MARITIME

Innovation and Energy Efficiency

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29th of May 2019

Maritime Advisory in a nutshell

Maritime Advisory

Service

We support **maritime customers** with **technical & commercial advisory** to **design, build and operate** their assets **efficiently, safely and compliant**

Areas of expertise

- **Fluid Engineering**
- **Structures**
- **Mechanical & Systems Engineering**
- **Noise & Vibration**
- **Safety, Risk & Reliability**
- **Shipping Advisory**
- **Life Cycle Management**

ECO Solutions

- **ECO Lines**
- **ECO Retrofit**
- **ECO Assistant**
- **ECO Insight**

Facts

- Part of **DNV GL Maritime**
- Offices in **Norway, Germany, China, Singapore, Greece, Dubai, USA, Australia**
- **~280 highly skilled staff**
- **~160 services**
- Vast **computational capacities**

Ungraded

Maritime Advisory - Advanced Engineering Services

	Fluid	Structures	Mechanical & Systems	Noise & Vibration	Risk & Safety
Design optimisation	Hull lines & appendages	Structures	Systems		
Design for compliance, safety, availability	Design loads	Global strength	Shaft alignment	Global vibration	Alternative design
	Resistance & propulsion	Local strength	Strength & fatigue	Propeller excitation	Explosion, fire & evacuation
	Seakeeping	Fatigue	Shaft vibration	Local vibration	Safety & reliab of sys & comp
	Manoeuvring	Structural capacity	HIL testing	Vibration of machinery	LNG systems & components
	Gas flows	Composites	Network testing	Noise	Technology qualification
	Stability	LNG tanks		Shock	Arctic shipping
					Cyber security
Trouble shooting & LCM	Experimental investigations and cross discipline trouble shooting				
	Life cycle management				

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	Life cycle management				

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Operational profile and main dimensions assessment

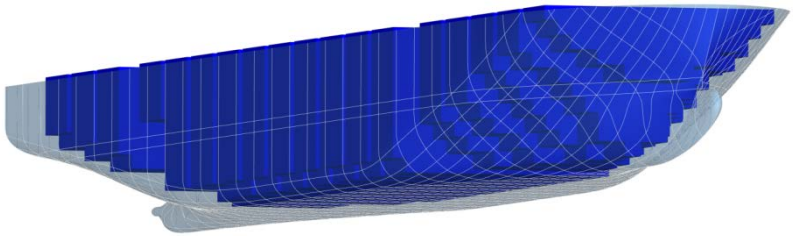
AIS Workbench

- E.g. **AIS operational profile analysis** for HMM of three different CV alliances, i.e.3M, The Alliance and Ocean Alliance (65 vessels, 11 classes) to derive the operational profile for their envisaged newbuildings

Power Index / Row Labels	Column Labels 10%	20%	30%	40%	50%	60%	70%	80%	90%	100%	Grand Total
10.	0.1%	0.2%	0.2%	0.1%	0.1%	0.1%	0.1%	0.1%	0.0%	0.1%	0.9%
10.5	0.4%	0.5%	0.6%	0.4%	0.4%	0.4%	0.4%	0.4%	0.3%	0.0%	3.9%
11.	0.5%	0.7%	0.8%	0.7%	0.6%	0.7%	0.4%	0.4%	0.3%	0.0%	5.0%
11.5	0.4%	0.6%	0.7%	0.5%	0.4%	0.5%	0.4%	0.4%	0.2%	0.2%	4.3%
12.	0.4%	0.7%	0.7%	0.6%	0.6%	0.7%	0.5%	0.5%	0.3%	0.1%	5.1%
12.5	0.4%	0.6%	0.8%	0.7%	0.7%	1.2%	0.5%	0.8%	0.5%	0.3%	6.5%
13.	0.4%	0.6%	0.8%	0.8%	0.8%	1.2%	0.7%	1.0%	0.6%	0.5%	7.3%
13.5	0.4%	0.8%	1.0%	1.2%	1.2%	1.9%	1.2%	1.6%	0.9%	0.6%	10.7%
14.	0.4%	0.7%	1.0%	1.1%	1.3%	1.9%	1.7%	1.8%	1.1%	0.2%	11.2%
14.5	0.4%	0.7%	1.1%	1.2%	1.5%	2.2%	1.8%	2.2%	1.4%	1.3%	13.7%
15.	0.3%	0.5%	1.0%	1.0%	1.4%	2.0%	1.8%	2.1%	1.6%	0.9%	12.7%
15.5	0.3%	0.5%	1.1%	1.1%	1.6%	2.4%	2.2%	2.4%	1.8%	0.8%	14.3%
16.	0.1%	0.1%	0.4%	0.3%	0.5%	0.7%	0.7%	0.8%	0.7%	0.0%	4.4%
Grand Total	**4.4%**	**7.1%**	**10.0%**	**9.8%**	**11.2%**	**15.9%**	**12.5%**	**14.4%**	**9.8%**	**5.0%**	**100.0%**

Main Dimension Parametric Study

- Selection of **optimum main dimensions** based on a “cost per cargo mile” model and a parametric optimisation study
- Model includes capacity utilization, average speed, building cost, mortgage, interest rate, fuel price, days at sea, etc.
- Optimization includes hydrostatics, light ship weight, prediction of speed / power curves, and determination of maximum cargo intake for a range of cargos



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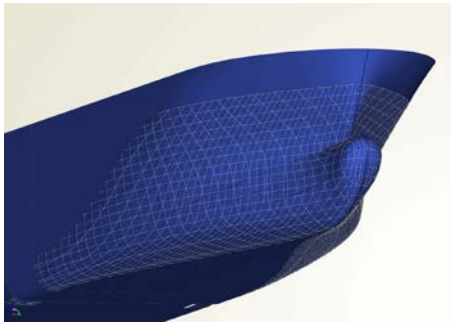
Parametric optimization approach (1/2)

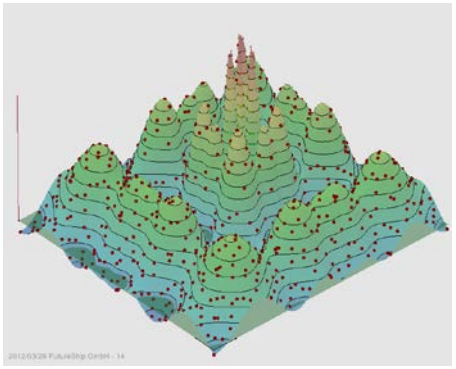
Parametric Setup

- Parametric hull model
- Validation of constraints
- >50 parameters allow large design space
- Genetic algorithms control hull evolution



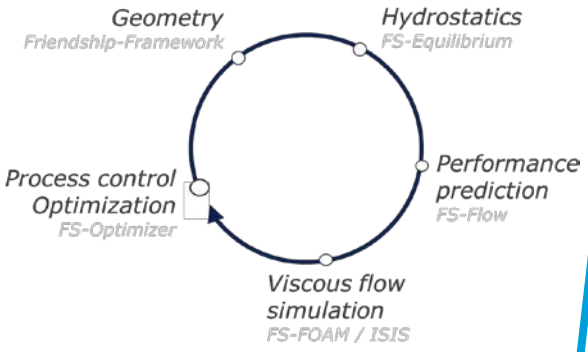
Design Space Exploration

- Explore design space exploration (~1,000 designs)
- Assess constraints impact and improvement potential
- Find best design directions

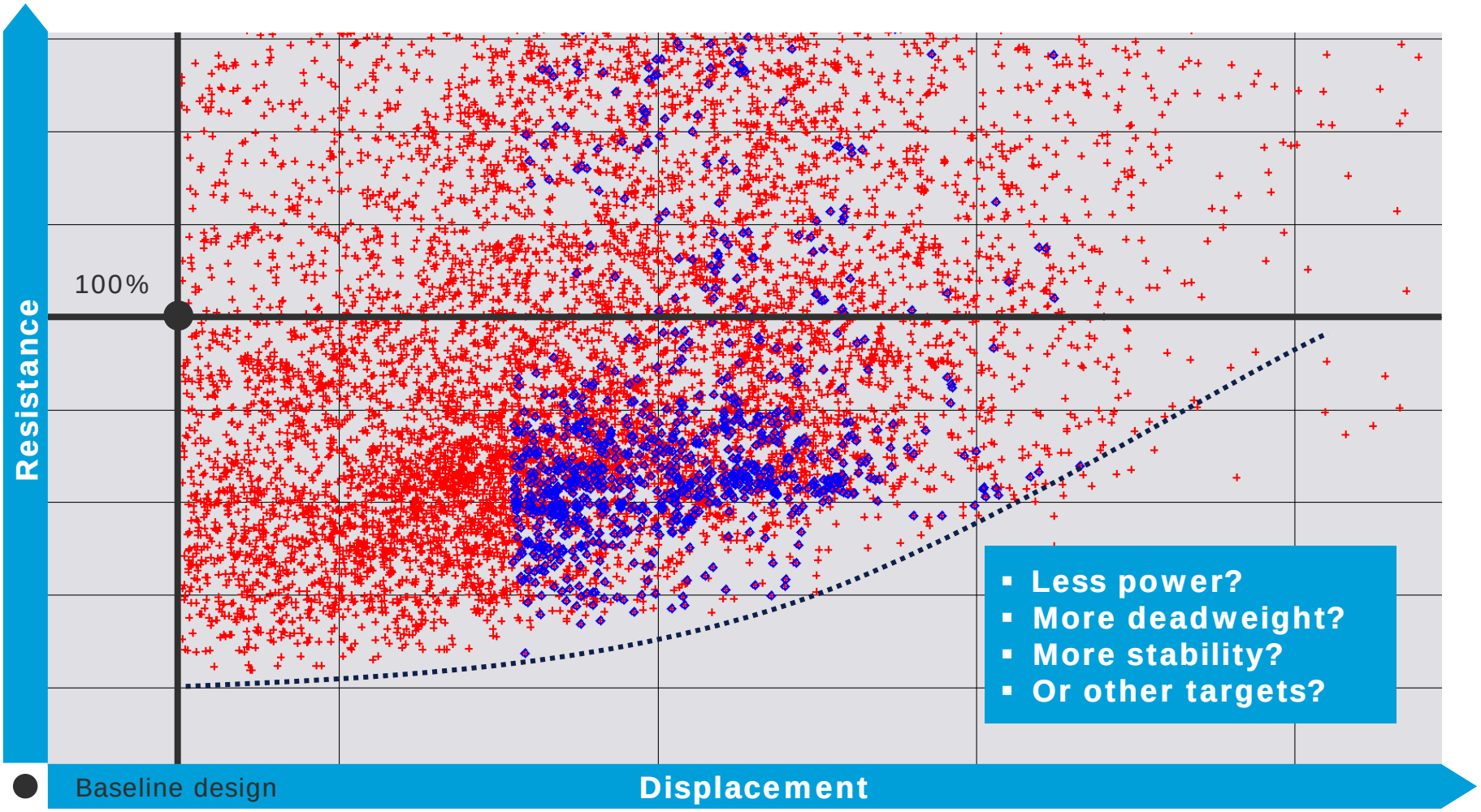


Global Design Optimization

- >20,000 variants investigated
- Balancing of multiple objectives (e.g. stability and power requirements)



Typical result of global optimization phase



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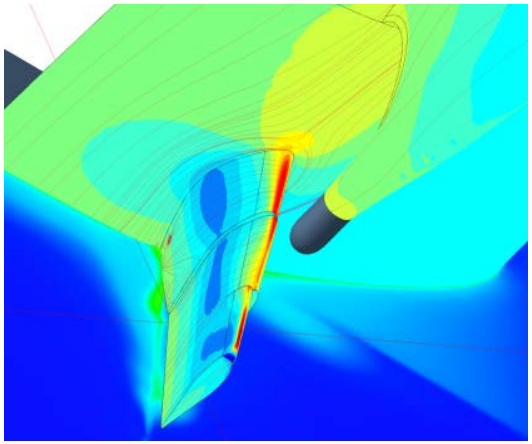
Parametric optimization approach (2/2)

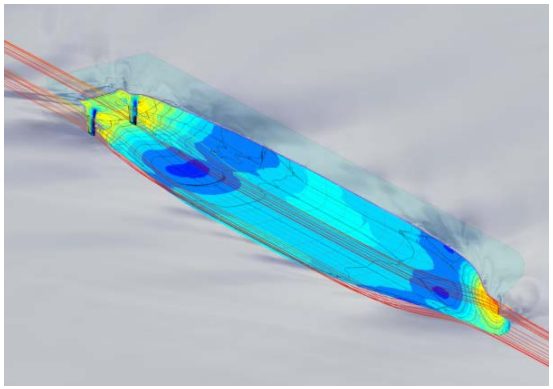
Viscous Wake Optimization

- Optimize wake for propulsive efficiency and pressure pulses (~1,000 designs)
- Ranking of wake quality by DNVGL's unique wake indicators



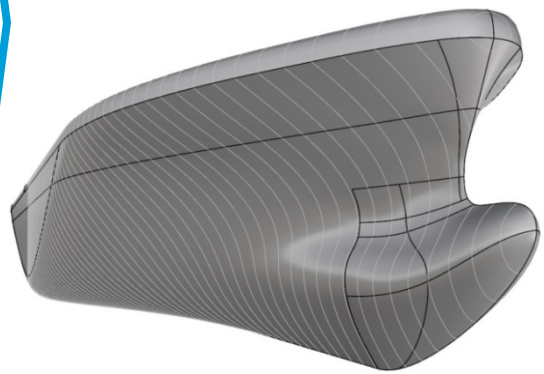
Detailed CFD Analysis

- Absolute, quantified performance prediction for entire operational profile
- Propeller wake assessment

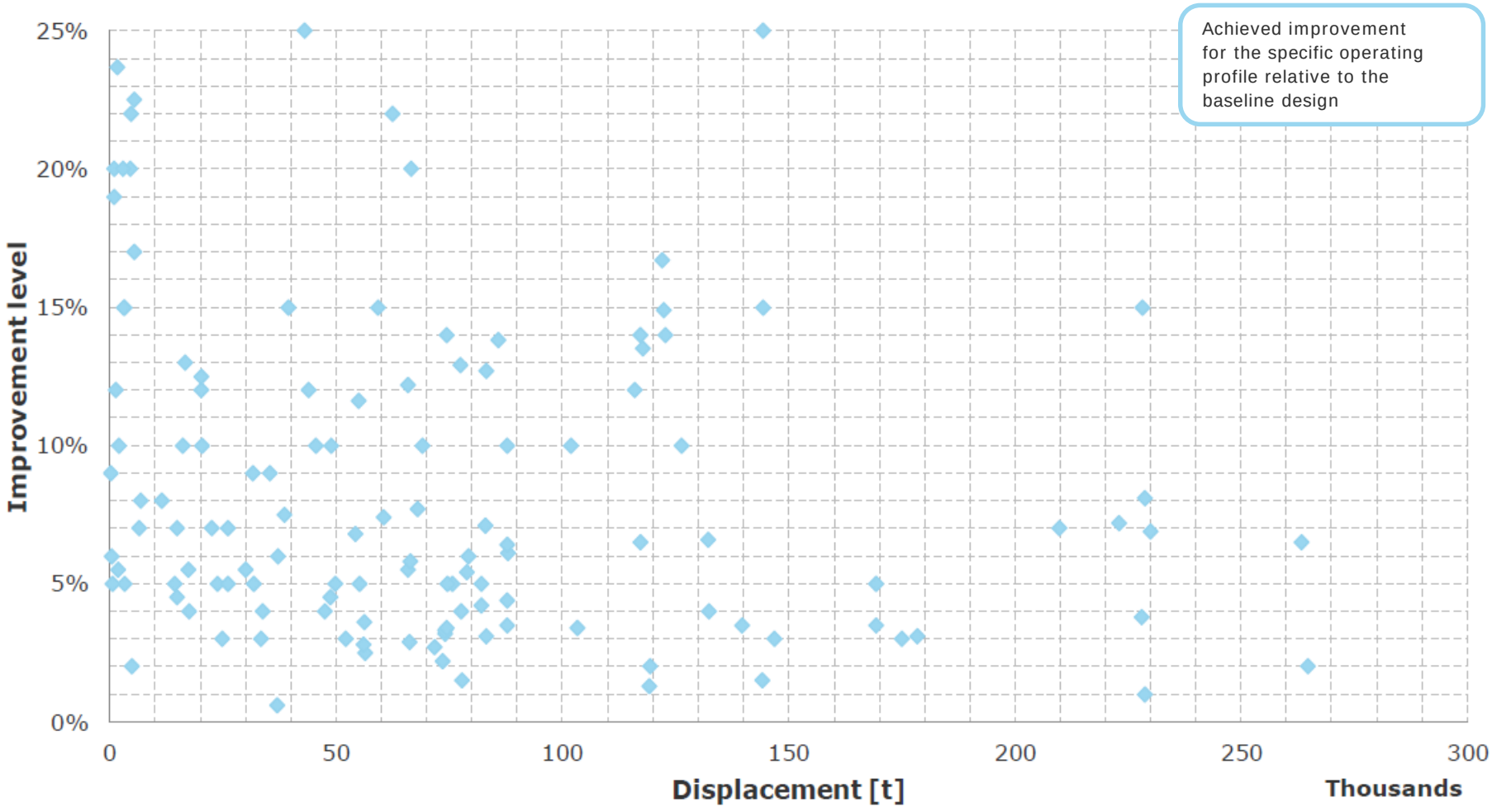


Post Design Preparation

- Final fairing of hull lines
- 3d geometry for model tests and further steps



Improvement levels



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Benefit Case - ECO Lines for Hapag-Lloyd Cruises 230 Pax expedition cruise liner

SITUATION AND CRITICAL ISSUE

Hull line optimization for two 230 Passenger Expedition Cruiser

Due to polar operations bunker cost are second highest operating costs for this type of cruise vessel. DNV GL was contracted by **Hapag-Lloyd Cruises** to explore and utilize the hydrodynamic savings potential

DNV GL SOLUTION

- A dedicated **formal hull lines optimization** using state of the art optimization and analysis techniques was carried out in three steps.
  - Exploration of the savings potential and definition of hard points and constraints
  - Global optimization to exploit this potential for valid designs with respect to GAP and stability
  - Fine tuning of the design to further improve stern slamming behavior
- A **close cooperation with Hapag-Lloyd Cruises and yard** was key to make the full savings potential accessible.

VALUE DELIVERED

- **> 10 %** saving in average over the defined operational profile by hull form optimization leading to a **ROI of less than 6 month**.

HAPAG 18/91 LLOYD CRUISES

Ungraded

Benefit Case – ECO Lines for a Meyer Werft newbuilding

SITUATION AND CRITICAL ISSUE

Hull Line Optimization of modern cruise liner

For a new cruise liner the Meyer ship yard tried to push the current state of the art further in order to make its offer to ship owners even more attractive.
DNV GL was contracted to optimize the design for the operational conditions

DNV GL SOLUTION

- DNV GL's team ECO-Lines service was applied
- This includes **parametric modelling** of the ship hull shape and subsequent hydrodynamic analysis
- A **substantial set of boundary conditions** to conform with the design constraints made this project exceptionally complex

VALUE DELIVERED

- While **maintaining** the already outstanding performance of the hull at the **design condition**, a **substantial improvement of almost 5%** could be identified for the **slower operating modes** by taking advantage of a **radical different bulb shape**

Ungraded

Maritime Advisory - Advanced Engineering Services

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Trouble shooting & LCM	Experimental investigations and cross discipline trouble shooting				
	Life cycle management				

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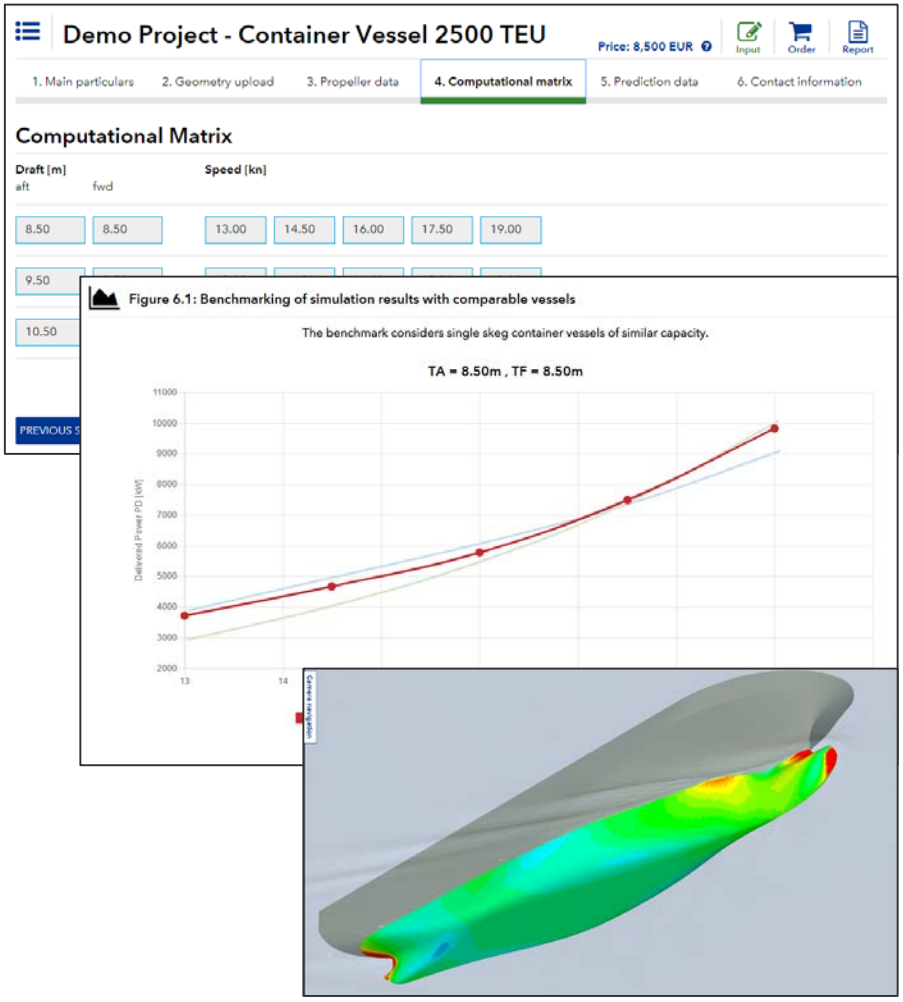
Ship Performance Simulator



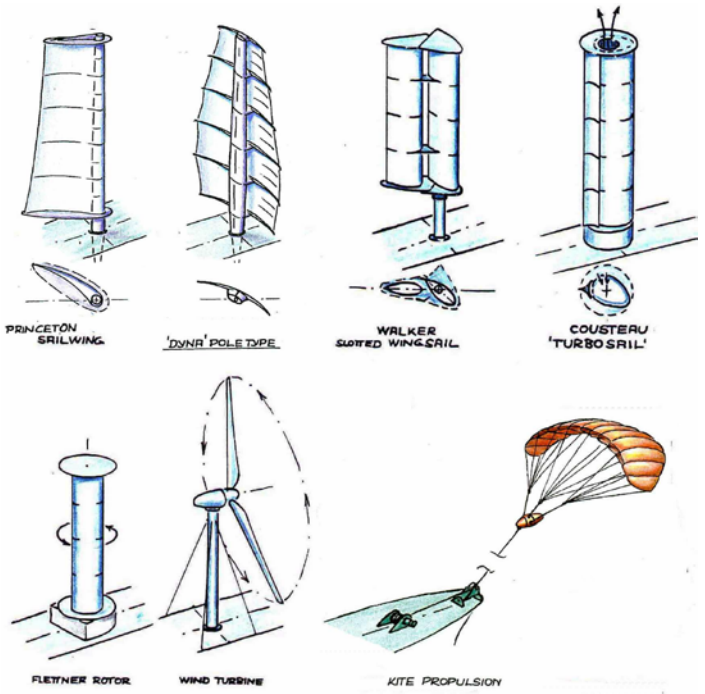
- **SPS** application on Veracity allows to **analyze, compare and benchmark design variants with respect to power** demand
- **Full-scale** computational fluid dynamics (CFD) simulations, utilizing a **VoF-RANSE** (Volume of Fluid Reynolds-averaged Navier-Stokes equations)
- Yields web-based report, including a **performance benchmark** against database designs, hydrostatics, **trial prediction**, 3D visualization and expert conclusion
- Input required: 3D hull geometry IGES file, drafts, speed range, propeller main particulars and information on appendages
- Receipt of your report within **1 week**

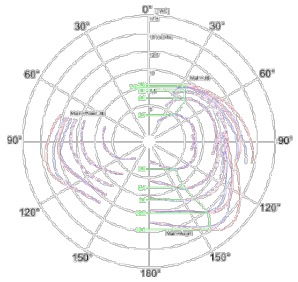
Ungraded

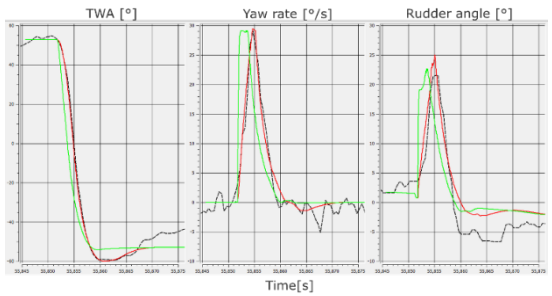
Sailing simulation and assessments

- Steady state and maneuvering simulation in 6 DOF
- Unique tool for performance assessment and maneuvering of wind powered craft
- Various levels of interfacing to 3rd party tools

- Sailing velocity prediction and maneuvering simulation
  - Stability evaluations
  - Maneuver analysis
  - Performance analysis
  - Race analysis
- Performance and maneuvering optimization







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Benefit Case Sails - Assessment of CO2 savings potential by wind propulsion

SITUATION AND CRITICAL ISSUE

Assess the savings potential of a wind Power assisted cargo vessel

Various means of utilizing wind assisted propulsion for commercial vessels are proposed to our customers. However, it is not clear how these concepts will actually perform on a specific trade.

DNV GL SOLUTION

- Modeling the aero- and hydrodynamic components of the craft within DNV GL's unique performance assessment tool FS-Equilibrium. This tool has specifically been developed for sail performance assessment.
- Computing the performance and possible CO2 savings for the vessel depending on course and wind speed.
- Assessing the CO2 savings on specific routes taking into account the specific seasonal climate and wind conditions along the track. Conventional tracks as well as sail propulsion optimized tracks are evaluated.

VALUE DELIVERED

- By means of a statistical evaluation a sensible assessment of the attainable savings is compiled.
- Specific saving potential for given trade routes for the considered wind propulsion concept.
- Trade offs between sailing time and savings for wind propulsion optimized routes
- ROI calculation
- Basis for knowledgeable decision making when investing into wind propulsion systems.

Maritime Advisory - Advanced Engineering Services

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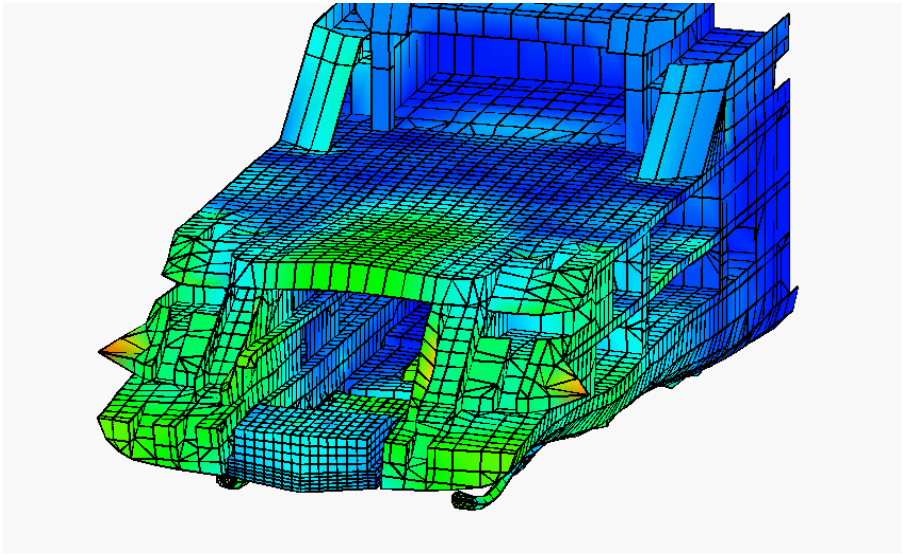
	Life cycle management				

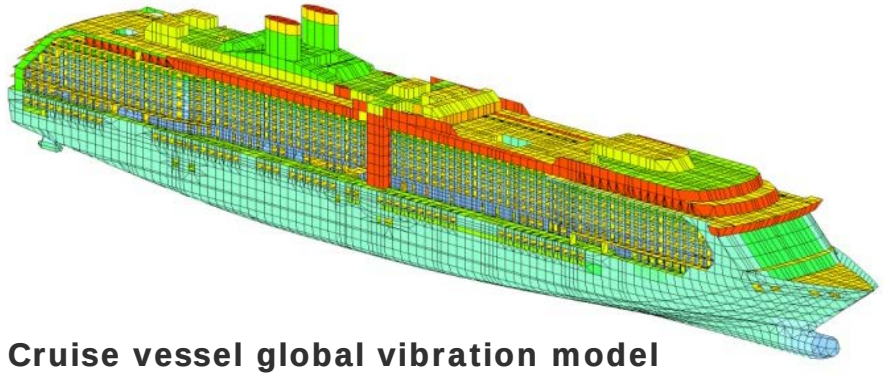
Ungraded

Global vibration analysis

- Computation of **natural frequencies** and **forced vibration** amplitudes by FE considering different service conditions
- **Excitations from engines, propellers, slamming** etc. can be considered
- Stringent automation of the analysis process enables to investigate the effect of **design variants in very short time**
- Customers benefit from
  - **increased vibration comfort** for passengers and crew
  - **reduced risk** of vibration damage and related repair cost and downtime of the vessel
  - minimised risk of exceeding **contractual N&V limits**



Yacht aft structure



Cruise vessel global vibration model

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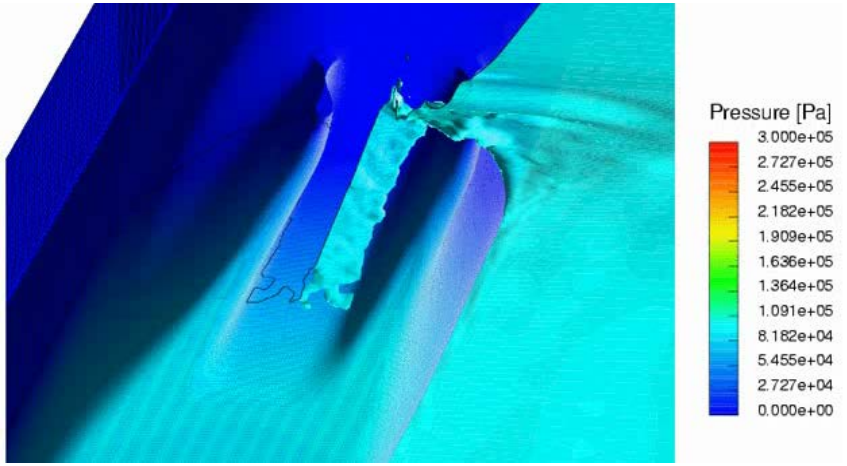
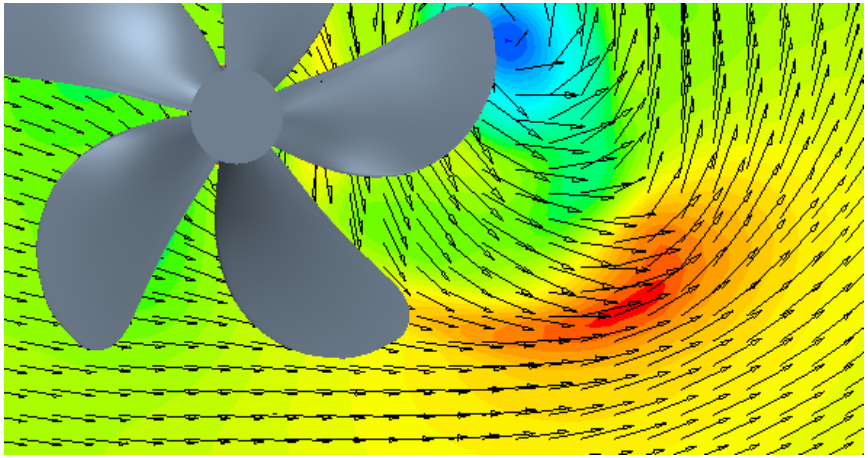
Analysis of critical exciters for global vibration

- Direct calculation of **slamming forces**
- Yields valid input for **N&V simulations** and insights on potentially required **design changes of the stern**





- **Propeller analysis** to determine **cavitation, pressure impulses, hydro-acoustic noise** and **dynamic forces on blades and shaft**
- Yields valid **input for N&V simulations**, insights to **reduce excitations** & **radiated noise** and helps to **ensure compliance**

Ungraded

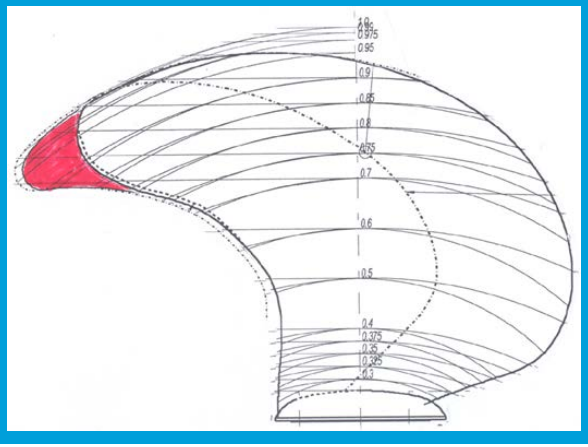
Benefit Case – Structural vibration issues due to propeller excitation

SITUATION AND CRITICAL ISSUE

Noise and vibrations in aft ship

Noise and vibrations in the aft ship of a yacht were not meeting the specified design criteria.

Too high noise levels and severe vibrations were observed during the new building sea trial.



DNV GL SOLUTION

- Assist the owner and yard in **identification of the root cause** of the noise and vibration problem
- The **propellers were identified**, by means of measurements, as being the major source of the excitation
- A **propeller-blade redesign** was proposed, modifying the blade tips, based on experience based methodologies
- DNV GL consultants gave on site advise to the ship yard

VALUE DELIVERED

- Verification measurements proved the solution being correct and the specified **noise and vibration levels were met**
- Bringing the **ship back to service on time**
- The yard was facing a significant **loss in reputation** if the ship delivery was delayed and the cause of the delay were know. This **was avoided**

Benefit Case – Structural vibration due to stern slamming

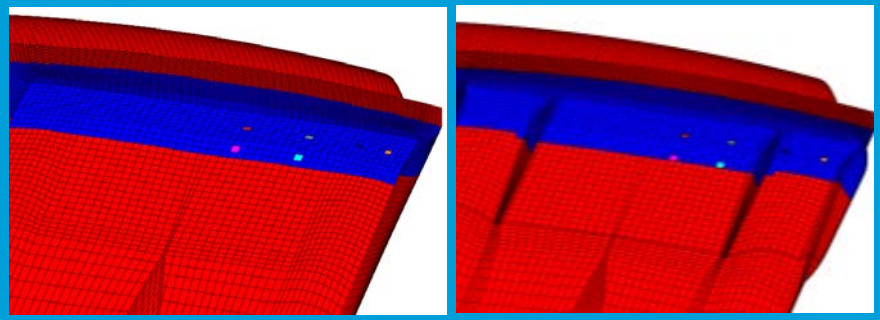
SITUATION AND CRITICAL ISSUE

Stern slamming of a megayacht

Customer wanted to avoid noise caused by stern slamming impacts while anchoring at berth.

Not a typical design load task because problem is a comfort issue but not safety-related.

DNV GL was asked to find design solutions to effectively reduce noise due to stern slamming.



DNV GL SOLUTION

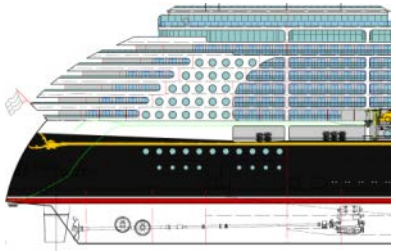
- **Measurements** confirmed stern slamming to be the source of noise and vibration
- **CFD simulations replicated measured impact pressures**
- Several types of **retrofittable appendages were numerically investigated** in order to mitigate severity of slamming
- **Profiles mounted alongside the propeller tunnels** turned out to best **reduce slamming** pressures while not impairing propulsion performance

VALUE DELIVERED

- Design solutions for reducing impact pressures at the stern were found
- Retrofitting of profiles significantly **increased passenger comfort** while anchoring

DNV GL offers a holistic noise control program

Stage 1: Early design review

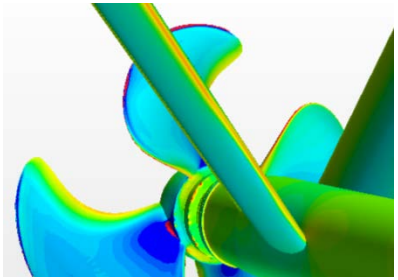


Favourable design changes can be found early, examples:

- Changed propeller diameter/rpm
- Design changes (e.g. change location of restaurant or suites)

Estimates of floor systems as input to purchase and weight calculations

Stage 2: Evaluation of excitation sources



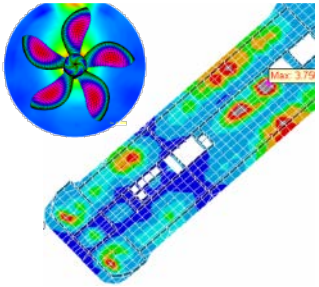
Detect sweetspot between efficiency and forces induced by propellers

Changes in propeller design to avoid high forces

Avoid “problem” engines

Relevant for SILENT notation

Stage 3: Noise and Vibration analyses



Optimization of floor systems and other noise reducing measures

Reduce the risk of excessive vibrations during sea trial

Evaluate favourable engine phasing

Optimize the structural design, such as stiffener and girder dimensions, pillar locations, bulkheads, etc.

Stage 4: Noise and Vibration measurements

Verification of the noise and vibration situation

Assistance if any issues occurring during sea trial, examples:

- Vibration of machinery
- Vibration during a particular phasing of engines
- Noise around exhaust system
- Silencer efficiency

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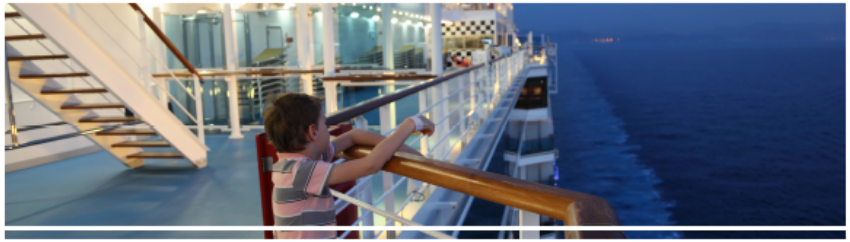
Related Class Notations

SAFER, SMARTER, GREENER

DNV·GL



MARITIME

COMFORT CLASS

Enhanced comfort and safety

Comfort Class is a voluntary class notation comprising a systematic evaluation of the comfort on board different ship types. Comfort Class gives owners, operators and yards the opportunity to apply well defined criteria. This ensures predictability in the specification and ordering phase, giving all parties a common understanding of the desired comfort.

Background
Habitability on board ships have been a major concern for ship owners and oil companies during the last two decades. This is related to crew being able to get sufficient rest when they are off duty and ensure satisfactory comfort for passengers on board cruise ships and yachts.

DNV GL Solution
Vessels which fulfill the requirements applicable for this notation will be given the class notation COMF-V(crn) on noise and vibration and/or COMF-C(crn) on indoor climate. The requirements are divided into three grades depending on the level of comfort achieved, i.e. comfort rating number (crn) 1, 2 and 3. Rating number 1 represents the highest level of comfort and 3 represents an acceptable level of comfort. Additionally, rating number 3 ensures compliance with MSC.337(91) on noise and ISO 6954 on vibration.

Compliance to the rules is to be verified through measurements when the vessel is completed.

OTHER RELEVANT SERVICES

- Noise prediction
- Local and global vibration analyses
- Verification measurements
- Troubleshooting
- Vibration Class
- Silent Class

Value delivered
- Number of accidents have proved to be significantly reduced after implementation of Comfort Class
- A high level of comfort increases the performance and vigilance of the crew - consequently safer operation of ships
- The hability on board is a significant parameter for the ship's rating and reputation in the market

SAFER, SMARTER, GREENER

DNV·GL

MARITIME

SILENT CLASS

Increased profits and data quality - reduced environmental footprint

SILENT class is the first set of rules for underwater noise emission from vessels ever published. The voluntary class notation will ensure vessels with satisfactory realistic underwater noise emissions thereby increasing data quality and catch rates and reducing the environmental footprint.

Background
Vessels such as seismic, fishing, offshore and research vessels rely on a controlled underwater noise emission in order to perform their tasks proficiently and effectively. Other vessels and in particular cruise vessels may need to demonstrate a controlled noise emission.

DNV GL Solution
Vessels which fulfil the requirements applicable for this notation will be given the class notation. The requirements for underwater noise levels are specified for four types of operations:
- **Fishery (F):** Vessels engaged in fishing
- **Seismic (S):** Seismic surveys vessels using acoustic streamers
- **Research (R):** Research and particularly noise critical vessels
- **Acoustic (A):** Vessels using hydroacoustic equipment as important tools in their operation, e.g.survey vessels, ocean research vessels, pipe layers, diving vessels, various offshore support vessels, naval vessels, etc
- **Environmental (E):** Any vessel demonstrating a controlled environmental noise emission

OTHER RELEVANT SERVICES

- Design review
- Verification measurements
- Troubleshooting
- Noise prediction
- Local and global vibration analyses
- Vibration class
- Comfort class

Value delivered
- Increased catch rates and profits
- Higher quality of scientific research data
- Increased quality of hydroacoustic data
- Demonstrate low environmental footprint
- Avoid costly delays when accessing regulated areas

Ungraded

Maritime Advisory - Advanced Engineering Services

	Fluid	Structures	Mechanical & Systems	Noise & Vibration	Risk & Safety
Design optimisation	Hull lines & appendages	Structures	Systems		
Design for compliance, safety, availability	Design loads	Global strength	Shaft alignment	Global vibration	Alternative design
	Resistance & propulsion	Local strength	Strength & fatigue	Propeller excitation	Explosion, fire & evacuation
	Seakeeping	Fatigue	Shaft vibration	Local vibration	Safety & reliab of sys & comp
	Manoeuvring	Structural capacity	HIL testing	Vibration of machinery	LNG systems & components
	Gas flows	Composites	Network testing	Noise	Technology qualification
	Stability	LNG tanks		Shock	Arctic shipping
					Cyber security
Trouble shooting & LCM	Experimental investigations and cross discipline trouble shooting				
	Life cycle management				

Ungraded

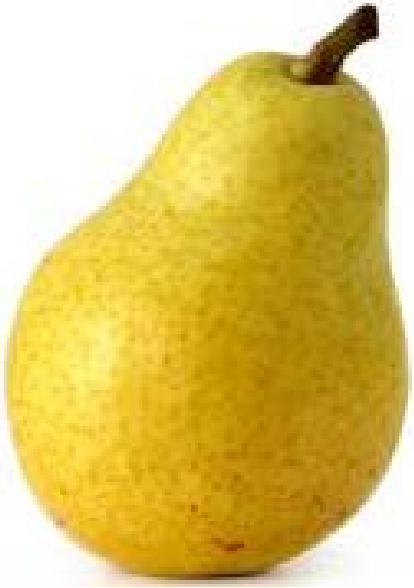
Alternative design

- Alternative Designs offer **individual** and **innovative solutions**
- generate **more income** for owner, **reduce** construction and/or operational **costs**

- **Exemplary** alternative design are:
  - Oversized main vertical zones
  - Large life/tender boats
  - Unconventional or innovative materials
  - Novel systems or components not yet known to maritime market

Alternative design

Prescriptive Design
rule compliant



Alternative Design
fulfilling functions and requirements of prescriptive design

- Analysis **verifying the equivalence of alternative designs** based on prescriptive / deterministic rules
- Analysis methods and process is geared to **MSC/Circ.1002 /1212 /1455** and has to be agreed with the administration, if applicable
- **Widens the design and solution** space in terms of e.g. innovative
  - **Design**
  - **Systems**
  - **Components**
  - **Materials**
  - **Operation**
- Yields more **attractive and competitive** designs

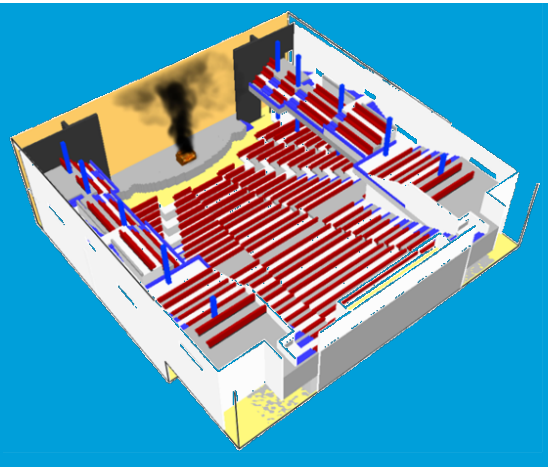
Benefit Case - Alternative design large MVZ

SITUATION AND CRITICAL ISSUE

Enlarge vertical zone of cruise ship

Increased capacity of a theatre aboard a cruise ship by enlarging a main vertical zone (>48m)

DNV GL was asked to demonstrate equivalent safety of the proposed alternative design according to SOLAS II-2/17 and MSC/Circ.1002



DNV GL SOLUTION

- Overall **Hazard Identification**
- Identification of relevant scenarios
- Quantification with use of **fire & evacuation simulations**
- Holistic **fire risk calculations**
- Propose of (fire) risk control measures
- **Documentation** of acceptable fire safety and equivalency to SOLAS design
- **Coordination** with stakeholders

VALUE DELIVERED

- Elaboration of risk mitigating measures for alternative design
- Ensure a high level of fire safety by assessed alternative design
- Chance of innovative design to create wide open rooms and/or large public spaces
- Customer followed DNV GL's recommendations and achieved approval

Benefit Case - Alternative design large lifeboats

SITUATION AND CRITICAL ISSUE

Increased the capacity of the life boats of a cruise ship

The capacity of life boats exceeded 150 persons, thus an equivalence analysis was required

The shipyard asked DNV GL to quantify the risk for the reference and the alternative life saving appliance design, performing an evacuation analysis

DNV GL SOLUTION

- Performance of **engineering analysis** according to MSC/Circ.1212
- **Failure Mode and Effects Analysis** (FMEA) was carried out
- **Event Tree Modelling** was required to quantify the risk
- **Evacuation Analysis** is performed to determine the evacuation time required

VALUE DELIVERED

- Proof of **equivalent level of safety** for alternative LSA design
- It was proved that the alternative design shows a **better evacuation safety than the reference design**
- Elaboration of **risk mitigating measures** for alternative design
- Customer followed DNV GL's recommendations and **achieved class approval**

Maritime Advisory - Advanced Engineering Services

	Fluid	Structures	Mechanical & Systems	Noise & Vibration	Risk & Safety
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Trouble shooting & LCM	Experimental investigations and cross discipline trouble shooting				
	Life cycle management				

Ungraded

Arctic shipping risk assessment & winterisation

- **Arctic Shipping Risk** – Facilitate and provide HAZID and Risk Analyses related to Arctic operations
- **Winterisation** – facilitate workshops, review and advisory related to new designs. optimisation, risk and energy mitigating solutions, operational procedures etc. Prepare documentation for the Notation
- **GAP analysis:** Rules and Regulations – Advisory related to regulatory framework; DNVGL, IMO, ISO, IACS etc. Includes maintaining an overview of the regulatory framework
- **Technology Qualification** – Help our customers with Technology Qualification of new or known technology to be applied in Arctic conditions
- **Arctic Development Projects** – R&D and development related to Ice Load Monitoring, Ice Management, Field measurements
- **Safety culture and human factors** – advisory work related to human performance and behaviour under Arctic conditions

Benefit Case - Evaluate impact of Polar Code regulation on expedition cruise fleet

SITUATION AND CRITICAL ISSUE

Polar code assessment & classification

A cruise operator with a fleet of expedition cruise ships operating in arctic areas requested DNV GL to investigate impact of new IMO Polar Code regulation on their operation

The assessment included both technical and operational assessment of the fleet

DNV GL SOLUTION

- Assess vessel's technical capabilities against **IACS** and **IMO** polar category, indicating the equivalent polar class of the vessels
- Analyse vessel **itineraries** using **AIS data** and planned itineraries
- **Assess polar category** required for these itineraries
- Indicate main **modifications** necessary to upgrade vessels to required category, and devise an order-of-magnitude type **cost estimate**
- Evaluate if small **changes** to **itinerary** would result in significantly **lower** upgrade requirements

VALUE DELIVERED

- **Transparency** on IMO Polar Code classification of existing fleet for better planning of future operation
- **Technical requirements** of future newbuildings have been made transparent to enable efficient discussions with the yard
- Route and cost assessment of required modifications, **enabled management** to take well founded assessment of future alternative routes
- The risk and technical assessment significantly **supported flag state approval** process

Thank you for your kind attention

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