# Fully Automatic Design Space Exploration by RANS Computations

Sebastian Uharek, FRIENDSHIP SYSTEMS

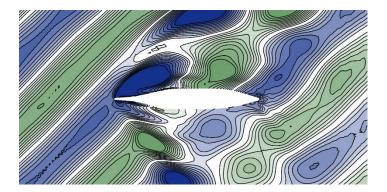
Stefan Harries, FRIENDSHIP SYSTEMS

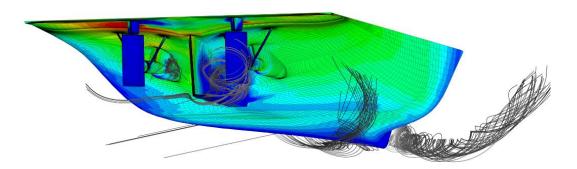
Andrés Cura Hochbaum, Technische Universität Berlin



#### About me

- Naval Architect from TU Berlin
- PhD Thesis on Numerical Prediction of Ship Manoeuvring Performance in Waves
- Working at Friendship Systems since April 2019





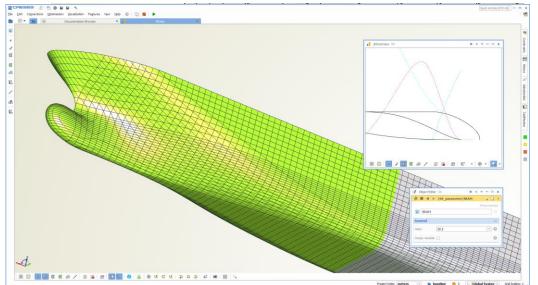
### Idea

- RANS code extensively used in R&D projects and for sophisticated applications
- Nevertheless, optimization projects in ship industry are often carried out using potential flow theory
- Drawbacks of RANS codes: More complicated setup, complicated grid design, increased computation time and more room for errors
- Goal is to undertake steps toward an easy to use and reliable setup

FLOW S		
SPEED [kn]	21	
		HOLISHIP
LOA [m]	183.58	
B [m]	27.6	
T [m]	7.1	
DISPLACEMENT [ m <sup>3</sup> ]	18971.53	
СВ	0.594	0/110
XCB [m]	74.33	
ZCB [m]	-2.98	
KM [m]	15.3	
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	RUN CFD	
RESISTANCE [kN]	547.15	00
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#### CAESES

- PIDO Platform for integration of various tools
- Parametric modelling of hull forms
- Connection of external tools using Software Connectors
- Powerful Optimisation algorithms (Dakota)

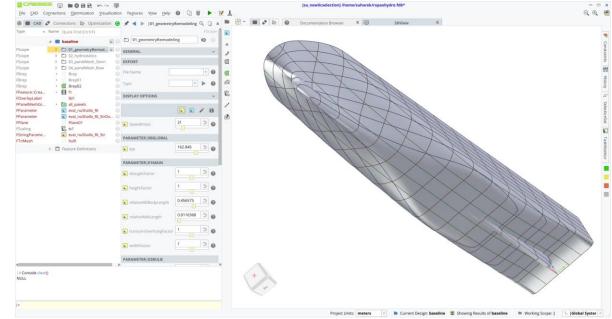


#### **Parametric model**



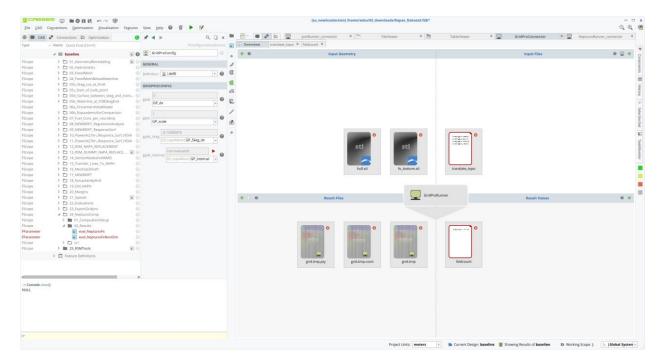
- Parametric model of a Ropax Ship developed in the scope of the Holiship project
- Twin-screw ship with skeg
- Total of 23 design variables





#### **Software connectors**

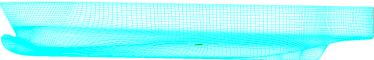
- Three chained connectors
  - Generate Grid
  - Preprocessing
  - Computation and basic postprocessing
- Execution of Jobs on HPC via Software Connector
- No manual interaction required after setup



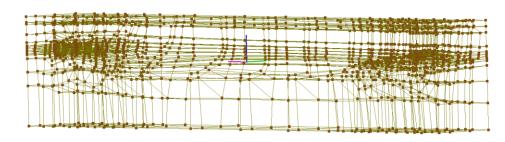
# Gridpro



- Computational Grid created with GridPro
- Topology separated from Geometry
- Translation of parts of the topology using command line tools provided by GridPro
- Internal surfaces required by GridPro can be generated in CAESES
- 800.000 cells, 6 minutes to generate, 6 grids in parallel



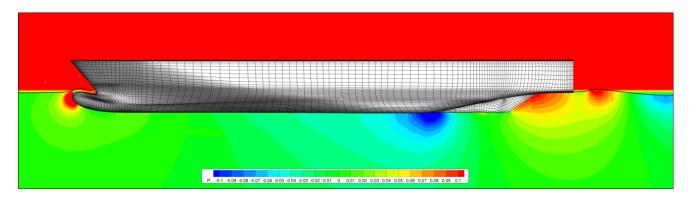






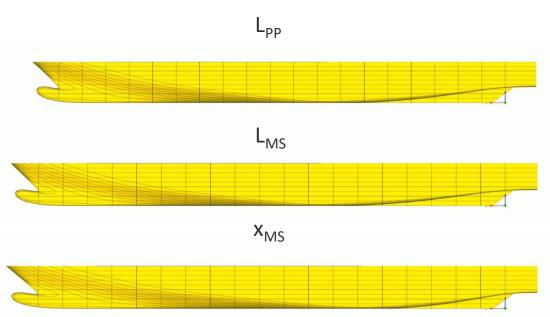
#### Neptuno

- In-House RANS code
  - Finite Volume
  - multi-block structured grid with non-matching interfaces
  - $-\,$  Standard k $\omega$  turbulence model by Wilcox
  - Two phase level set method

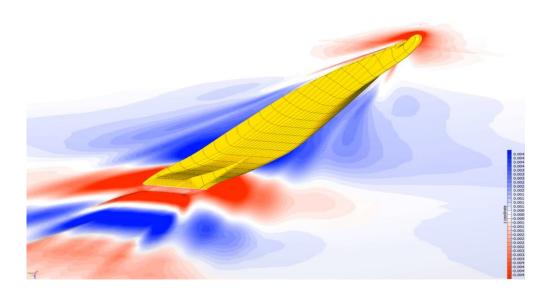


#### What do we do?

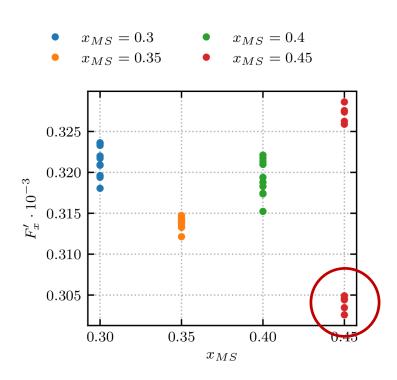
- Different means of design space exploration
  - Ensemble investigation
  - Sobol algorithm
  - Latin Hypercube Sampling
- Varied Parameters:
  - Length between perpendiculars (L<sub>PP</sub>)
  - Length of parallel midship (L $_{\rm MS})$
  - Position of parallel midship (x<sub>MS</sub>)
- No additional constraints



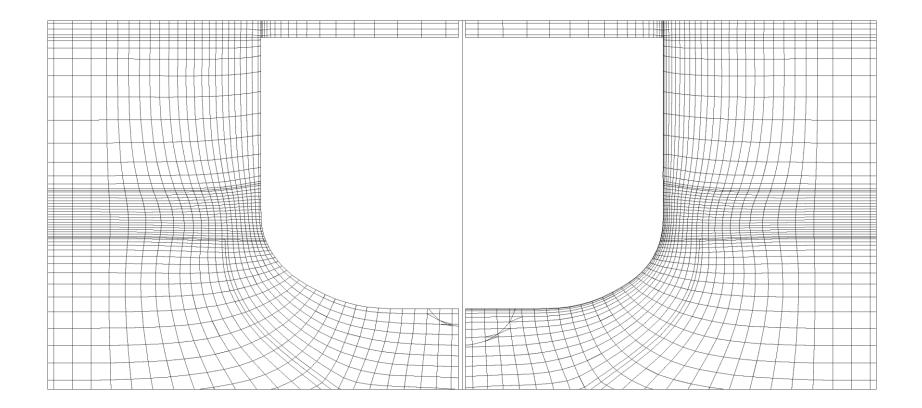
- Total of 120 computations run in parallel
- Computations carried out at virtual model scale of λ= 25 and 21 kn (Fn = 0.27)
- Average computation time



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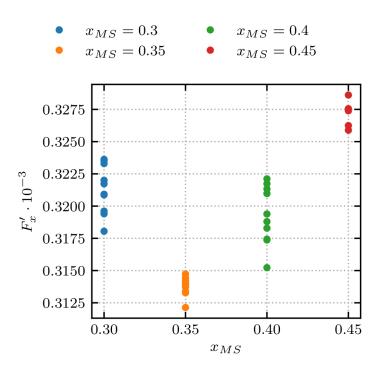


#### **Results: Mesh**

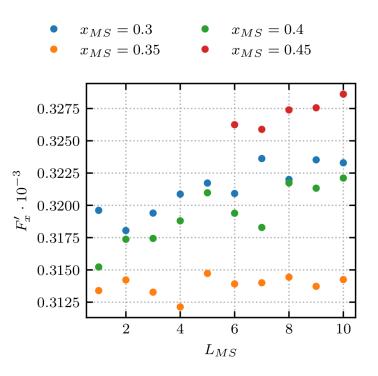




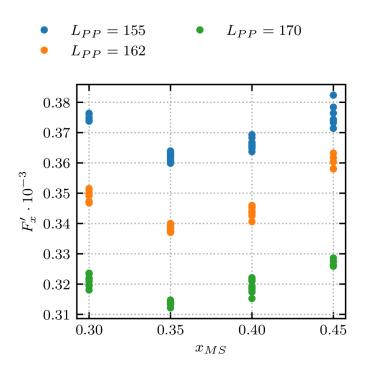
- Post processing script checks average y+ value on the hull and removes outliers
- Clear trends identified for parameter x<sub>MS</sub> and L<sub>PP</sub>
- No trends identified for L<sub>MS</sub> variation too small?

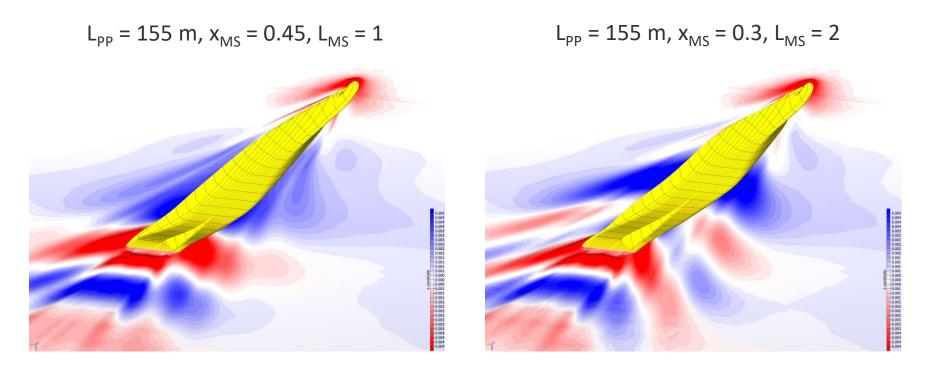


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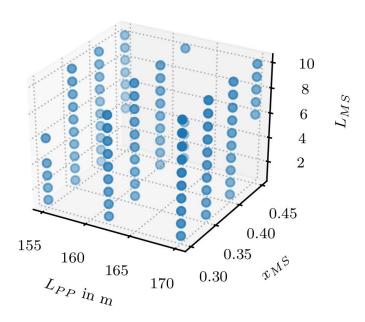
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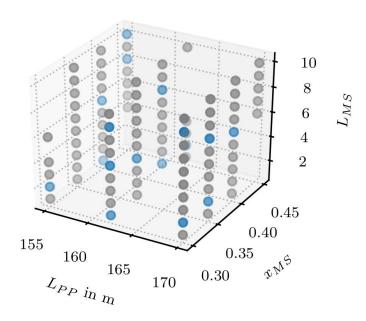


Difference: 8%

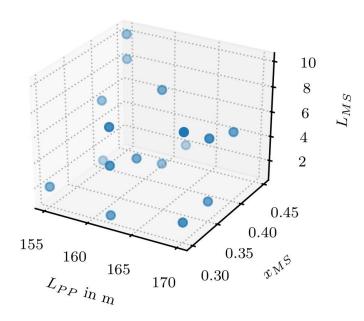
- Reduce computational time for optimisation even more by using a RSM model
- Randomly select 16 out of 100 initial design variants
- Generate a response surface model
- Recompute other 84 designs for validation

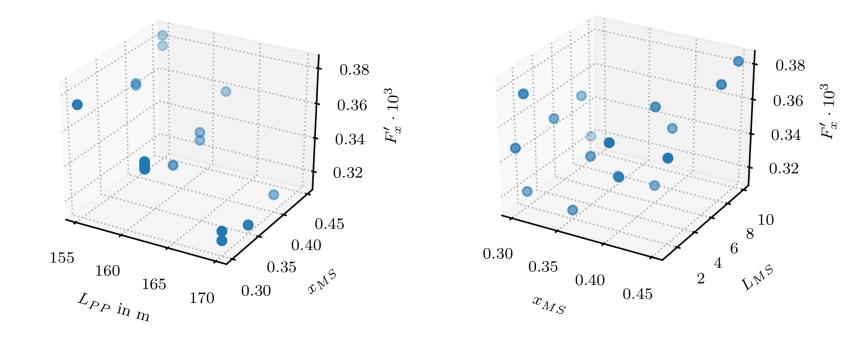


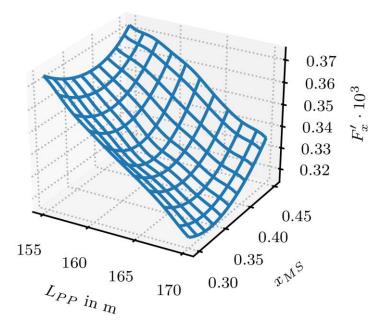
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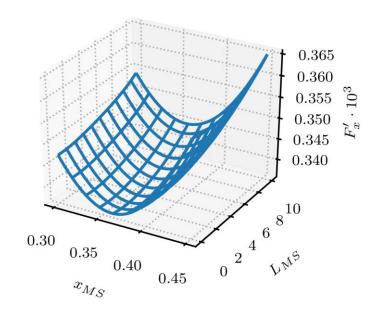


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## Validation of Response Surface Model

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Scope	D2_Hydrostatics		NepEns_04_des0457	170	9	0.45	-0.0001637777 -0.000	1686767 2.9912497
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Scope	O4_PanelMeshBelowWaterline		@ NepEns 04 des0386	155	10	0.35	-0.000	1869317 2.7253034
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Scope	<ul> <li>Osc_start_or_build_point</li> <li>Osd_Surface_between_skeg_and_trans (</li> </ul>	0	NepEns_04_des0458	170	8			2.6553554
Scope	OSe_Waterline_at_FOBSkegEnd	gpdx GP_dx V	NepEns_04_des0393	155	8	0.35	-0.0001803331 -0.000	1849506 2.5605394
Scope	D6a_FincantieriInitialModel	GP_dx •	NepEns_04_des0459	170	6	0.45	-0.0001631231 -0.000	1672994 2.5602137
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Scope	12_RSM_NAPA_REPLACEMENT		NepEns_04_des0407	162	10	0.35	-0.0001697872 -0.000	1724136 1.5468775
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Scope			NepEns_04_des0461	162	10		_	1826106 1.3619795
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Scope	20_Margins		NepEns_04_des0420	155	9	0.4	-0.000182967 -0.000	1853157 1.2836741
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			NepEns_04_des0413	170	9	0.35	-0.0001568638 -0.000	0.95726356
			NepEns_04_des0397	162	9	0.35	+0.0001700102 +0.000	0.88447634
		•	NepEns_04_des0429	162	4	0.4 -	-0.0001720591 -0.000	1705506 0.87673363
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ULL			NepEns_04_des0441	162	10	0.4	-0.000	0.83219886
			NepEns_04_des0418	155	5			0.79130664
			NepEns_04_des0416	155	7	0.4	-0.0001846554 -0.000	0.79028287
			NepEns_04_des0442	170	3	0.4	-0.000 -0.000	1599667 0.78667776
			NepEns_04_des0421	155	3	0.4	-0.0001828528 +0.000	0.74387704
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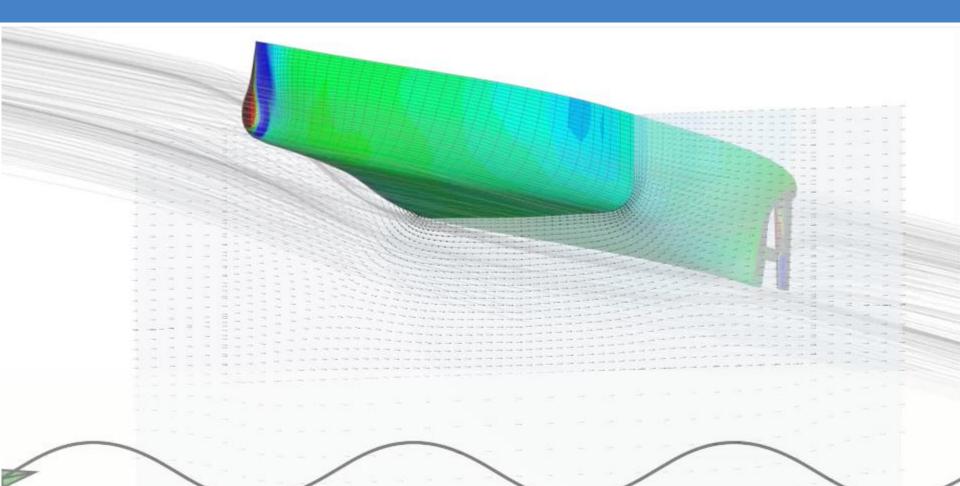
Project Units: 🗰 💌 🔹 🔍 🖿 Current Design: baseline 👳 Showing Results of baseline 🗈 Working Scope: | 😓 Global System

### **Conclusion and Future Work**

- Robust and fully automatic design space exploration
- High-quality grids, automated quality checks (grid dependence study) can be included
- RSM model shows very good results
- Employ more sophisticated design space exploration methods to reduce number of designs

		G•	
SPEED [kn]		21	
LOA [m]	183.58		
B [m]	27.6		
T [m]	7.1		
DISPLACEMENT [ m <sup>3</sup> ]	18971.53		
СВ	0.594		
XCB [m]	74.33		
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	RUN CFD		
RESISTANCE [kN]	547.15		
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			-X• -Y• -Y• -Z

# Thank you for your attention



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