

# Looking back and looking forward: Simulation-Driven Design and Data-Driven Engineering

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FRIENDSHIP SYSTEMS AG

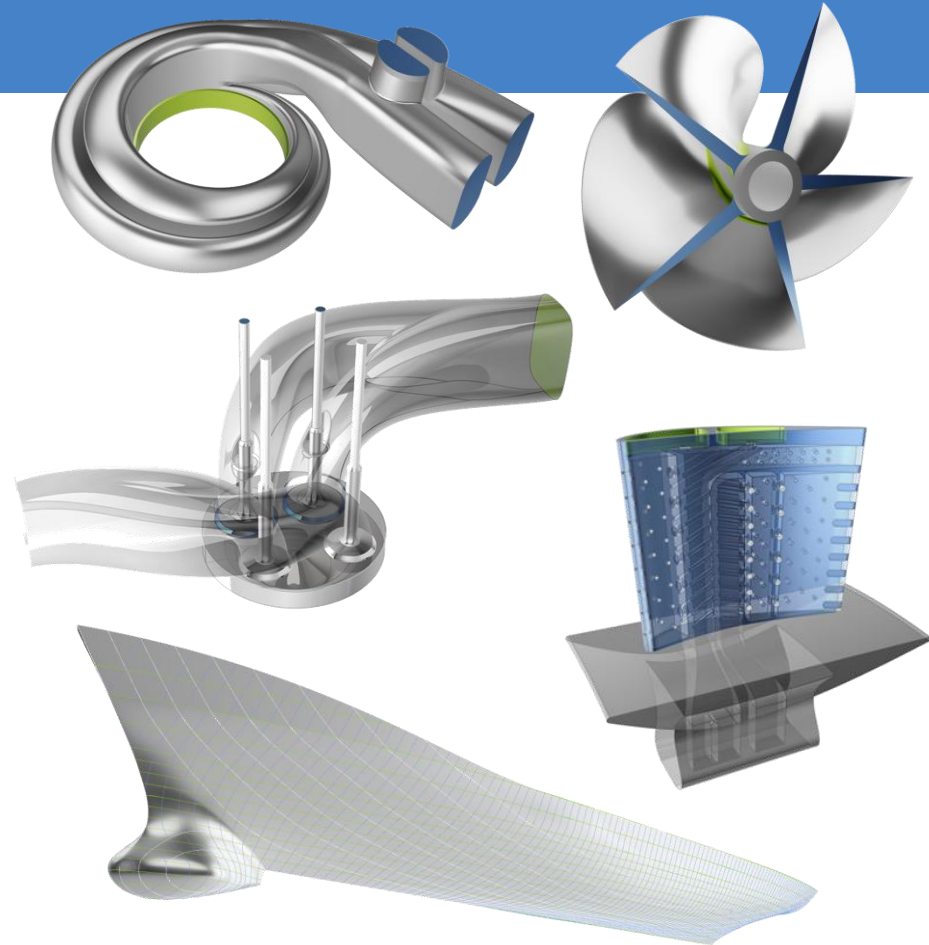
March 31, 2026



FRIENDSHIP SYSTEMS

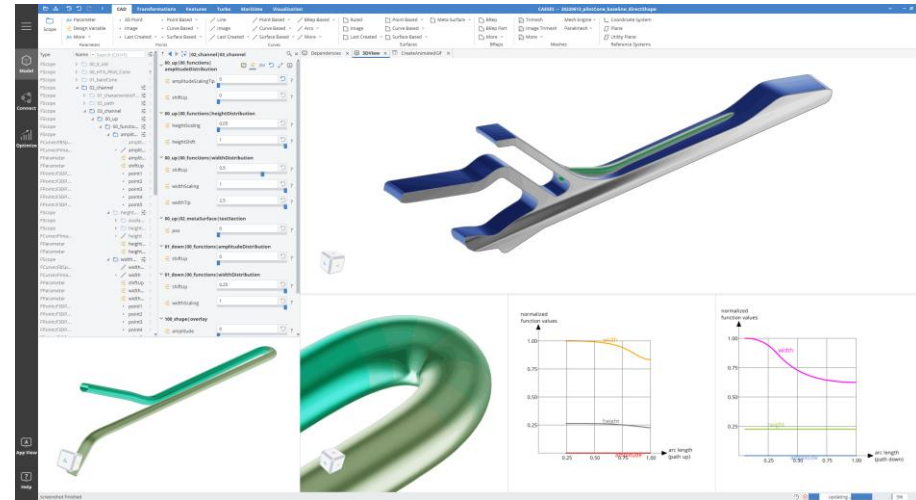
# Overview

- Looking back
  - Simulation-driven design over 25 years
  - Dedicated functionality
    - Design velocities and parametric-adjoint simulation
    - Principal Component Analysis (PCA)
  - Synthesis and surrogates
  - Comprehensive toolbox
  - Dedicated workflows
- Looking forward
  - New R&D projects
    - DesignAssist
    - FIT-HORIZONS
  - CAESES Insight for data-driven engineering



# Simulation-Driven Design (SDD)

- 2002: “Never heard of it!”
- 2007: “It worked for a double-ended ferry. But does it really work for a container carrier, too?”
- 2012: “We can do this by hand. And simulations are not reliable enough anyway.”
- 2017: “Well, we would like to try it, too.”
- 2022: “All of our designs undergo SDD.”



J.C.R. Licklider, 1965

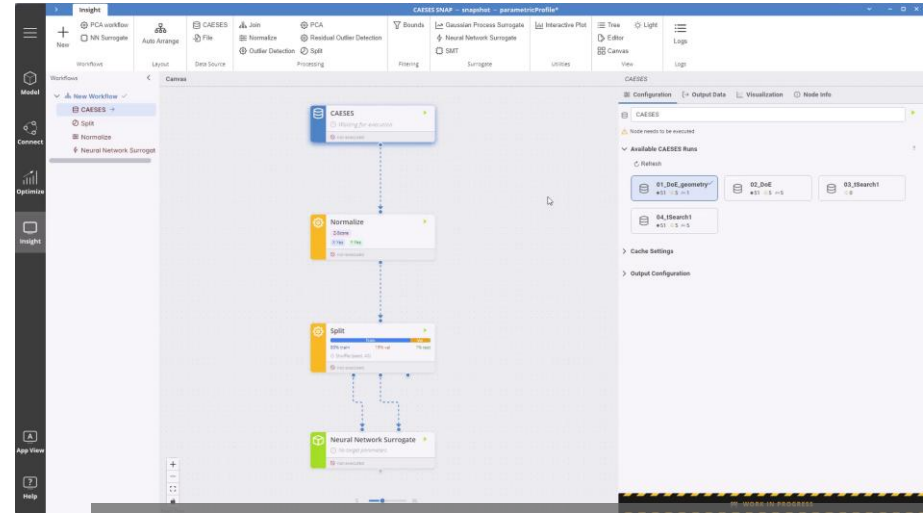
“People overestimate what can be done in one year, and underestimate what can be done in ten.”

American psychologist and computer scientist



# Data-Driven Engineering (DDE)

- 1992: “A neural network?  
What is the professor talking about?”
- 2003: “ANNs correlate input data and output data?  
Really?”
- 2016: “What are surrogates?”
- 2024: “Where do we get the data from?”
- 2026: “We need AI to stay competitive!”



J.C.R. Licklider, 1965

“People overestimate what can be done in one year,  
and underestimate what can be done in ten.”

American psychologist and computer scientist



# History and major technology and product upgrades

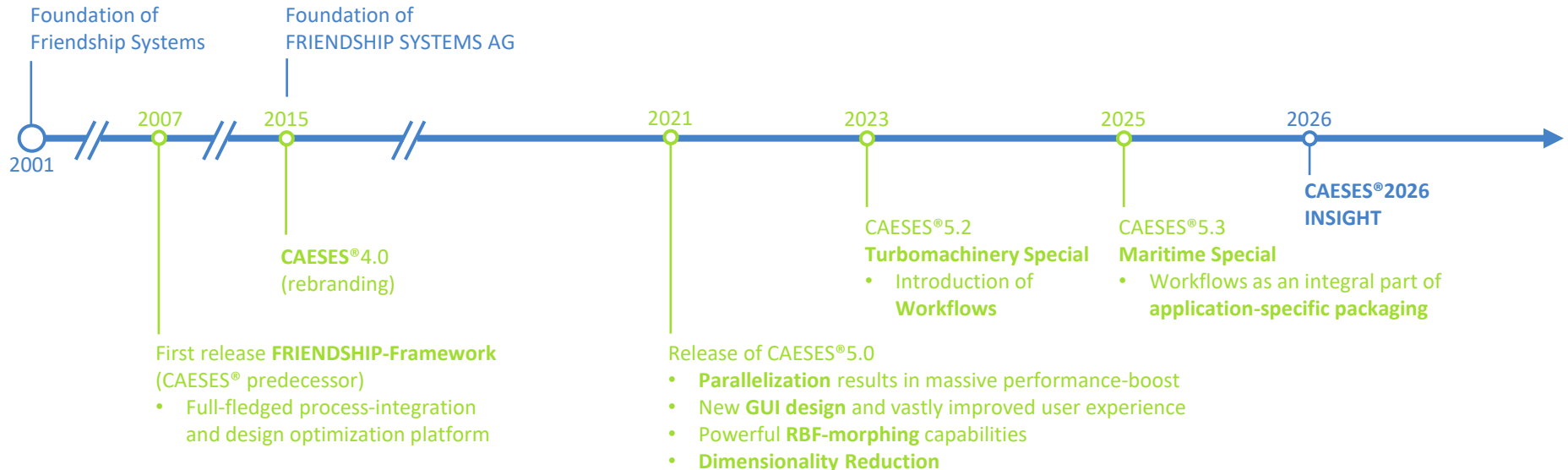
## Simulation-Driven Design

- **Robust variable geometry:** Fully- and partially-parametric models
- **Integration:** Flexible coupling to external simulation codes
- **DoE and optimization:** Data generation and data management



## Data-Driven Engineering

- **Verticals:** Workflows, application-specific functionality, web apps
- **Usability:** UI-UX improvements, morphing, operations
- **Machine Learning and AI:** INSIGHT



# Looking back

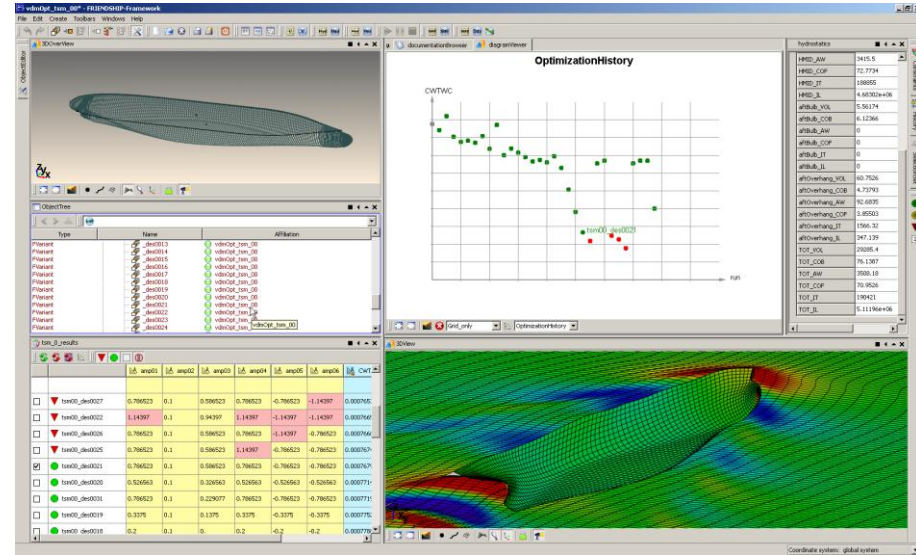
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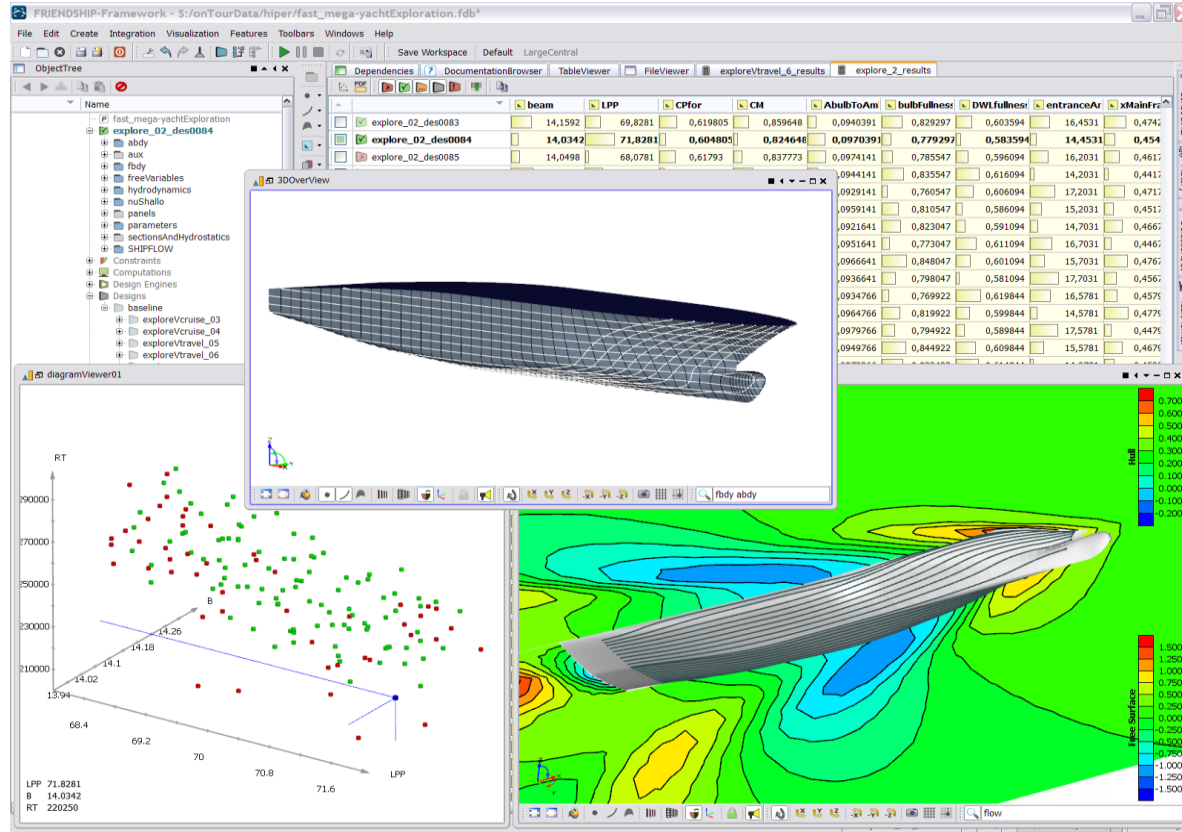
# Young and innocent in 2001



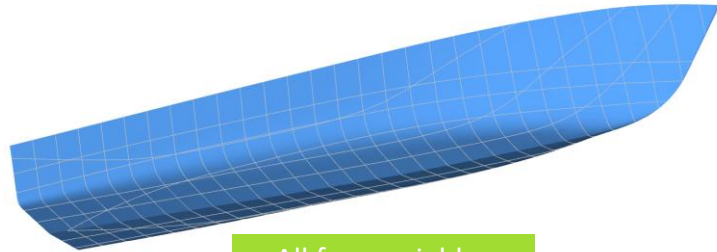
# FRIENDSHIP-Framework replaces FRIENDSHIP-Modeler in 2007



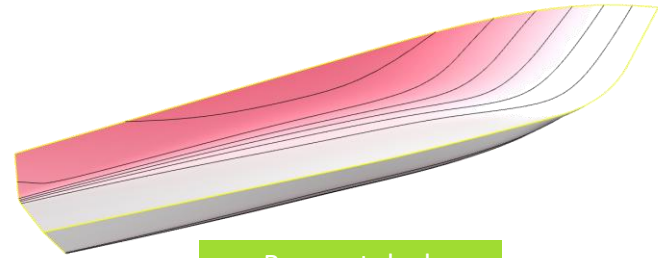
# GUI in 2010 with first numerical hull series



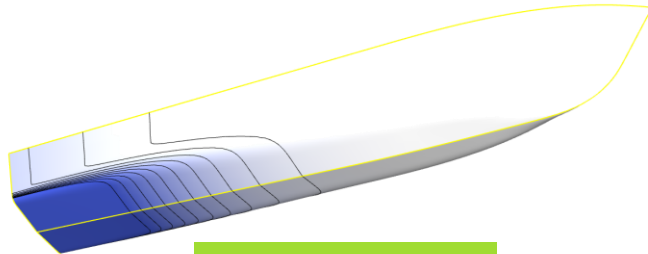
# Design velocities for parametric-adjoint simulation



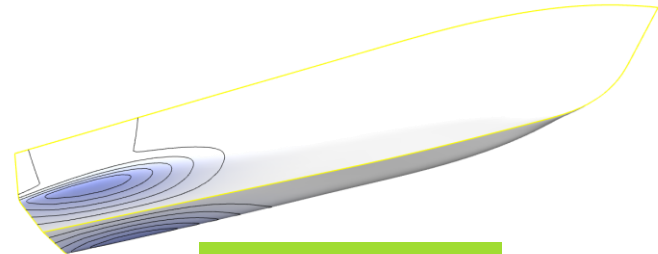
All free variables



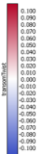
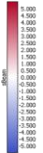
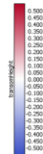
Beam at deck



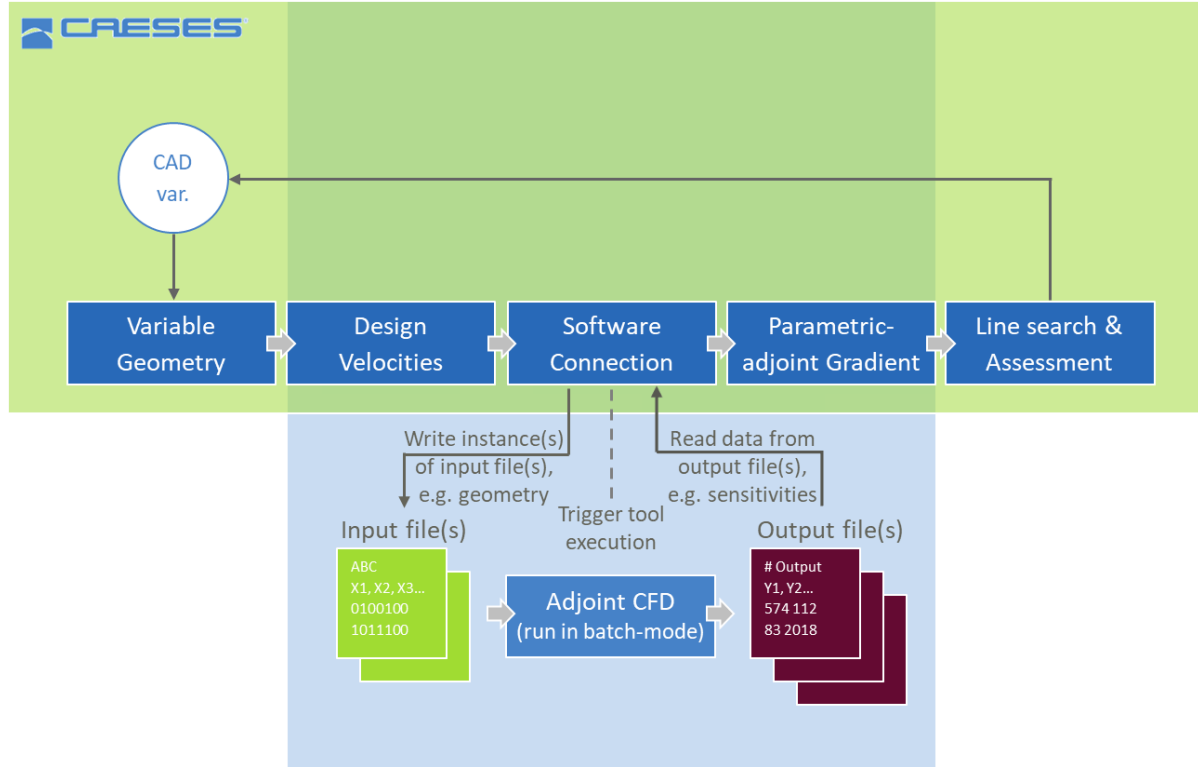
Transom height



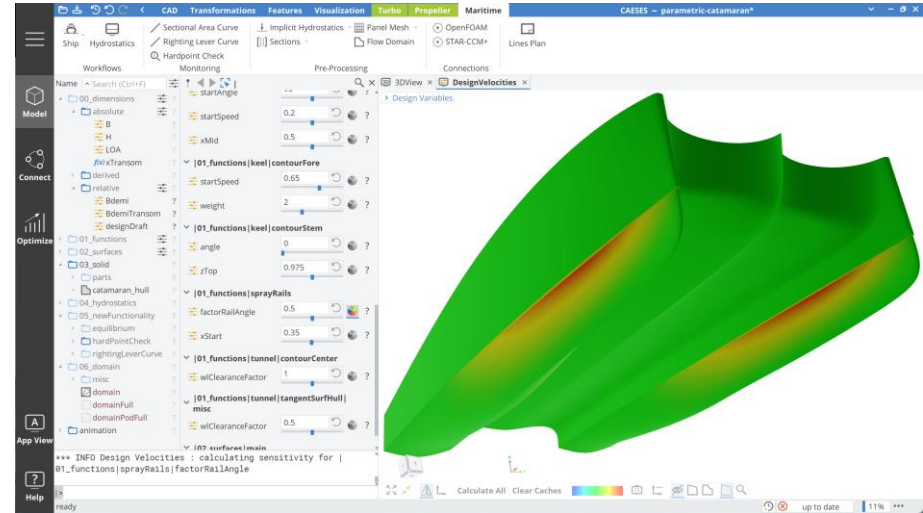
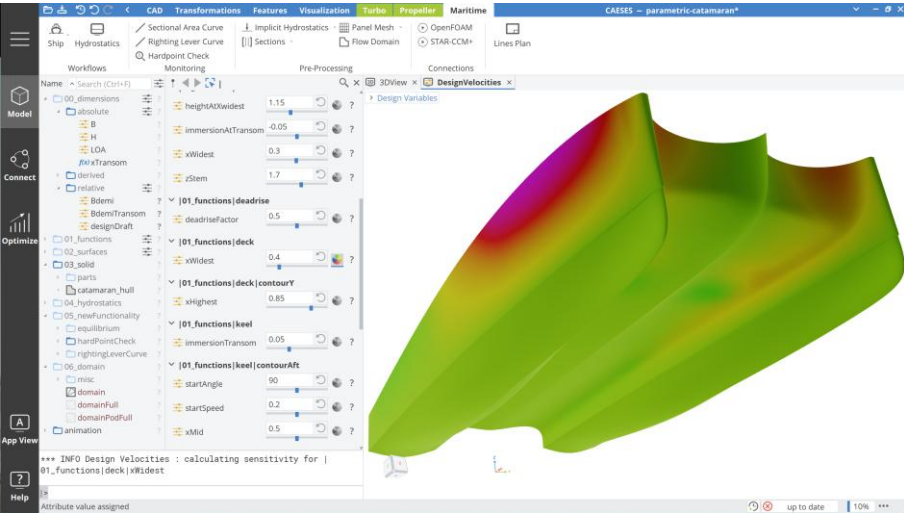
Transom twist



# Introduction of parametric-adjoint simulation



# Design velocities for investigating parametric models

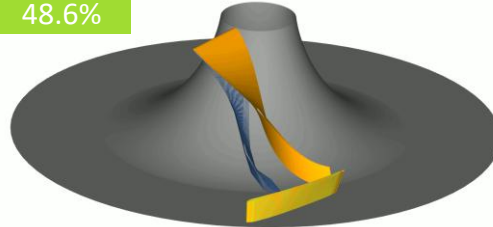


# PCA for dimensionality reduction

Design Variables				
	Design Variable	Lower	Value	Upper
1	ANGLE_HUB	-10	0	10
2	ANGLE_SHROUD	-10	0	10
3	MID_SHIFT_DELTA	-2	0	2
4	MID_SHIFT_POS	0.3	0.5	0.8
5	BETA_HUB_LE	-40	45	50
6	BETA_HUB_TE	45	50	55
7	BETA_SHROUD_LE	25	30	35
8	BETA_SHROUD_TE	40	41.7	50
9	BETA_TanFactor_HUB_LE	0.4	0.5	0.6
10	BETA_TanFactor_HUB_TE	0.4	0.5	0.6
11	BETA_Tan_HUB_LE	-45	-45	-35
12	BETA_Tan_HUB_TE	-65	-60	-55
13	BETA_TAN_SHROUD_LE	-15	-10	-5
14	BETA_TAN_SHROUD_TE	-40	-35	-30
15	THETA_DELTA_SHROUD_LE	-10	-2	0
16	THETA_DELTA_SHROUD_TE	-10	0	10
17	Diff_BETA_HUB_LE	17	19	25
18	Diff_BETA_HUB_TE	28	37	44
19	Diff_BETA_SHROUD_LE_Delta	-4.5	-2	3.5
20	Diff_BETA_SHROUD_TE_Delta	-5	-1	8
21	Diff_BETA_Tan_HUB_LE	-30	-20	-10
22	Diff_BETA_Tan_HUB_TE	-7.5	0	10
23	Diff_BETA_Tan_SHROUD_LE	-30	-20	-10
24	Diff_BETA_Tan_SHROUD_TE	-10	10	20
25	Diff_THETA_DELTA_SHROUD_LE	-15	-3	8.5
26	Diff_THETA_DELTA_SHROUD_TE	-5	0	5

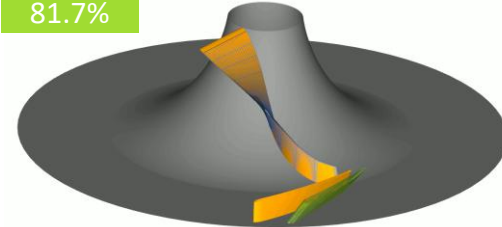
KLE mode 1 – main blade

48.6%



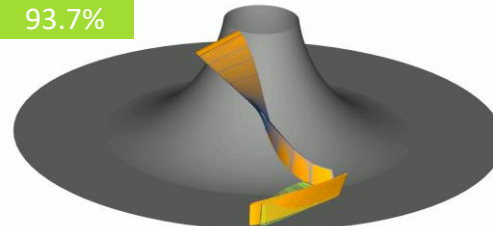
KLE mode 2 – diffuser

81.7%



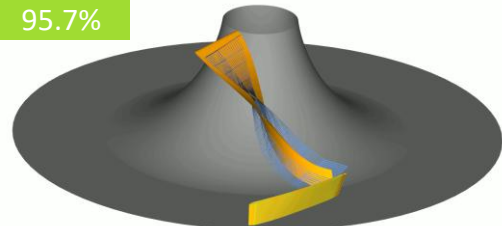
KLE mode 3 – diffuser

93.7%

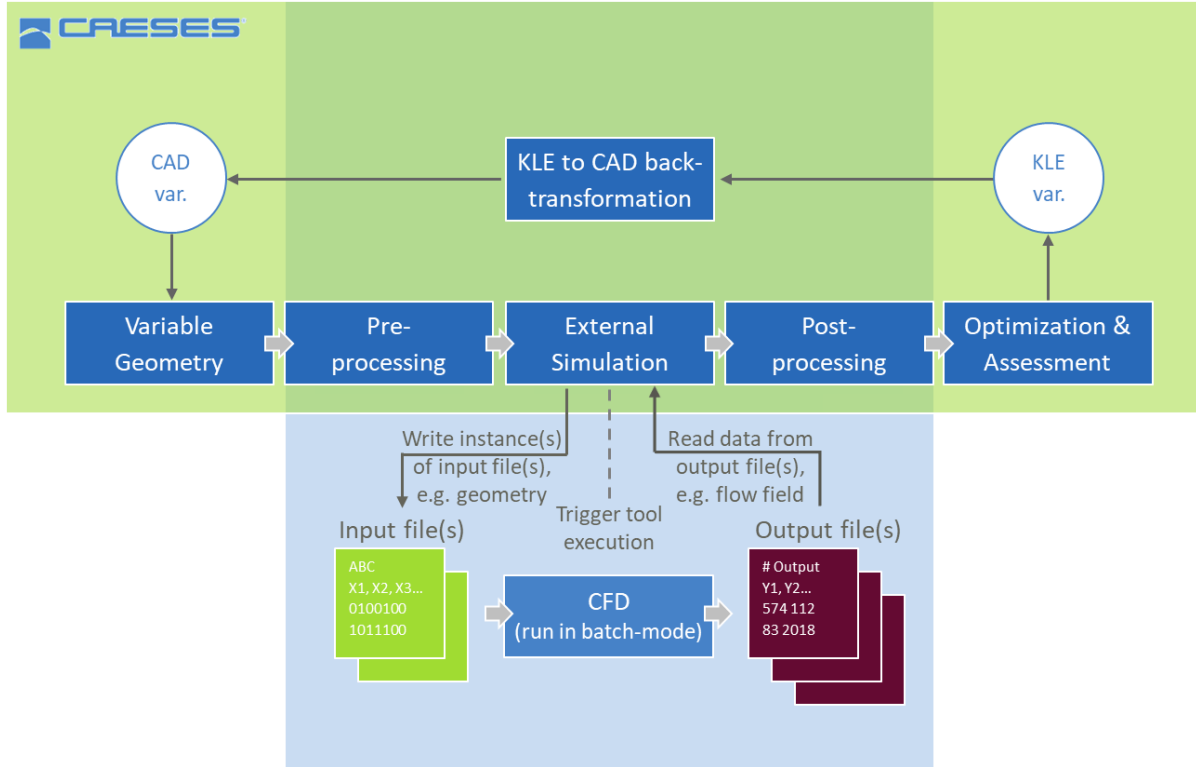


KLE mode 4 – main blade

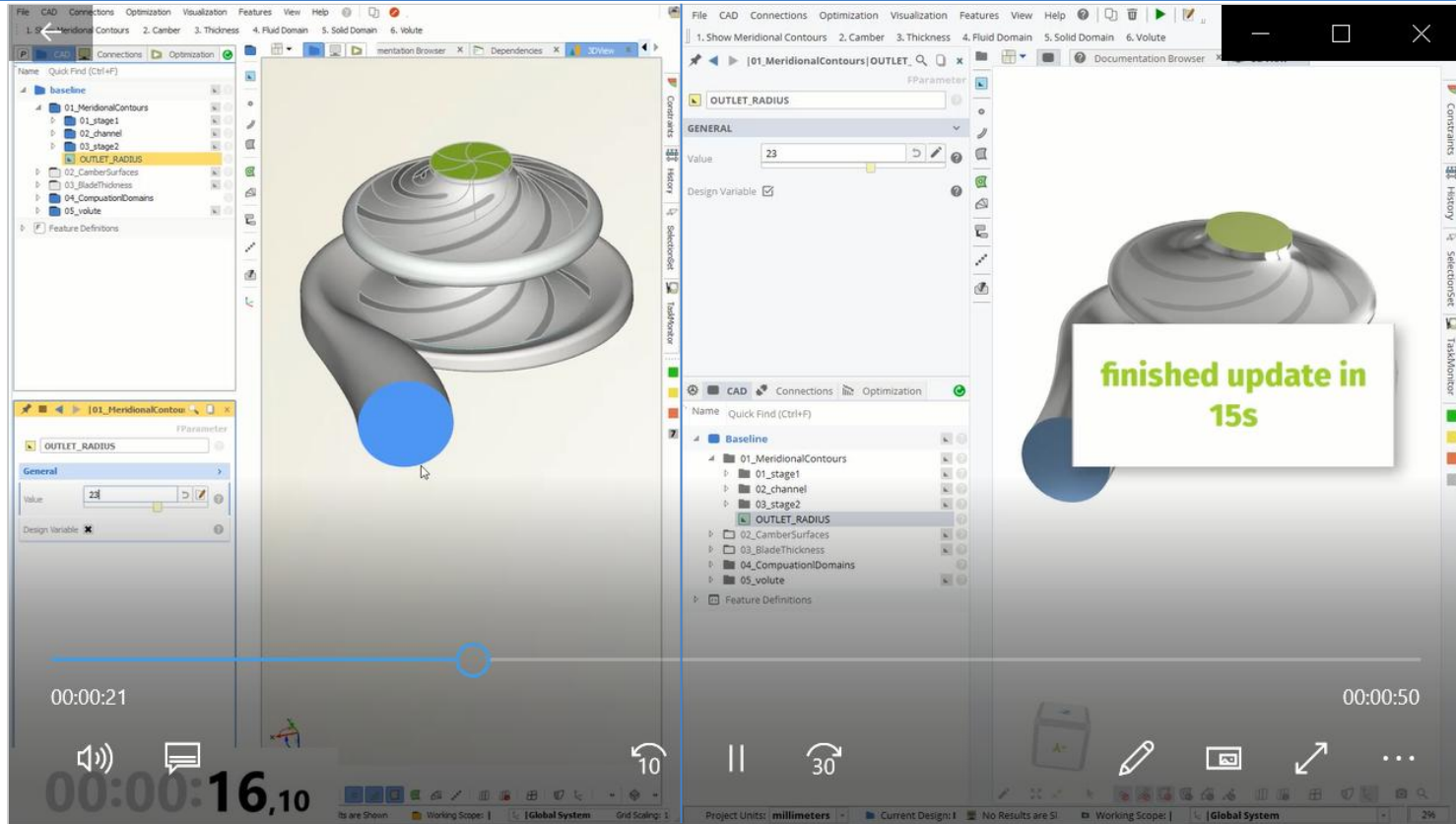
95.7%



# Introduction of PCA



# Sequential vs. parallel processing

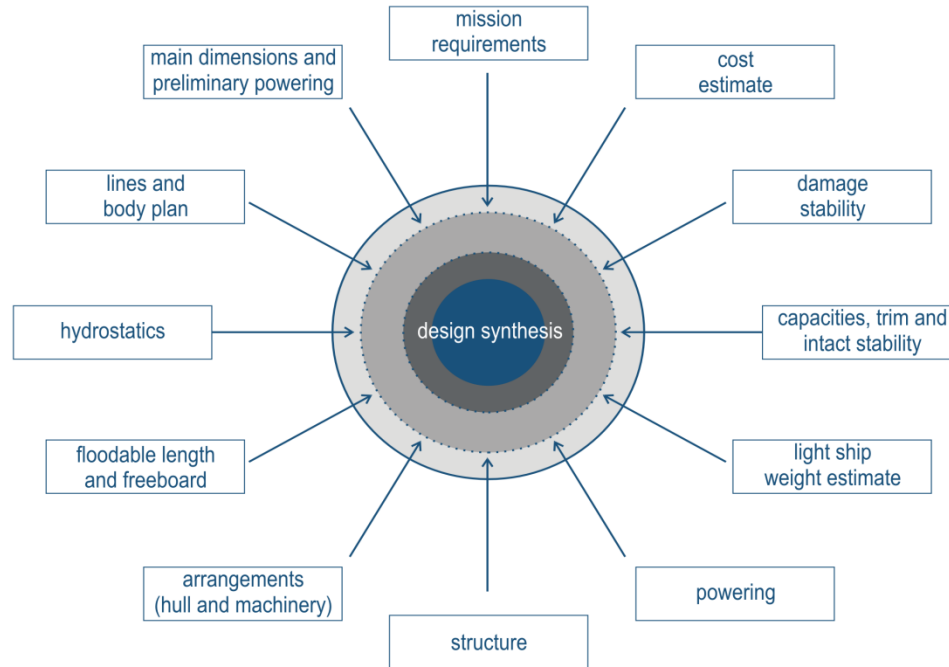


# Design synthesis in combination with surrogates

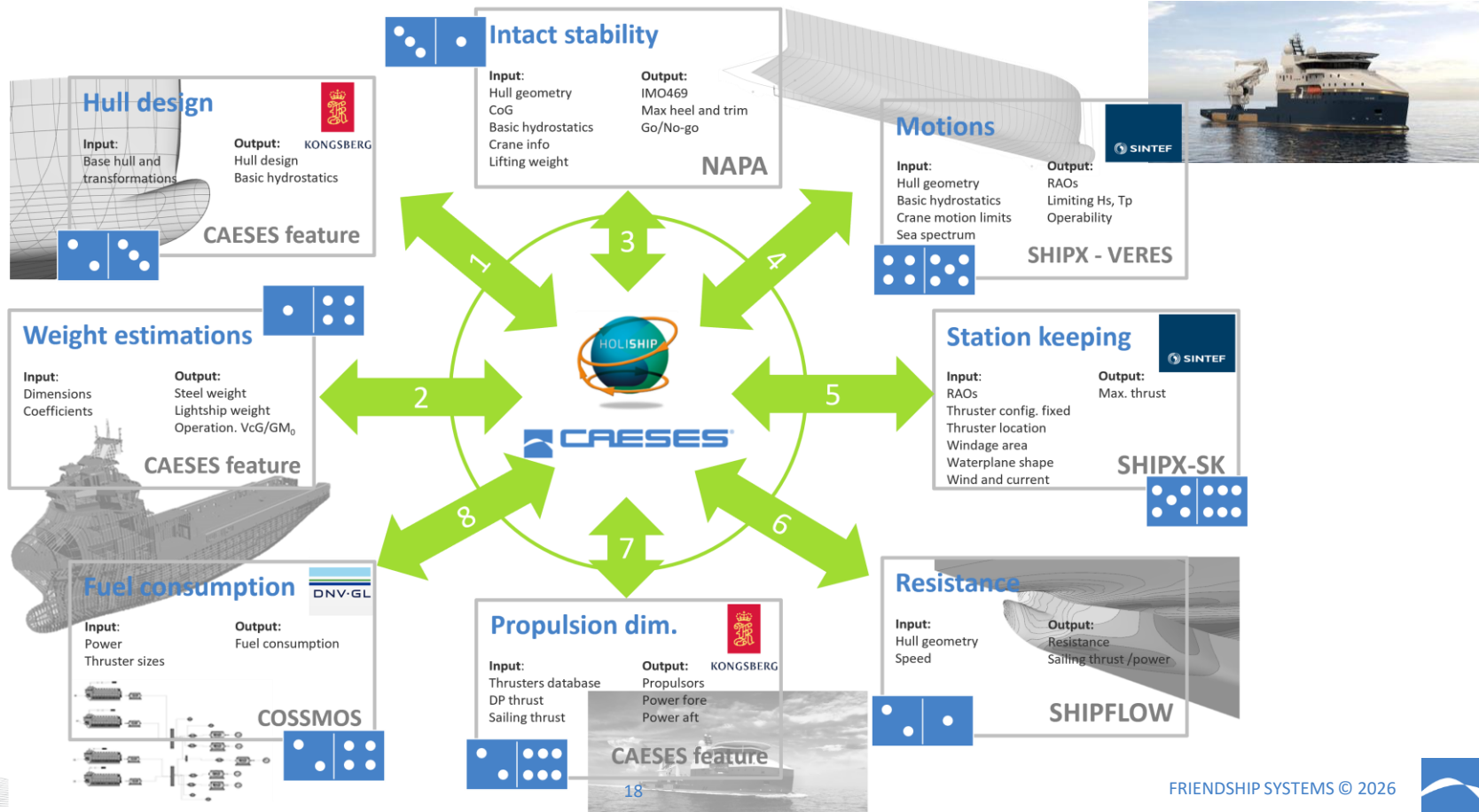
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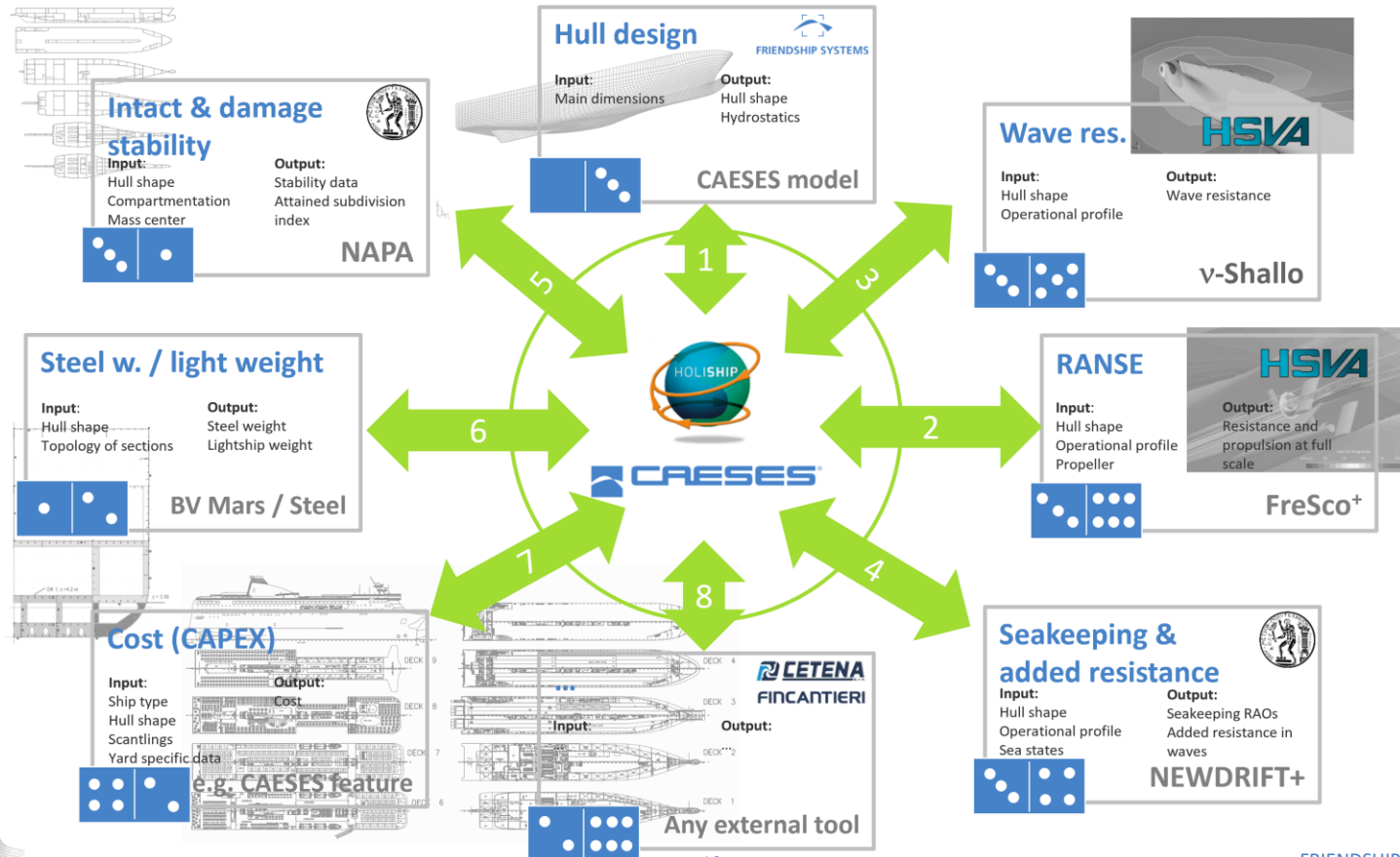
# Design phases – classic view of design spiral vs. holistic view



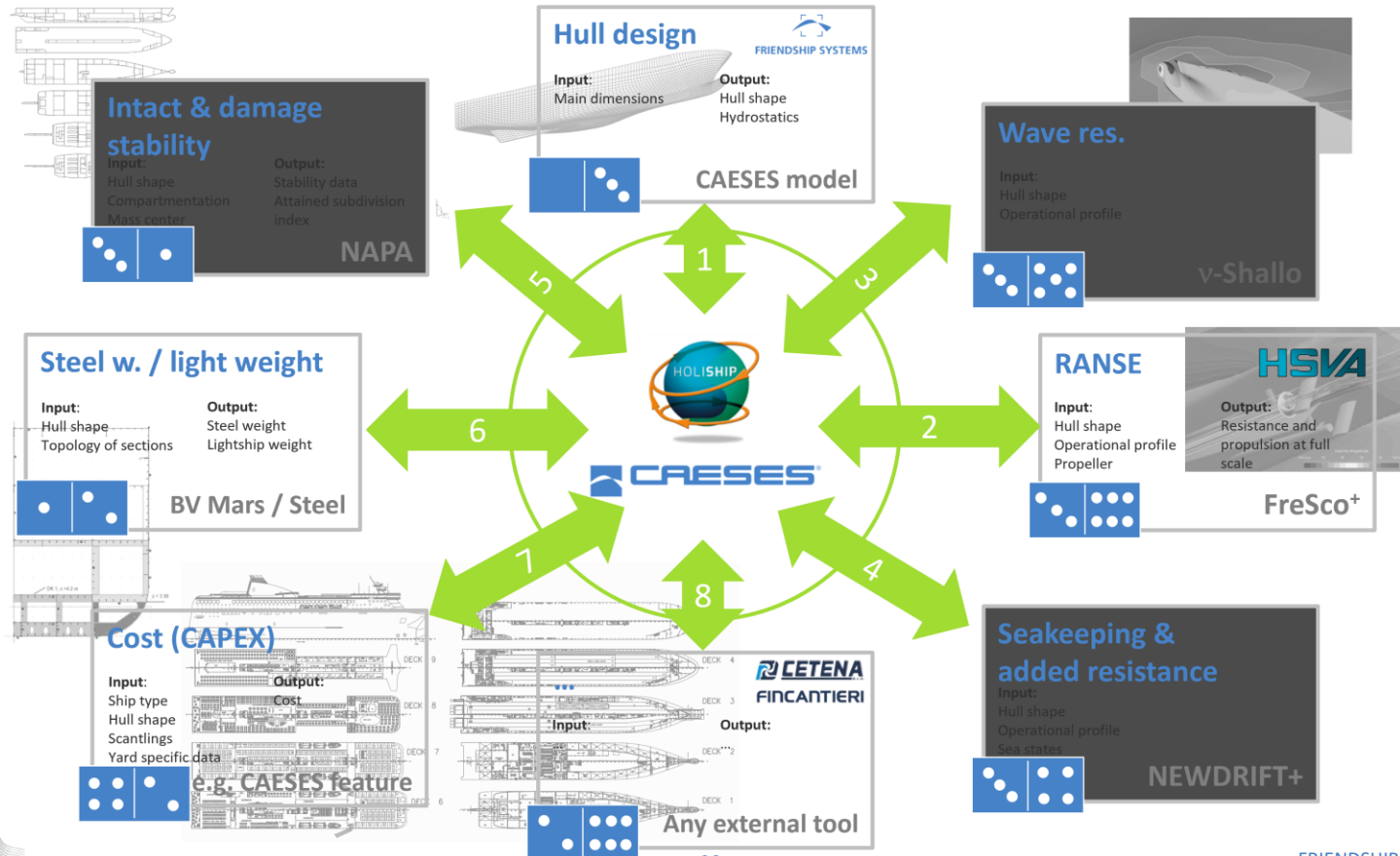
# Synthesis model: OSV



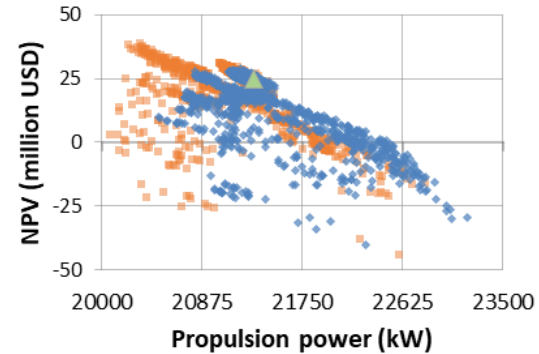
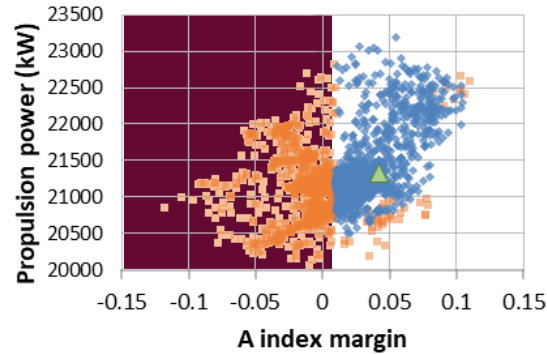
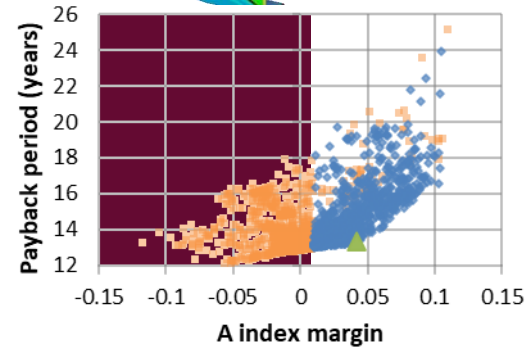
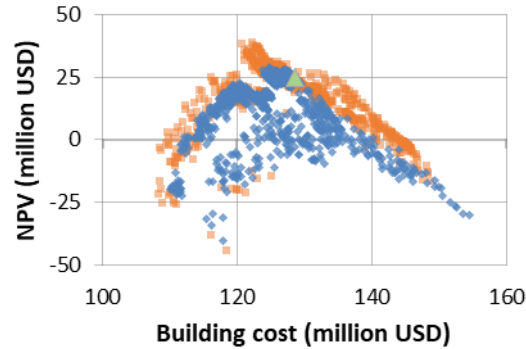
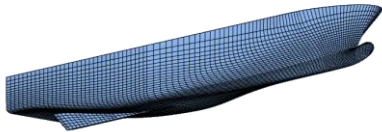
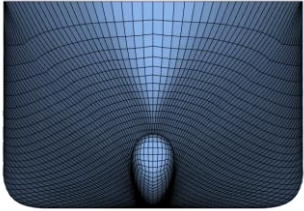
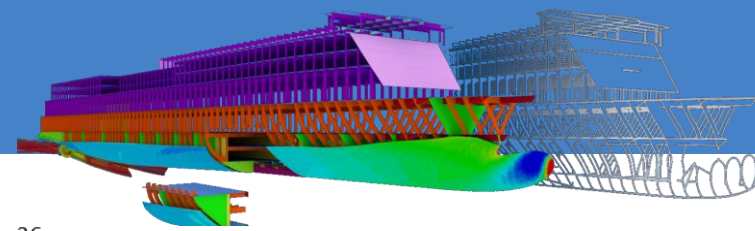
# Synthesis model: RoPax ferry



# Synthesis model: RoPax ferry



# Selected results for RoPax ferry

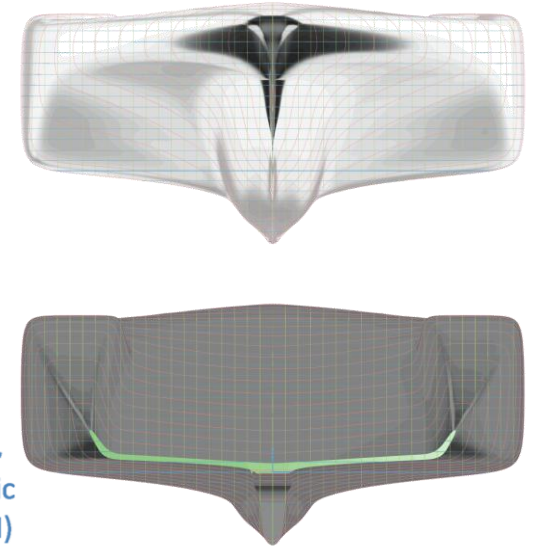
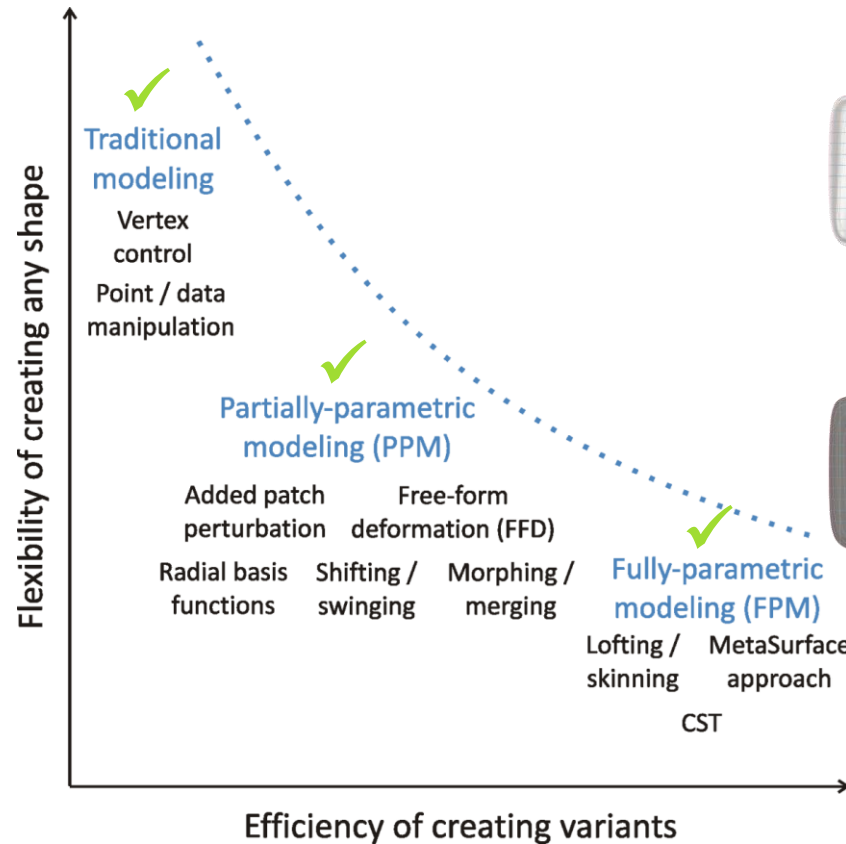
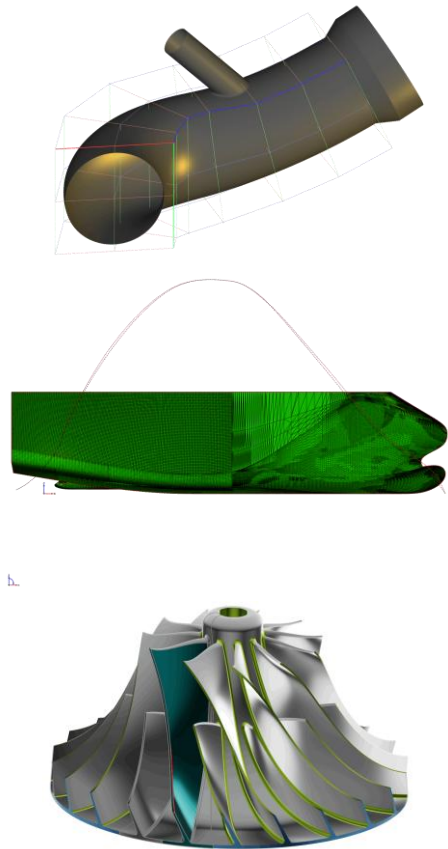


# Comprehensive toolbox for parametric modeling

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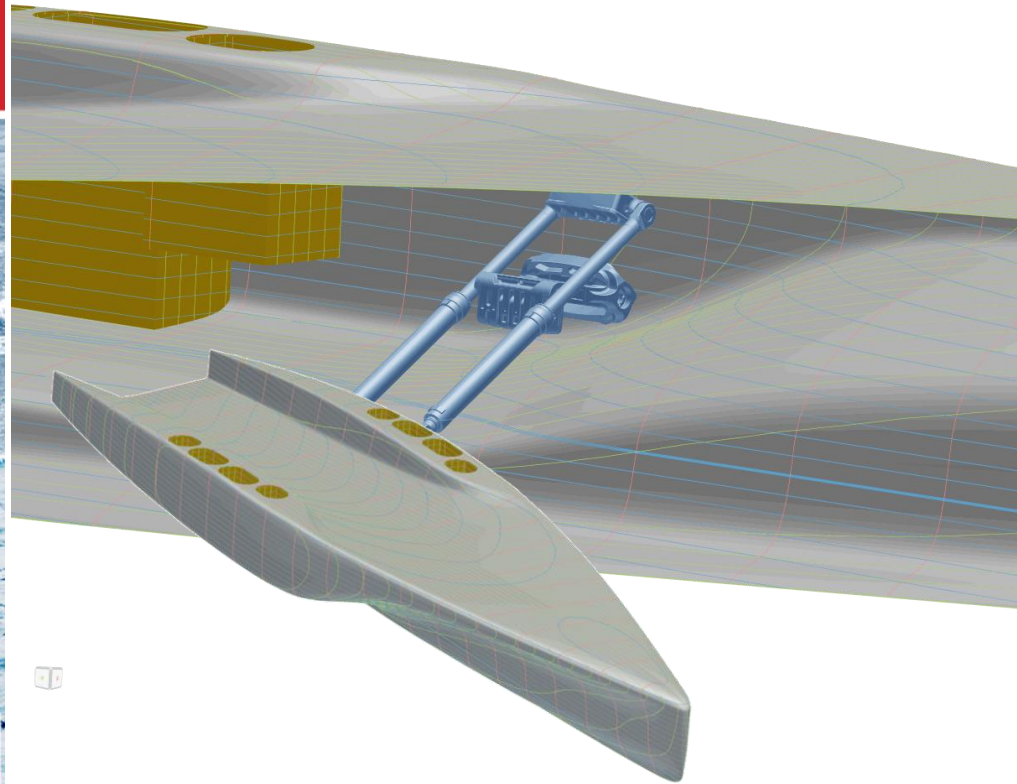
# Comprehensive toolbox for parametric modeling



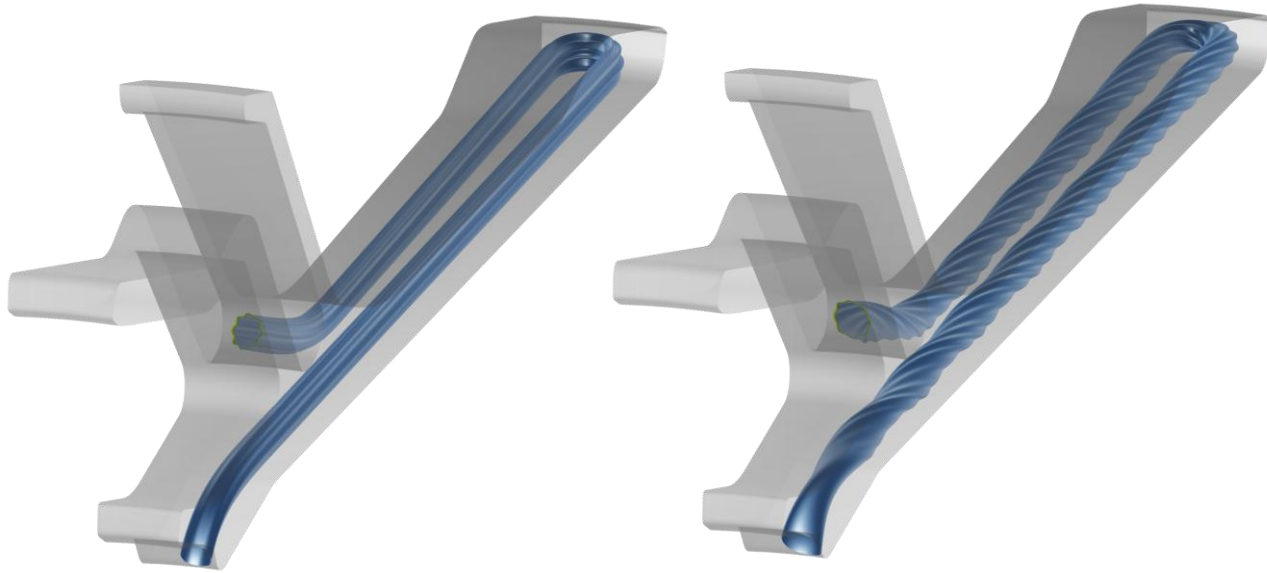
# Parametric model with more than 100 built-in constraints

LOUIS VUITTON CUP

WINNERS



# Parametric modeling for additive manufacturing in 2022

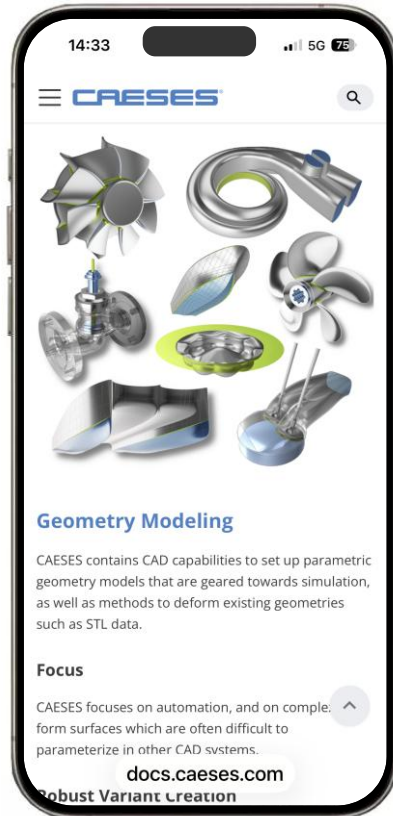
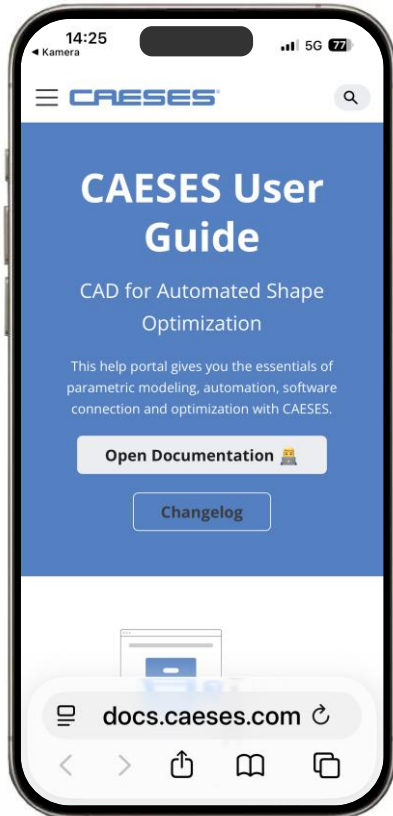


# Documentation and videos

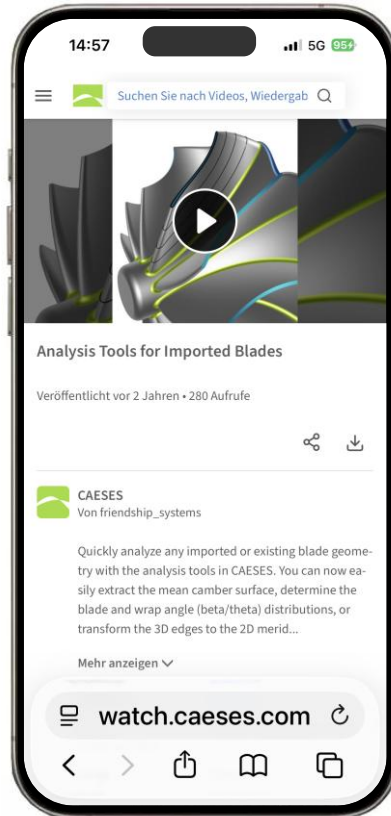
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# Comprehensive online documentation



# Video channel



# Dedicated workflows and appification

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# Dedicated workflows

- Motivation
  - Step-by-step process for the geometrical modeling of functional surfaces
  - Support designers in selecting and using context specific features (verticals)
  - Keep the project structure clean and organized
  - Speed up the modeling process
- Workflows
  - Turbomachinery
  - Propeller
  - Ship modeling



# Dedicated workflows

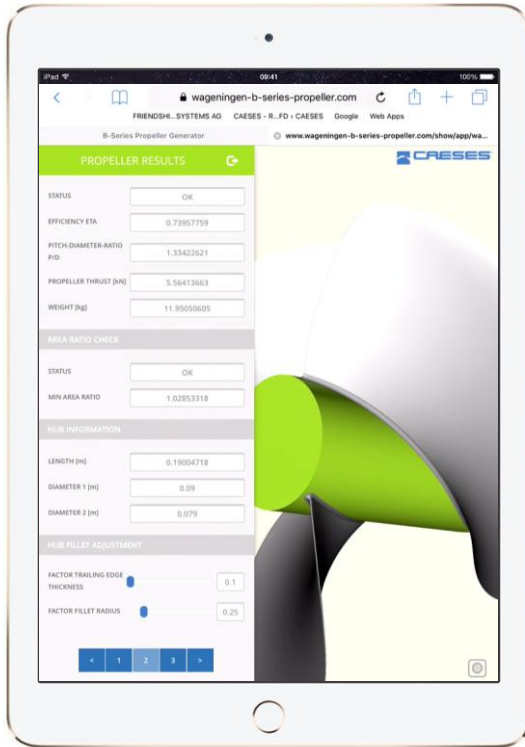
The screenshot displays the software interface for creating meridional contours. The top menu bar includes CAD, Transformations, Features, Turbo, Propeller, Maritime, Visualization, and CAESES - centrifugalCompressor\*. The left sidebar contains navigation icons for Model, Connect, Optimize, App View, and Help. The central workspace shows a 3D model of a blade section with labels for main LE, splitter LE, shroud, shroud gap, and hub. The right-hand properties panel is set to 'meridionalContours' and shows the following parameters:

- Reference Radius: 30
- Hub Contour: meridionalContours | hubContour | contour
- Shroud Contour: meridionalContours | shroudContour | contour
- Shroud Gap Contour: meridionalContours | shroudGapContour | gapContour
- Leading Edges:
  - meridionalContours | leadingEdgeMain | edge
  - meridionalContours | leadingEdgeSplitter | edge
- Trailing Edges:
  - meridionalContours | trailingEdge | edge

A dropdown menu is open for the Leading Edges section, showing the following options:

- Leading or Trailing Edge with 1 Intermediate Point
- Leading or Trailing Edge with 2 Intermediate Points
- Leading or Trailing Edge with 3 Intermediate Points
- Leading or Trailing Edge - Straight

# Web applications based on CAESSES



# Looking forward

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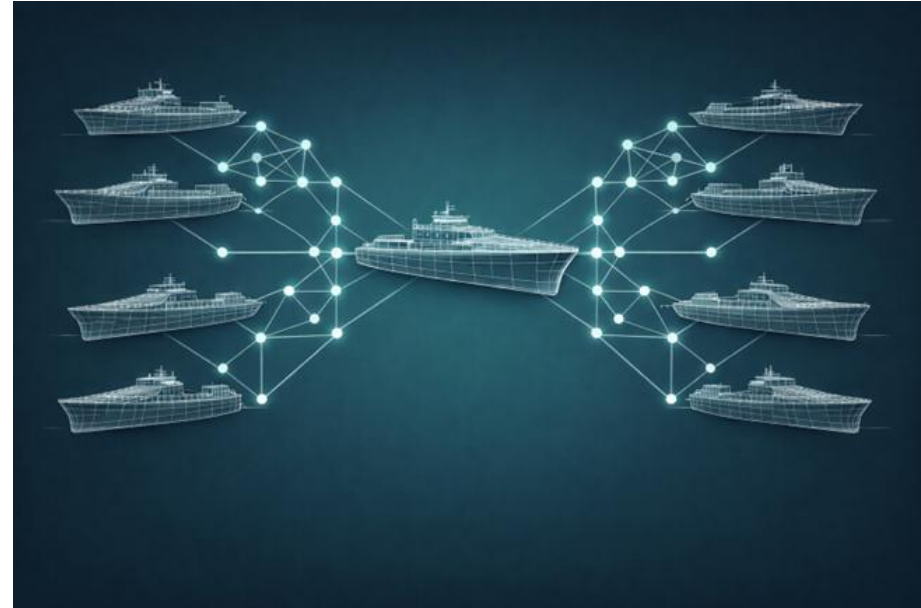


# R&D and investments

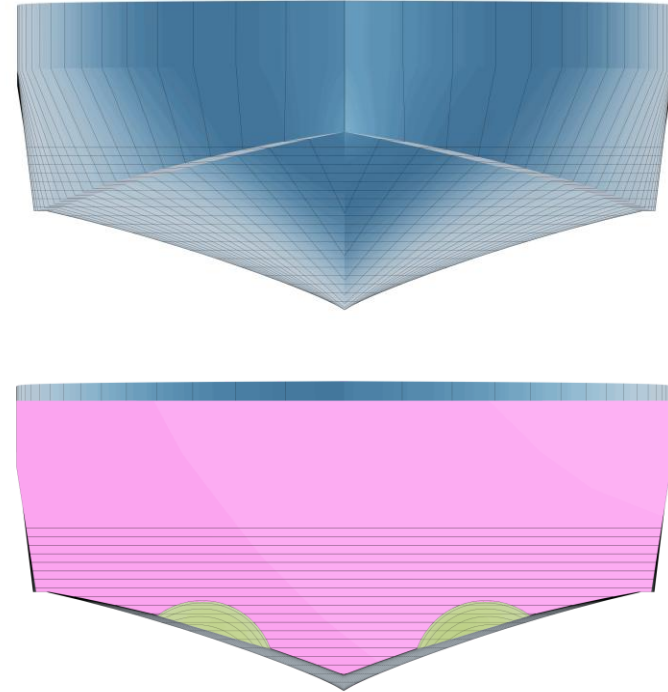
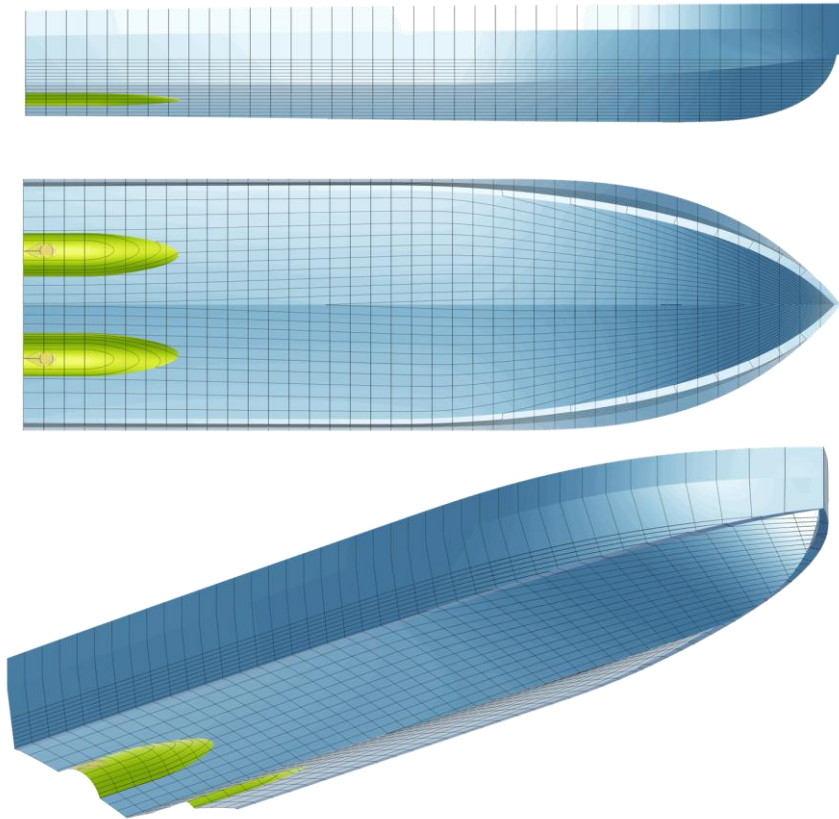
- Ongoing
  - RETROFIT55  
(EU project within Horizon Europe)
  - VIT-VI  
(German project within ProFIT)
  - DesignAssist  
(German project financed by BMW)
- Upcoming
  - FIT-HORIZONS  
(EU project within Horizon Europe)



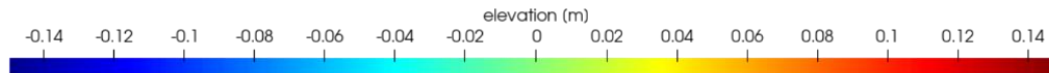
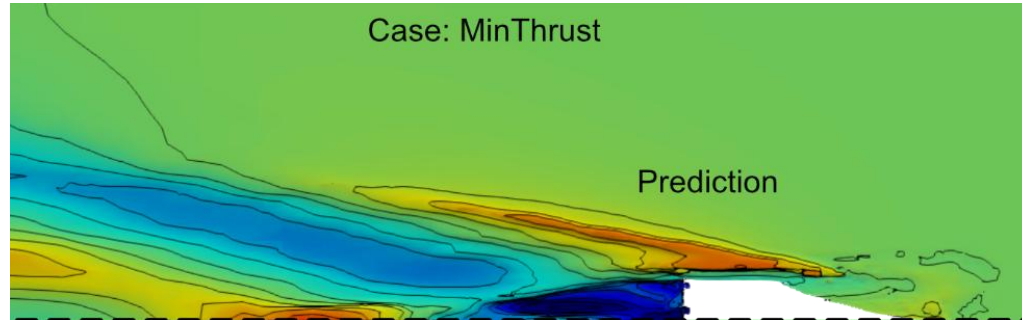
- AI-Supported Systems for the Design of New Ships and Retrofits
  - Strategic extension: AI-supported design evaluation within CAESES
  - New capabilities: Weight estimation, stability assessment, automated layouts – all parametric and variant-based
  - Practical relevance: RoPax and electric ferries as demonstrators with direct link to the energy transition



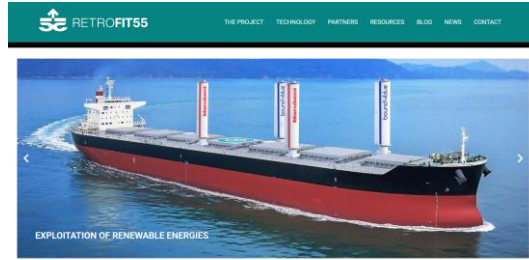
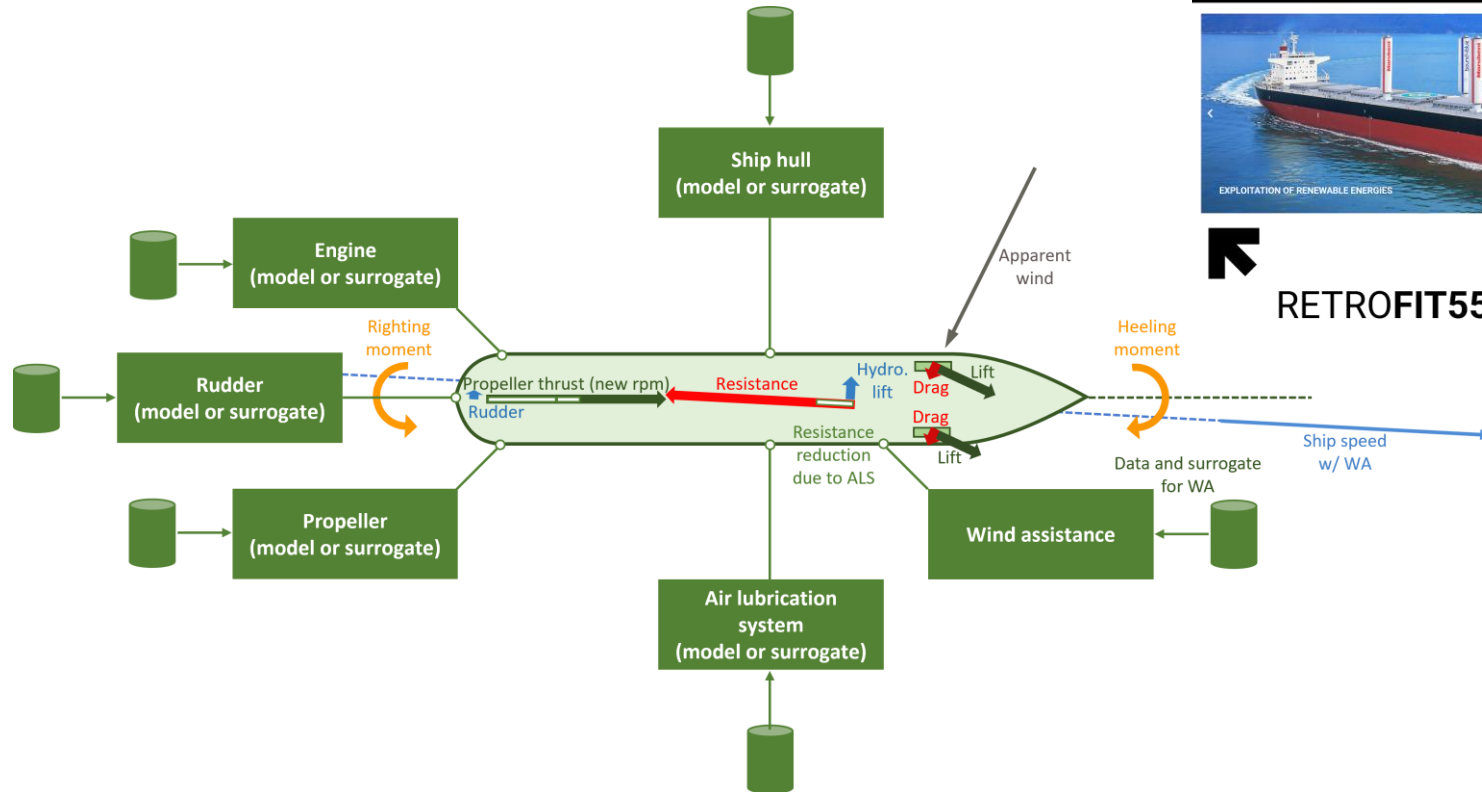
# Variation of the bare hull with tunnel kept constant



# ML results vs. CFD – Wave field for design with min. thrust



# RETROFIT55 and FIT-HORIZONS

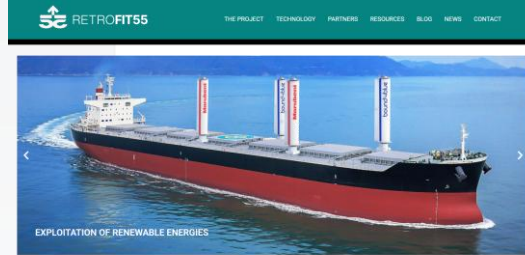
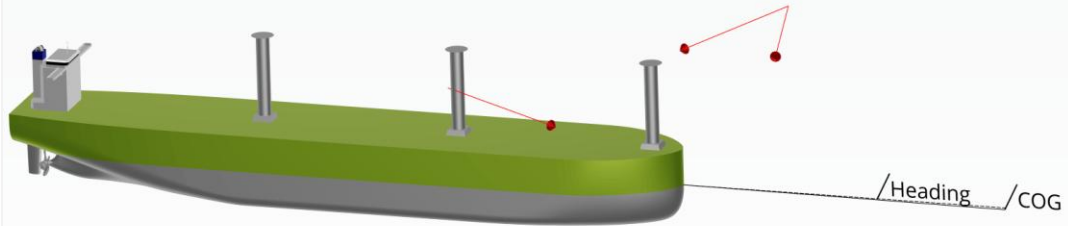
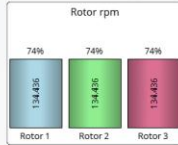


**RETROFIT55**



# RETROFIT55 and FIT-HORIZONS

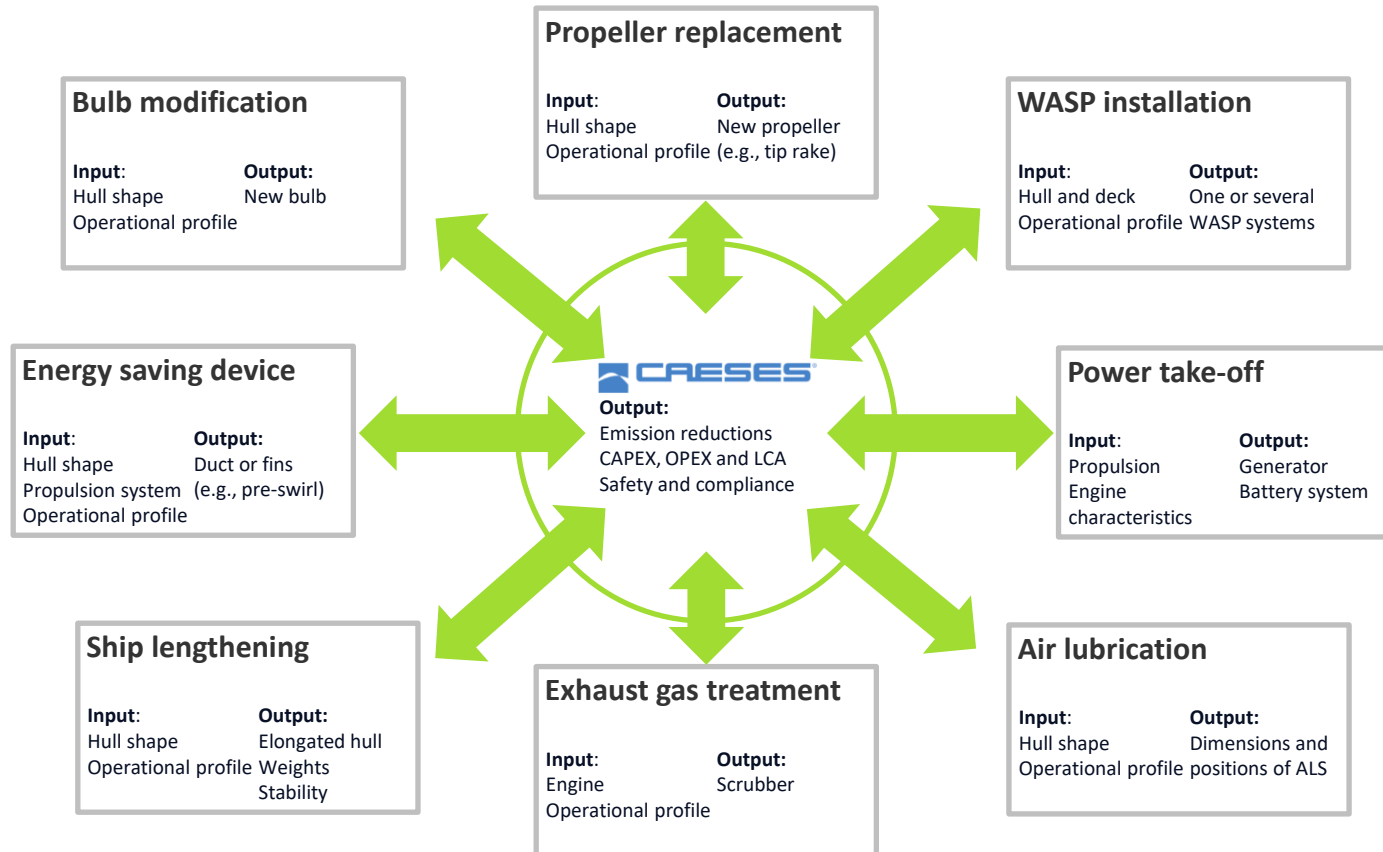
Conditions		Results	
TWA	105.000	driftAngle	-0.972 deg
TWS	22.500	rudderAngle	0.921 deg
shipSpeed	13.000	netSailThrust	285.252 kN
aws	23.096	powerSaving_high	23.552 %
awa	70.931	powerSaving_low	20.187 %



RETROFIT55



# FIT-HORIZONS – Many combinations to improve ships in service



# CAESES Insight (current developments)

The screenshot displays the CAESES Insight software interface. The top window title is "CAESES SNAP - snapshot - conventionalPropeller\_RCtestflight\_baseline\*". The interface is divided into several sections:

- Left Sidebar:** Contains navigation icons for Model, Connect, Optimize, Insight, App View, and Help.
- Top Panel:** Includes a "New" button and a menu with options like "PCA workflow", "NN Surrogate", "Optimization Example", "Auto Arrange", "CAESES", "File", "Normalize", "Split", "PCA", "Join", "Outlier Detection", "Expression Calculator", "Expression Selection", "Manual Selection", "Filtering", "Gaussian Process Surrogate", "Neural Network Surrogate", "SMT", "Optimizer", "Logs", "Light", "Settings", and "Tools".
- Canvas:** Shows a workflow titled "Train Test Split" with the following steps:
  - CAESES Design Runs (Run 1)
  - Manual Selection (36 / 38 selected)
  - Normalize Data (Scale: 1, Min: 0, Max: 1)
  - Train Test Split (75% Train, 25% Test)
  - Gaussian Process Surrogate (Avg fit: 0.9908)
- Right Panel:** Displays a 3D scatter plot titled "01\_ImportedResults\_included\_normalized\_train (2 datasets)". The plot shows data points for "train" (blue) and "test" (red) datasets. The axes are labeled with normalized function values:  $|01\_functions|01\_chord|deltaMaxChord$ ,  $|01\_functions|02\_pitch|deltaPitch$ , and  $|01\_functions|01\_chord|shiftMaxChord$ . A legend indicates that blue dots represent "train" and red dots represent "test".



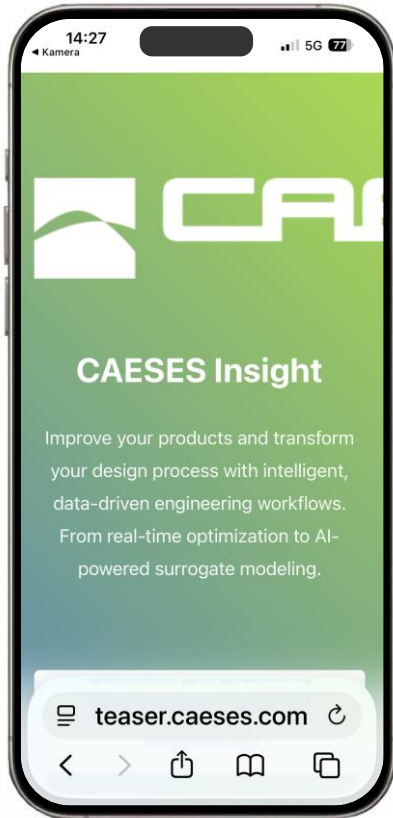


# CAESES Insight (current developments)

The screenshot displays the CAESES Insight software interface, titled "CAESES SNAP - snapshot - conventionalPropeller\_RCtestflight\_baseline\*". The interface is divided into several main sections:

- Top Panel:** Contains various tool icons and categories such as "CAESES", "Normalize", "Split", "Expression Selection", "Gaussian Process Surrogate", "Optimizer", "Logs", "NN Surrogate", "Auto Arrange", "File", "PCA", "Outlier Detection", "Manual Selection", "Neural Network Surrogate", "Light", "Settings", "Optimization Example", "Join", "Expression Calculator", "SMT", and "Tools".
- Canvas:** A central workspace showing a workflow of nodes: "CAESES Design Runs" (completed), "Manual Selection" (36/38 selected), "Normalize Data" (Score: 25, XYes: Yes), "Train Test Split" (75% Train, 25% Test), and "Gaussian Process Surrogate" (Avg. fit: 0.9988).
- Manual Selection Panel:** Shows a scatter plot of "OUT |05\_CFD|output..." vs "OUT |06\_diameterCo...". A "Remove (Alt)" button is visible. Below the plot is a "TO BE TESTED" section with a "Train Test Split" configuration showing a 75% Train / 25% Test split ratio.
- Gaussian Process Surrogate Panel:** Displays "Predicted vs Actual" plots for two different output keys. The top plot is for "OUT |05\_CFD|output|v1|KT\_1" with  $R^2 = 0.9982$ . The bottom plot is for "OUT |05\_CFD|output|v2|KT\_2" with  $R^2 = 0.9985$ . Both plots show a strong positive correlation between predicted and actual values.
- Bottom Panel:** A yellow and black striped banner with the text "WORK IN PROGRESS".

# CAESES Insight (current developments)



# Looking back and looking forward

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# FRIENDSHIP SYSTEMS

- Head office located in Potsdam, Germany
- Subsidiary in NYC, NY / Cambridge, MA
- Partner for simulation-driven design with 25 years of experience in parametric modeling, optimization and machine learning
- Agile team of 25+ people (primarily engineers, computer scientists and software developers)



## Climate Neutral Company

with First Climate



**Clear focus and dedication**

Simulation-Driven Design (SDD) and  
Data-Driven Engineering (DDE)



# Customers (selection)

## POWERTRAIN

**Garrett**  
ADVANCING MOTION

**SIEMENS**  
energy

## MARINE

**GRUNDFOS**

**Cummins**  
Turbo  
Technologies



**VARD**  
a Fincantieri company

**NIO**

**ISUZU**  
TRUCK

**KSB**

**mtu**

**MITSUBISHI HITACHI**  
POWER SYSTEMS

**KONGSBERG**

**INEOS**

**NAVAL**  
GROUP

**STELLANTIS**

**SUZLON**  
POWERING A GREENER TOMORROW

**VOITH**

**ABS**

**SAMSUNG**

**HONDA**



**MAN**



**Rolls-Royce**

**HYUNDAI**  
HEAVY INDUSTRIES



**thyssenkrupp**

**MOTOR HARLEY-DAVIDSON**  
CYCLES



**mazda**

**HYUNDAI**

**Sumitomo**

**TURBOMACHINERY**

**LÜRSEN**



**COTECMAR**

**aramco**



**TOYOTA**

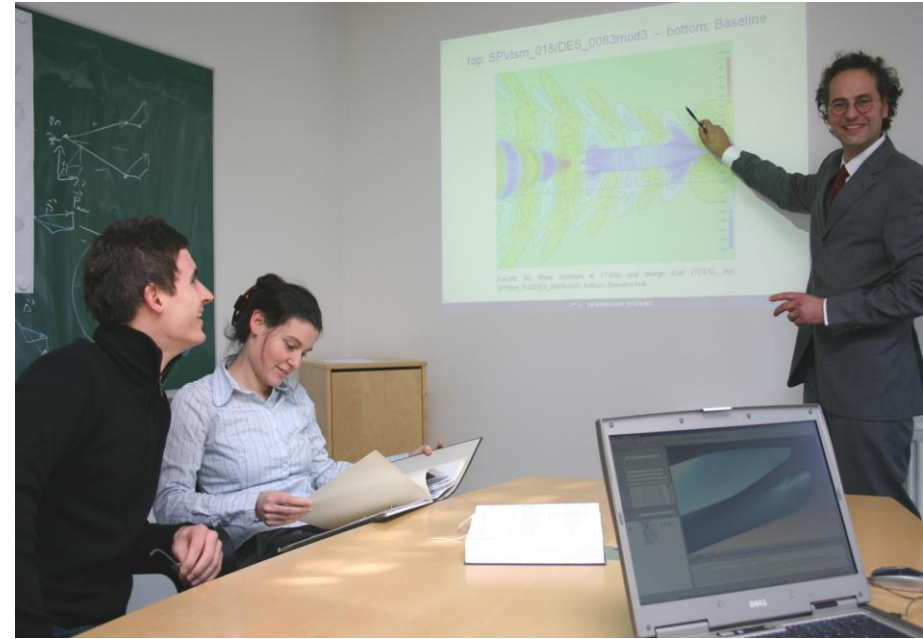
**Artemis**  
Racing

**YAMAHA**

Thank you very much for celebrating 25 years with us



# The years go by – but it is very worthwhile and still a lot of fun





[www.friendship-systems.com](http://www.friendship-systems.com)

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