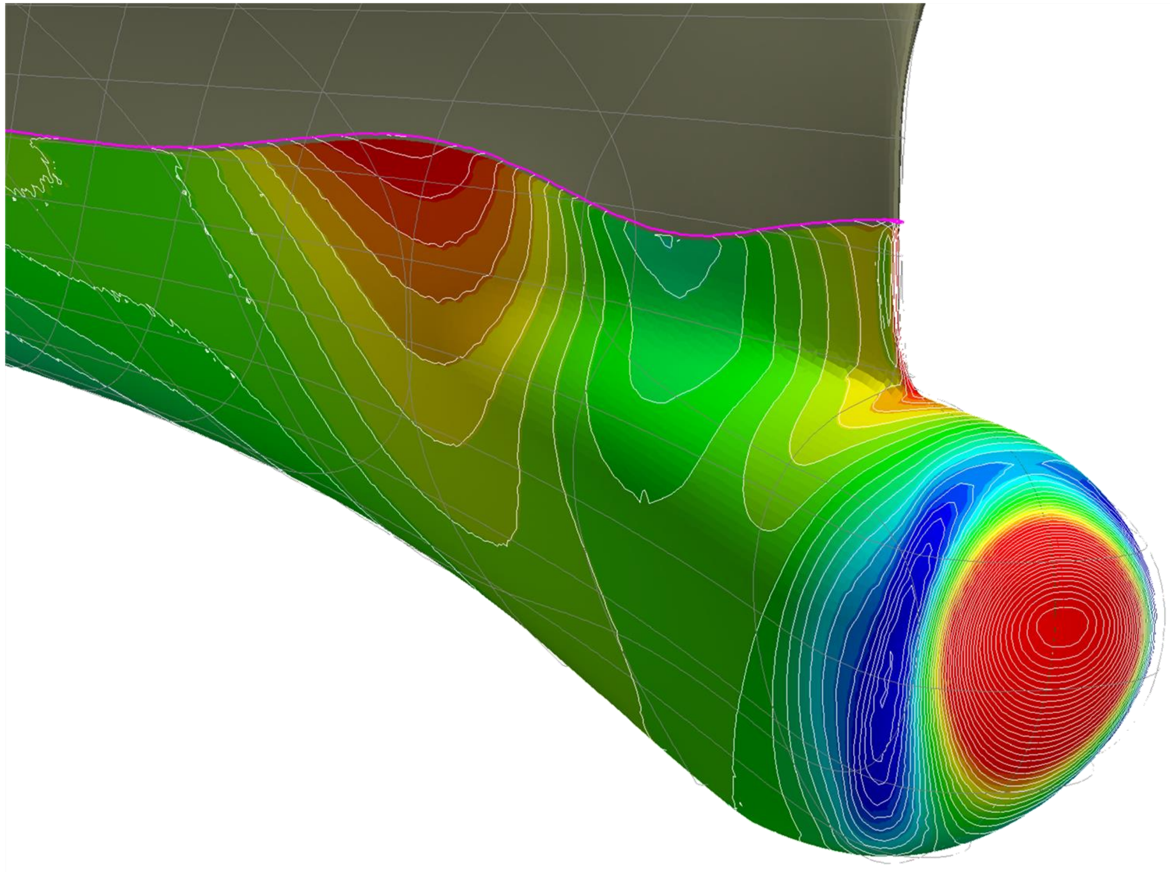


Optimization of bulbous bow



- Formal optimization on broad optimization range (typically 6 speed/draft combinations)
- ~5,000 designs → 30,000 CFD simulations
- A good coverage of the design space allows to detect trends, dependencies between the cases and max. (isolated) saving potential of each case
- Genetic algorithms converge rapidly towards the best design on the averaged profile

Validation by SPS



“Ship Performance Simulator” (SPS)

- RANSE based CFD solver
- Standardized setup and version control
- Predict calm water power demand
- Validate the savings, computed in the optimization
- Same accuracy level as can be achieved with model tests

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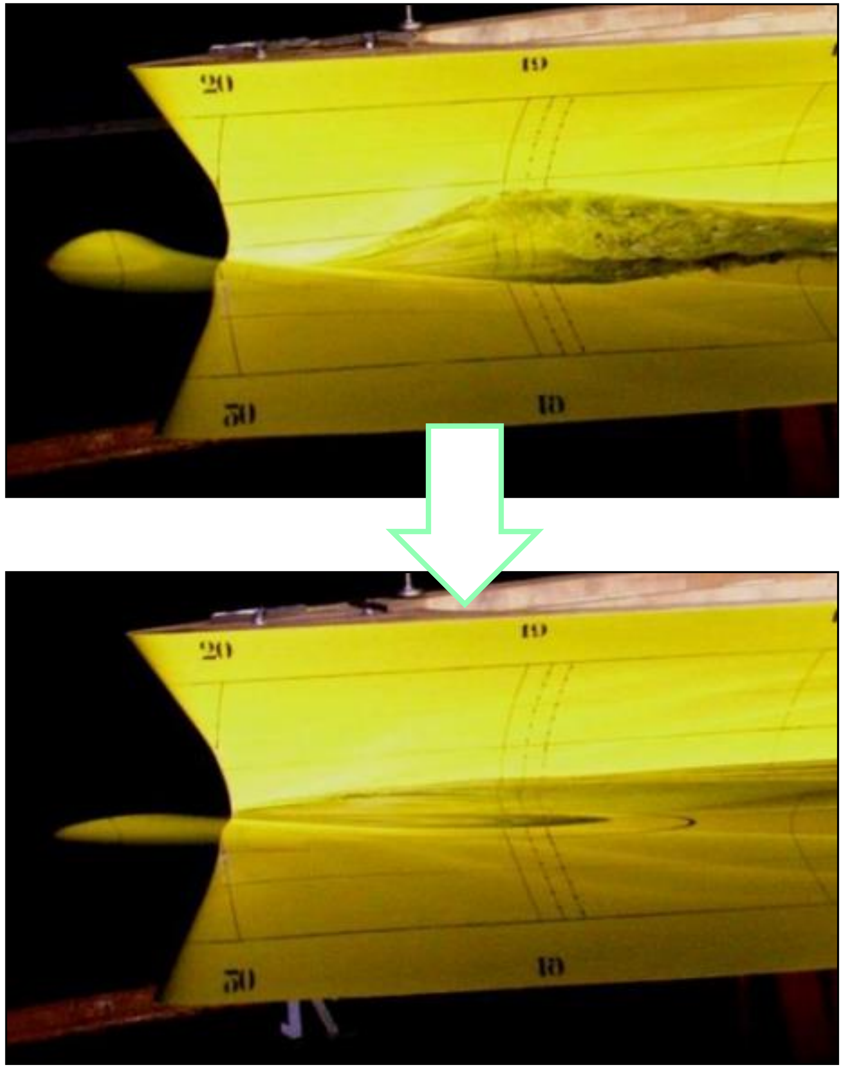
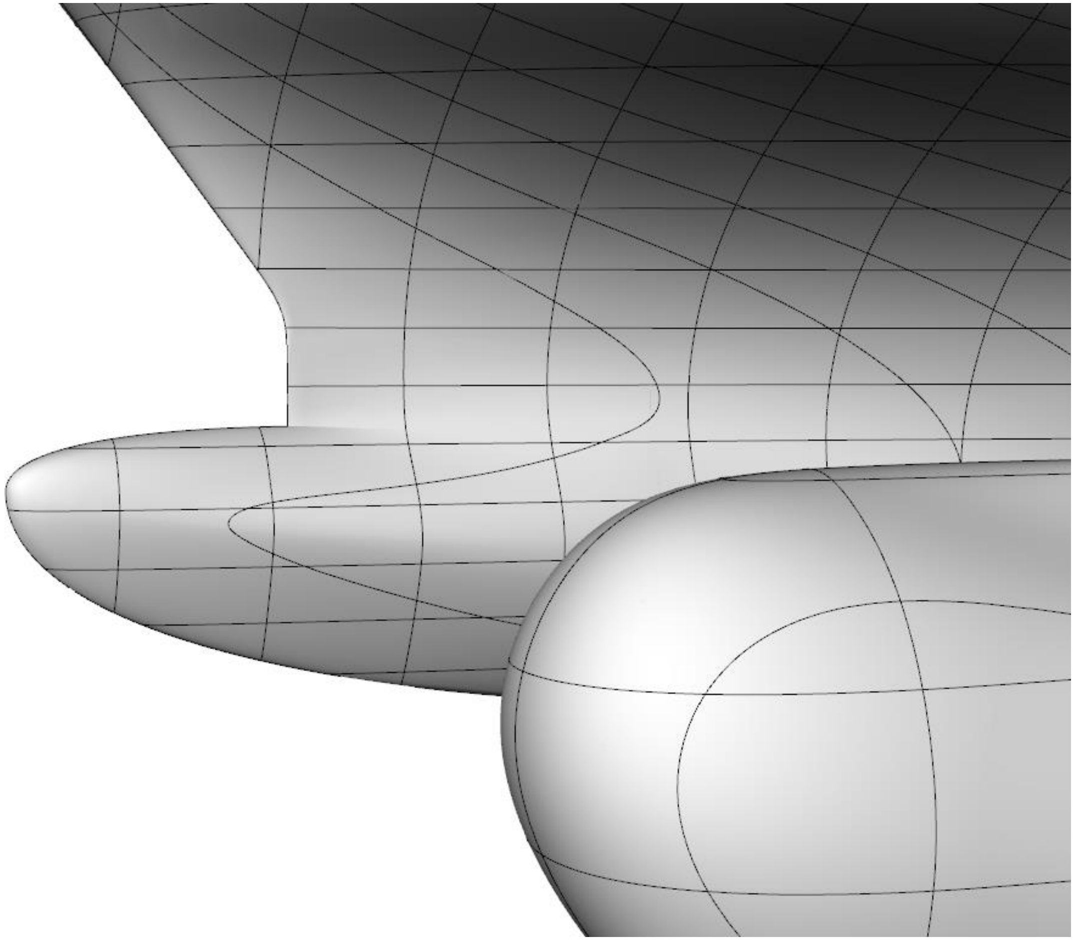
Conversion support

- Planning, attendance and evaluation of model tests
- Cooperation with design offices for bulbous bow construction
- Cooperation with propeller makers by sharing:
  - Propeller design or
  - CFD results or
  - Hull form models
  - Etc.



Done!



Photograph: courtesy of Reederei Claus-Peter Offen GmbH & Co. KG

Showcase 2,700 TEU vessel

Weights (based on power)	14.5 kn	16.5 kn	18.5 kn
TA = 8.0 m, TF = 7.0 m	12.2%	11.3%	7.5%
T = 9.5 m	5.4%	16.4%	1.8%
T = 11.5 m	21.2%	22.4%	1.8%


Source: Seaweb

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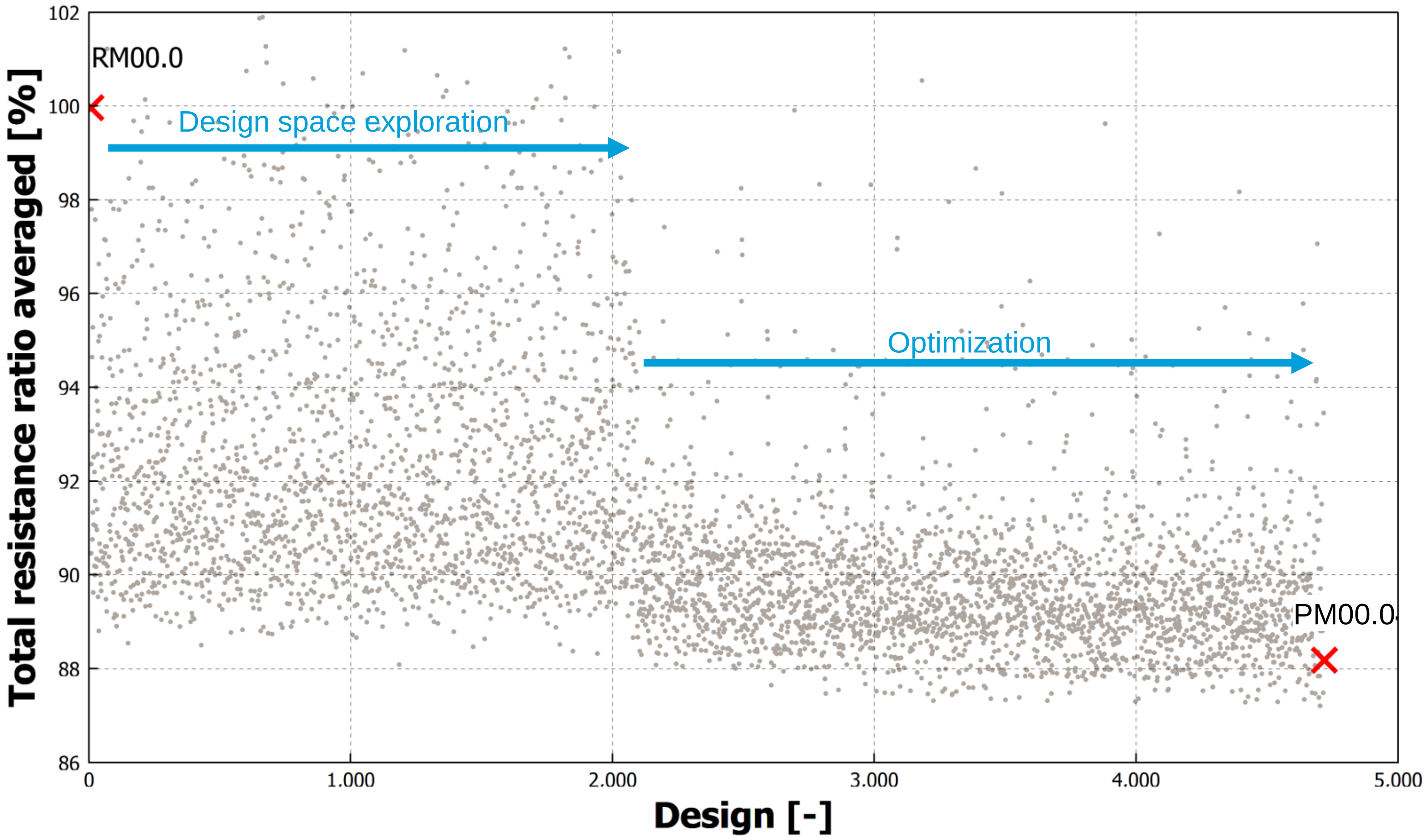
History plot of optimization (valid designs)



- The optimization created approx. 4,800 valid designs.
- The design space exploration formed the start population for the genetic algorithm in the actual optimization phase.
- The genetic optimization algorithm (NSGA2) converged rapidly towards the final design candidate.

Results

Saving in PD (Delivered power)	14.5 kn	16.5 kn	18.5 kn
TA = 8.0 m, TF = 7.0 m*	32.7%	34.6%	21.1%
T = 9.5 m	28.4%	19.2%	10.9%
T = 11.5 m	11.8%	4.4%	0.0%

- Weighted average saving sums up to 17.8%.

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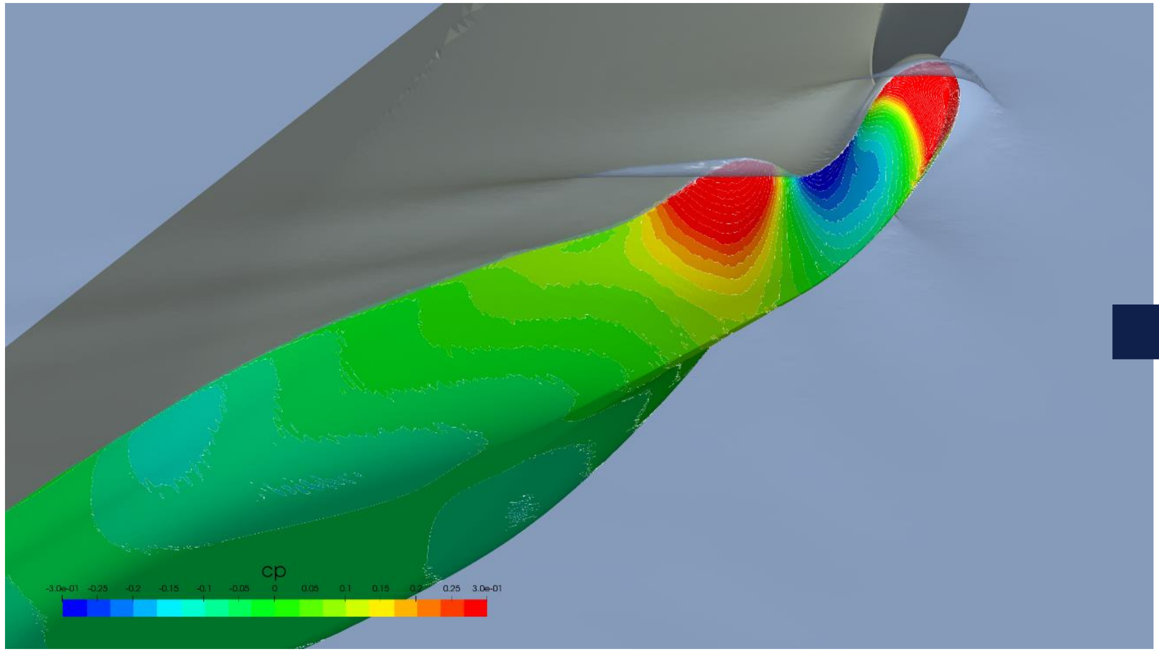
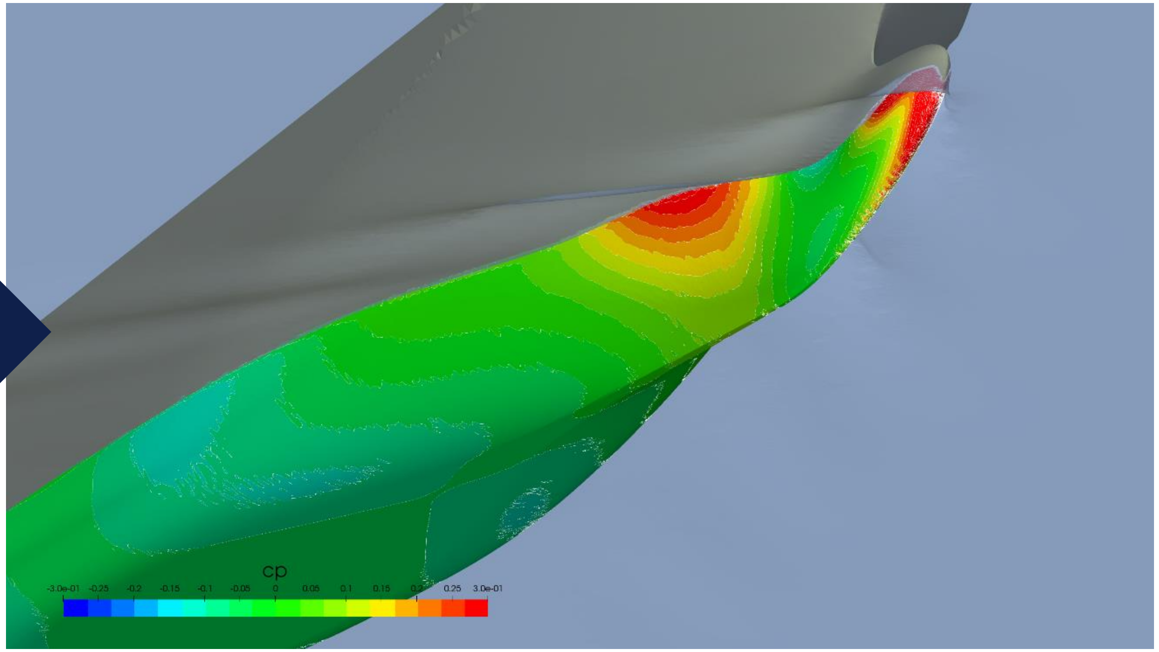
Results –
Dynamic pressure distribution and wave pattern

TA = 8.0 m, TF = 7.0m, v = 14.5 kn



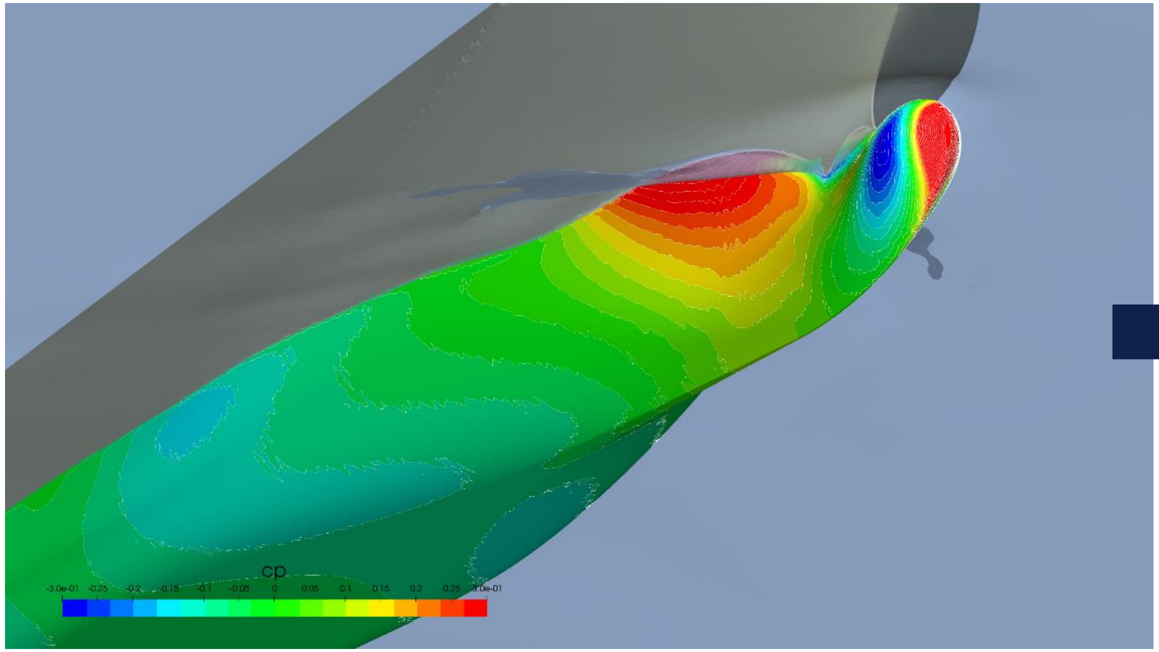
Original bulbous bow



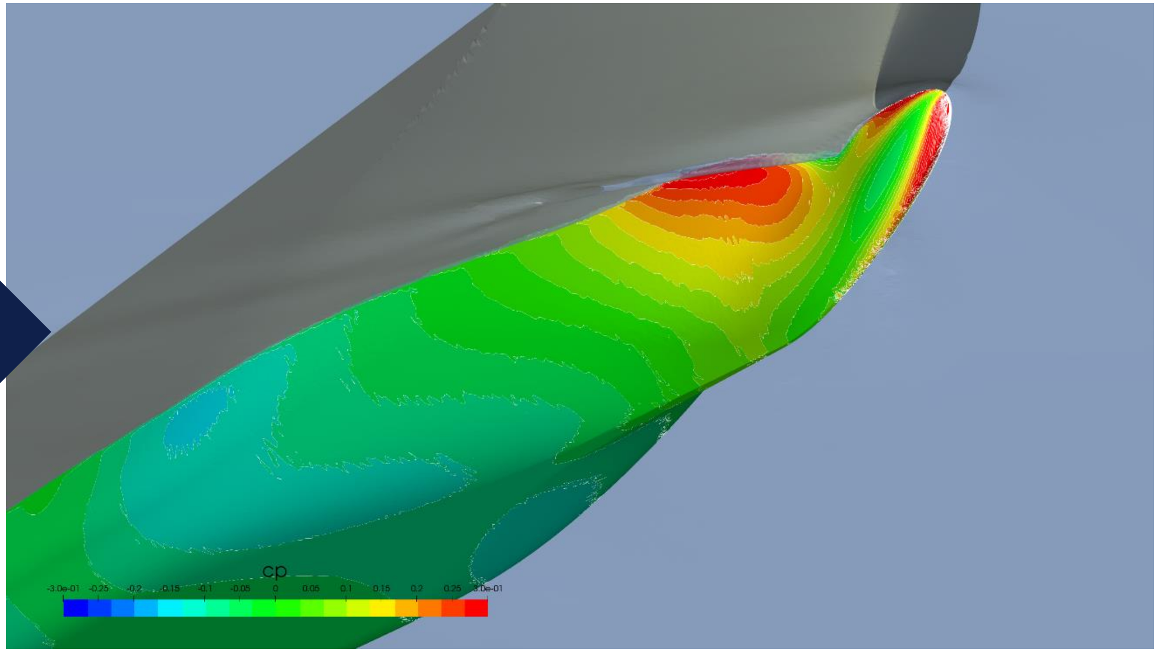
Optimized bulbous bow

Results –
Dynamic pressure distribution and wave pattern

T = 9.5 m, v = 16.5 kn



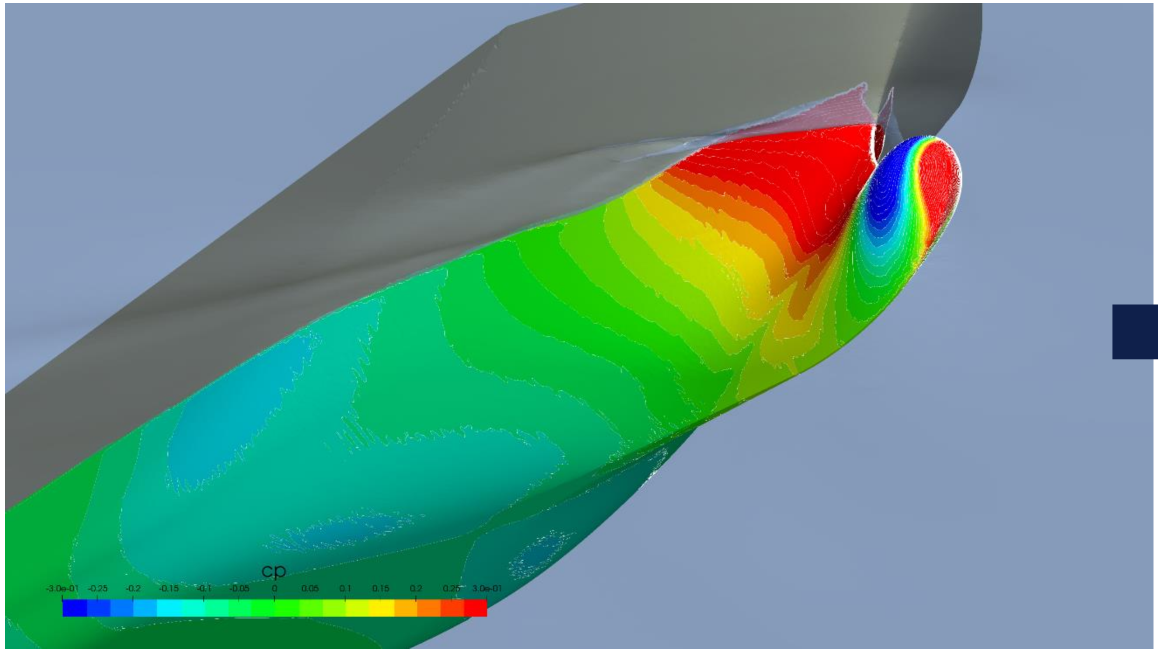
Original bulbous bow



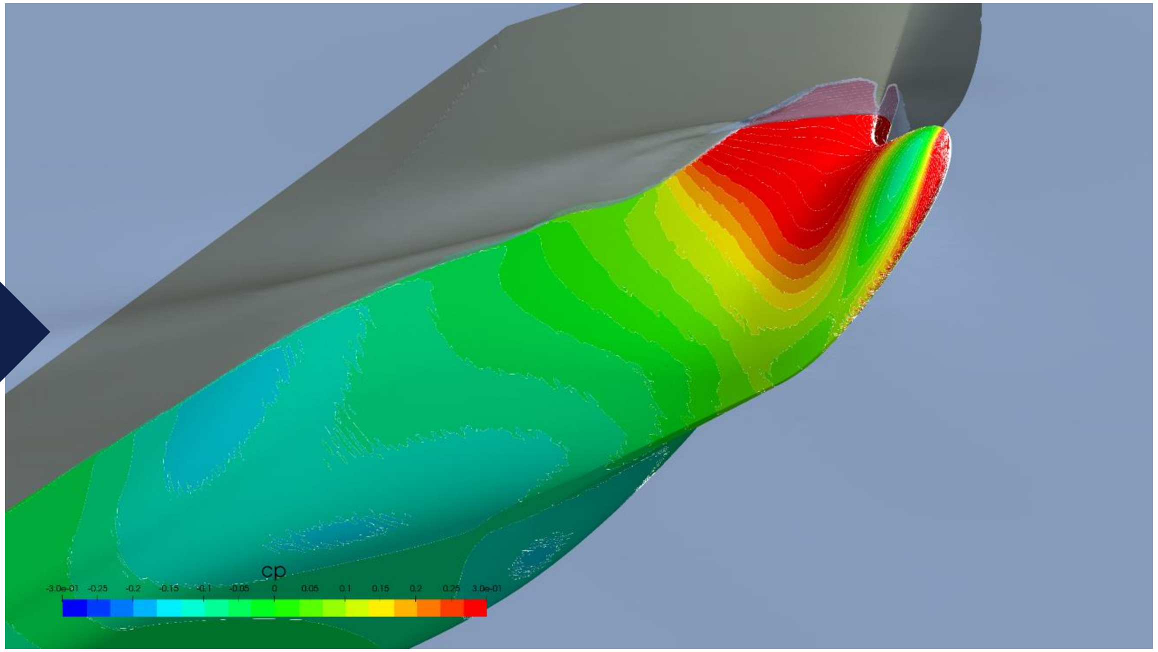
Optimized bulbous bow

Results –
Dynamic pressure distribution and wave pattern

T = 11.5 m, v = 18.5 kn



Original bulbous bow



Optimized bulbous bow

Bow retrofit savings potential

Saving estimation		
Average saving potential	17.8	**%**
Annual fuel savings per vessel	1,550	**t/vessel**
Annual CO_2 savings per vessel	4,800	**t/vessel**
Annual savings per vessel	1,000,000	**$/vessel**
Annual savings per class	2,000,000	**$/vessel class**
Return of investment (including conversion costs)	0.4	**years**

Assumptions		
Fuel price	650	$/ton
SFOC	190	g/kWh
Days at sea	255	t/vessel
Average main engine output	30	%
Conversion costs	400,000	$

- Please note that the ROI strongly depends on the conversion costs, which can vary significantly around the world.
- Operational details such as down times are not covered in this top-level assessment.
- Operation outside the considered optimization profile is neglected.

Thank you

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