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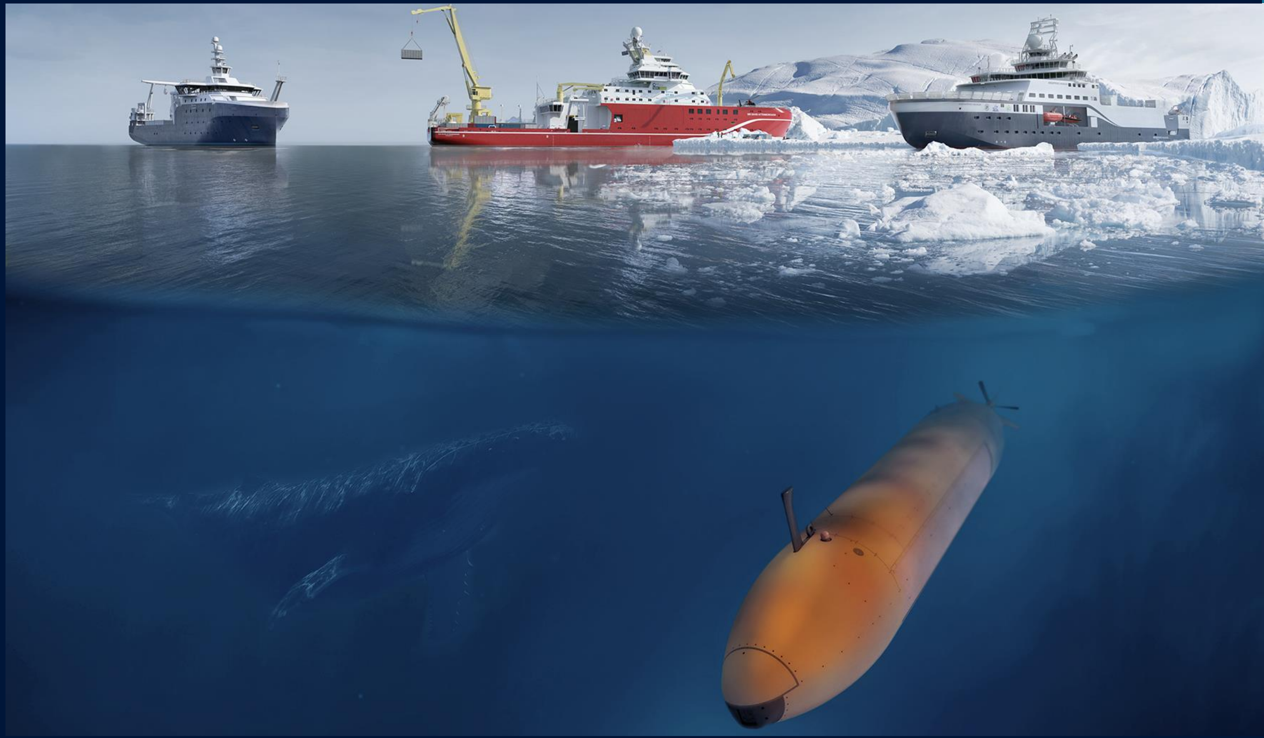
KONGSBERG MARITIME AS

Silent Propulsion in Icy Waters – IRSO 2024

21/10/2024

Trond Paulsen, VP – Research & SPV

GREEN AND EFFICIENT OPERATION IN EXTREME CONDITIONS



Agenda

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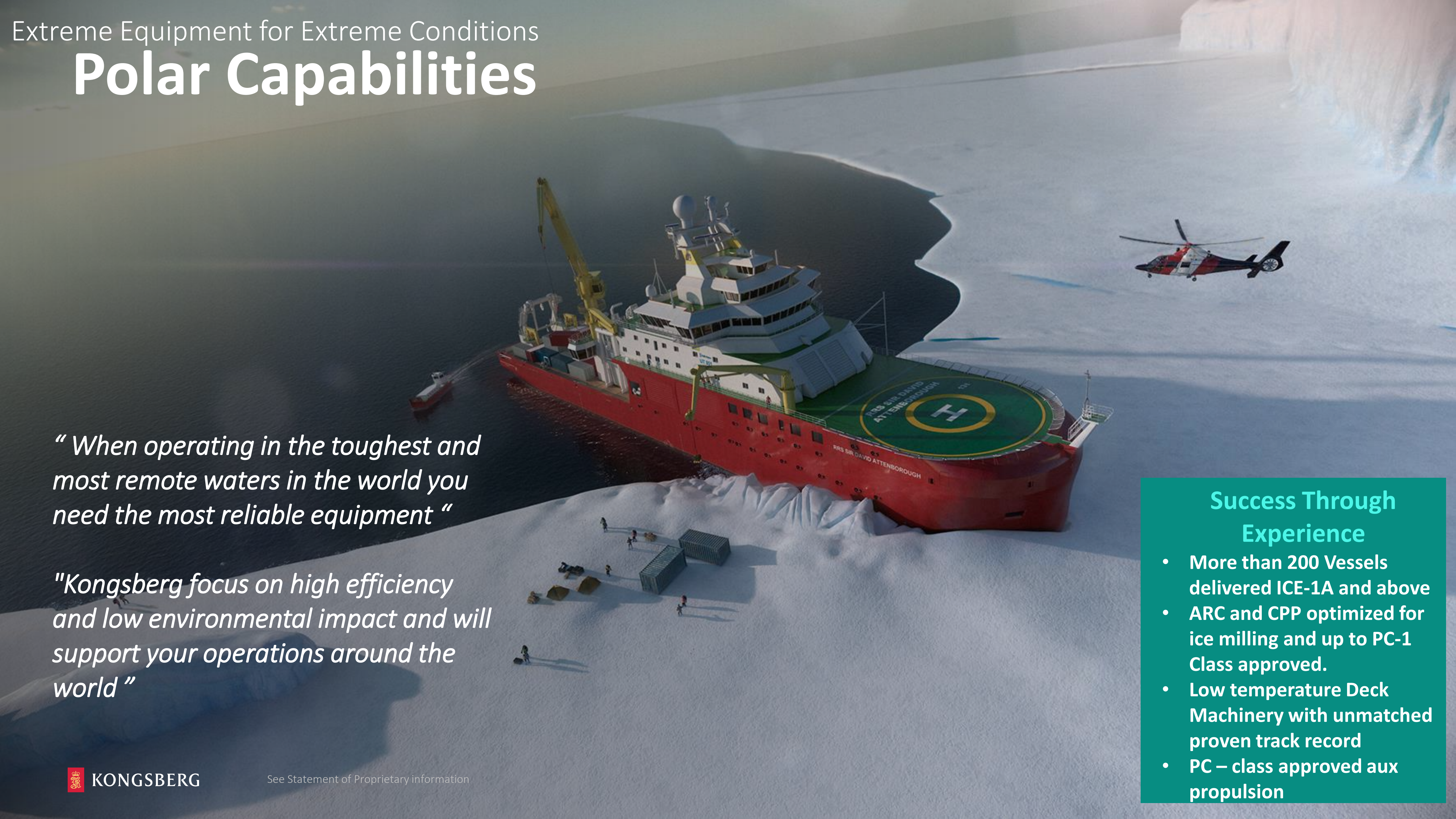
1. **Introduction Polar Capabilities**
2. Propeller design dimensioning for Polar Class
3. ARC thrusters Ice milling & Tipple screw
4. Silent notation and propeller cavitation
5. The great dilemma and system importance.
6. Case study – Sir David Attenborough blade stress monitoring



Extreme Equipment for Extreme Conditions

Polar Capabilities

“ When operating in the toughest and most remote waters in the world you need the most reliable equipment “

"Kongsberg focus on high efficiency and low environmental impact and will support your operations around the world ”

Success Through Experience

- More than 200 Vessels delivered ICE-1A and above
- ARC and CPP optimized for ice milling and up to PC-1 Class approved.
- Low temperature Deck Machinery with unmatched proven track record
- PC – class approved aux propulsion

Pyramid Strength

Dimensioning for Ice - principles

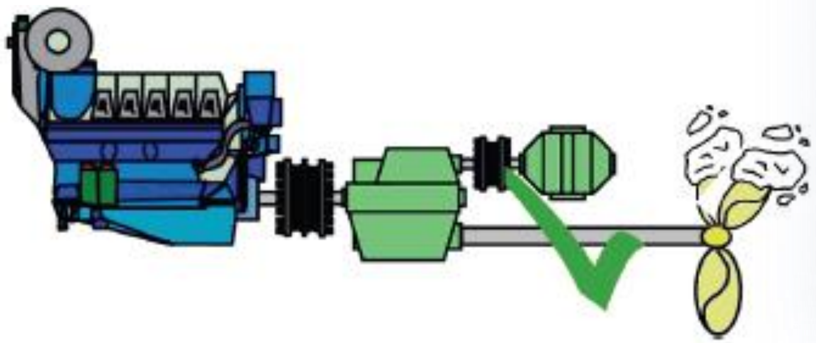
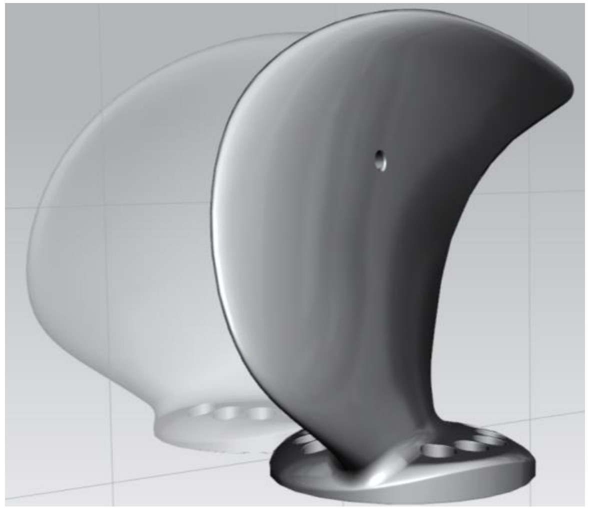
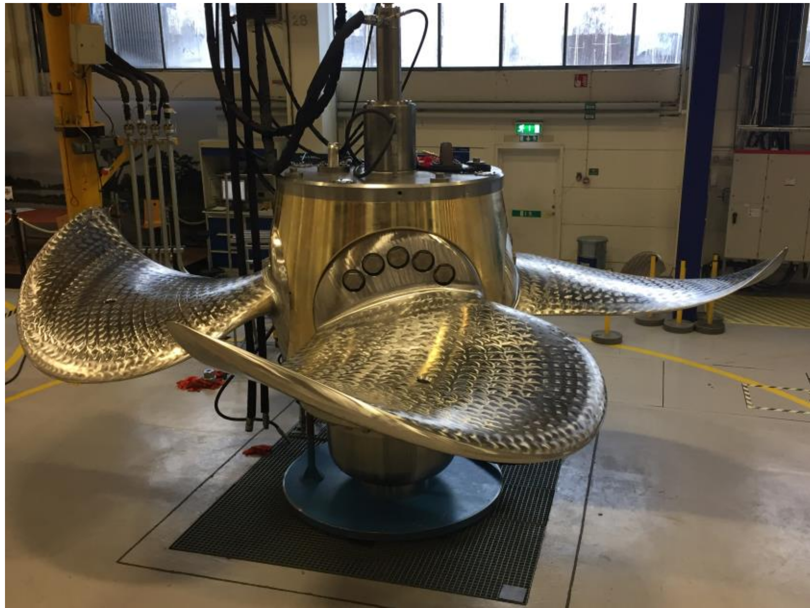


Figure 12 "Pyramide" or selective strength principal = blade failure before shafting failure

Figure: Picture taken from DNV classification note

- ❑ Blade failure before hub failure
- ❑ Hub failure before shaft failure
- ❑ Results in no too strong blades





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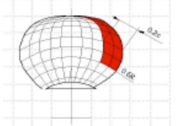
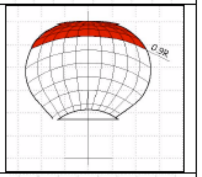
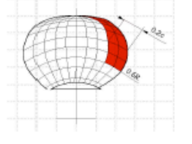
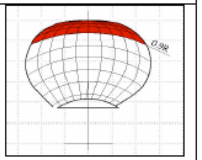
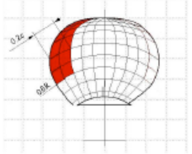
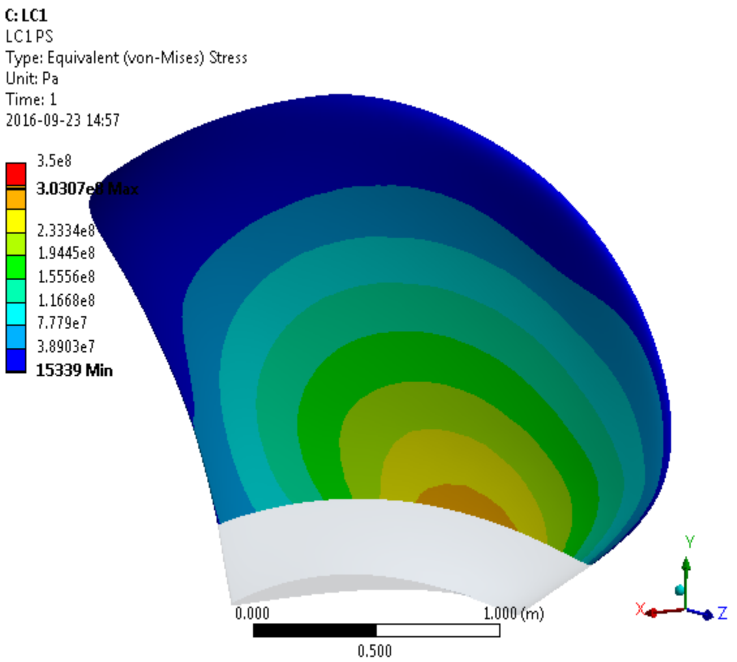
Ice Class Blade Strength

- ❑ Finnish-Swedish and Polar Class
- ❑ Load cases LC1 – LC5
- ❑ CP/FP, Open/Nozzle
- ❑ FE analysis required
- ❑ Thicker Blade design
- ❑ Stainless steel propellers vs bronze

	Force	Loaded area	Right handed propeller blade seen from back
Load case 1	F_b	Uniform pressure applied on the back of the blade(suction side) to an area from 0.6R to the tip and from the leading edge to 0.2 times the chord length.	
Load case 2	50 % of F_b	Uniform pressure applied on the back of the blade (suction side) on the propeller tip area outside of 0.9R radius.	
Load case 3	F_f	Uniform pressure applied on the blade face (pressure side) to an area from 0.6R to the tip and from the leading edge to 0.2 times the chord length.	
Load case 4	50 % of F_f	Uniform pressure applied on propeller face (pressure side) on the propeller tip area outside of 0.9R radius.	
Load case 5	60 % of F_f or F_b which one is greater	Uniform pressure applied on propeller face (pressure side) to an area from 0.6R to the tip and from the trailing edge to 0.2 times the chord length.	 e



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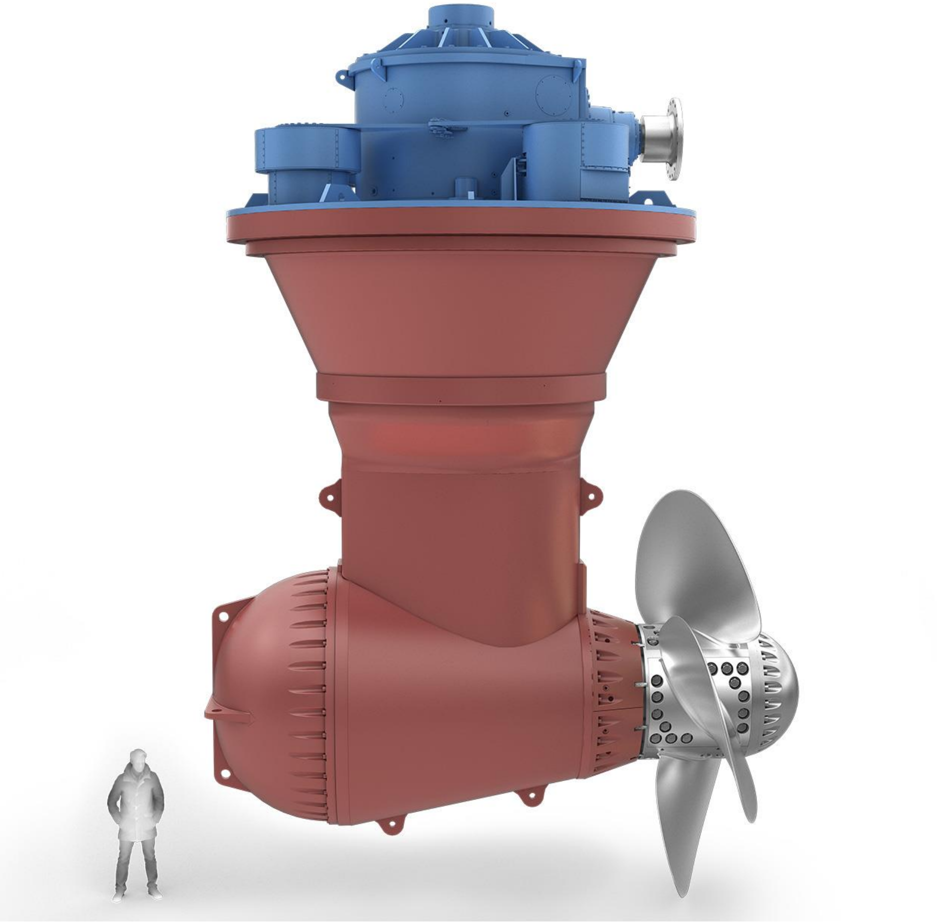
Arc Thrusters for Ice milling and tripple screw setups



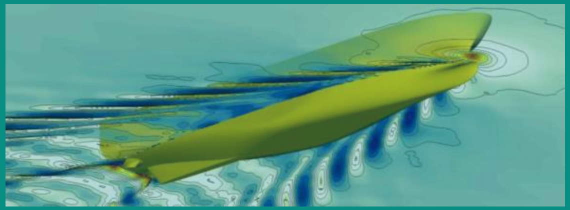
- ❑ Pushing / Pulling and ducted version available up to 9000kW
  - – Ducted pushing -> higher thrust (for example widening the channel)
  - – Open pulling -> better in ice milling
- ❑ PC2 / Icebreaker 7 design, silent notations in combintation with center shaftline.
- ❑ Used in various multipurpse and polar icebreakers, also Artic RV like Araon (KOPRI) and Norwegian polar institue.

KONGSBERG Systems to minimize Enviromental Impact

Silent Through Rough Waters

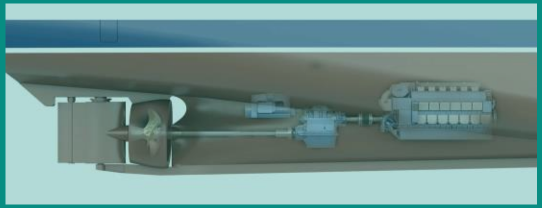
We look at the complete solution, making sure data collected is as good as possible while keeping emissions to a minimum

CFD and Empirical Data



- Hull design and propeller inflow
- Real Life Measurements and references
- Unmatched Kongsberg URN Experience

Optimizing the complete system



- Cavitation prediction and optimized propeller design
- Gear wheel noise prediction and optimalization
- Motor, Drives and other rotating machinery.
- EMC and other noise sources

Meeting Silent Notations

- DNV – Silent R
- ICES 209
- Silent A / S / F / E options

- Collaboration with Designers and Shipyards to achieve best possible results all propulsion setups

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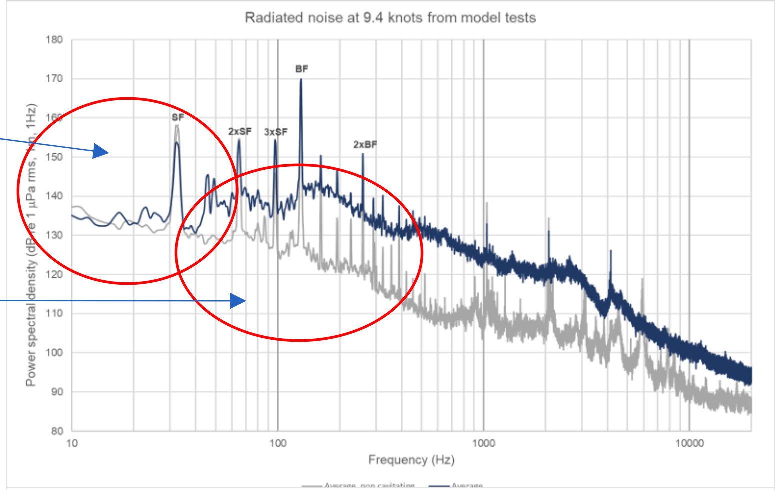
Underwater Radiated Noise (URN)

Propeller noise

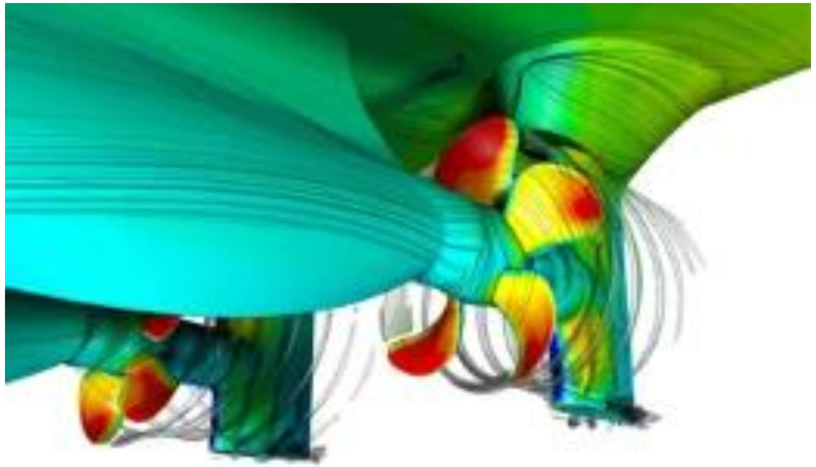
- ❑ Lower frequency noise dominated by blade passage and its multiples
- ❑ Tip vortex cavitation medium spectra
- ❑ Cavitation in general, broad banded

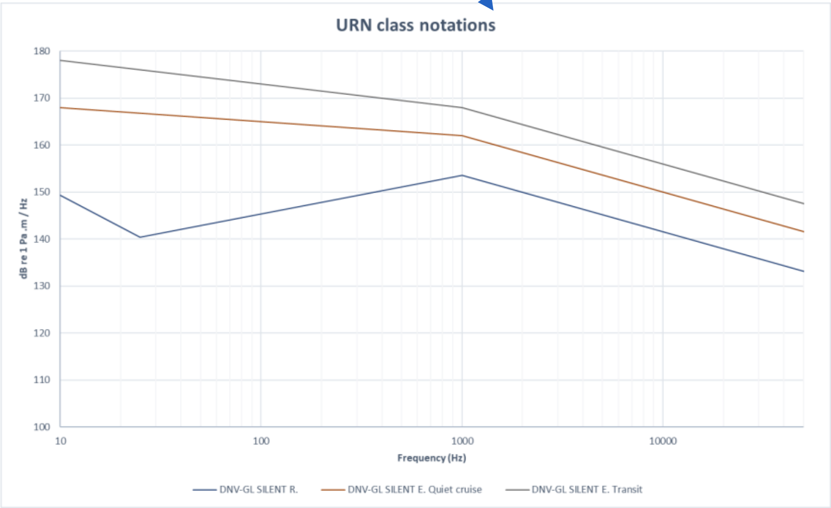
Spectra dominated by blade passage

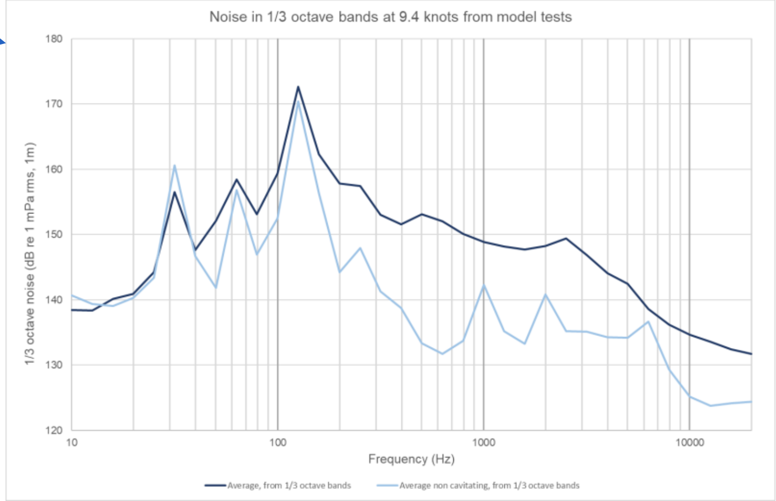
Spectra dominated by tip vortex cavitation



Requirements often related to 1/3 octave band





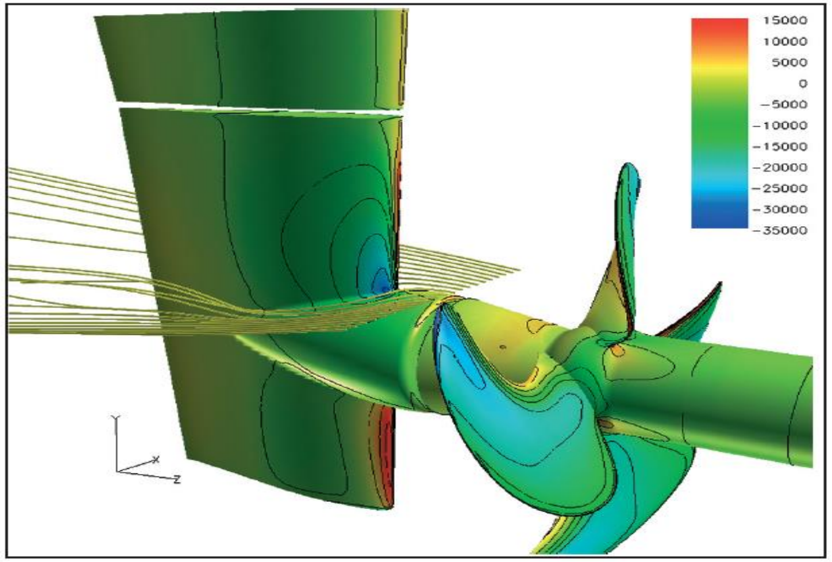


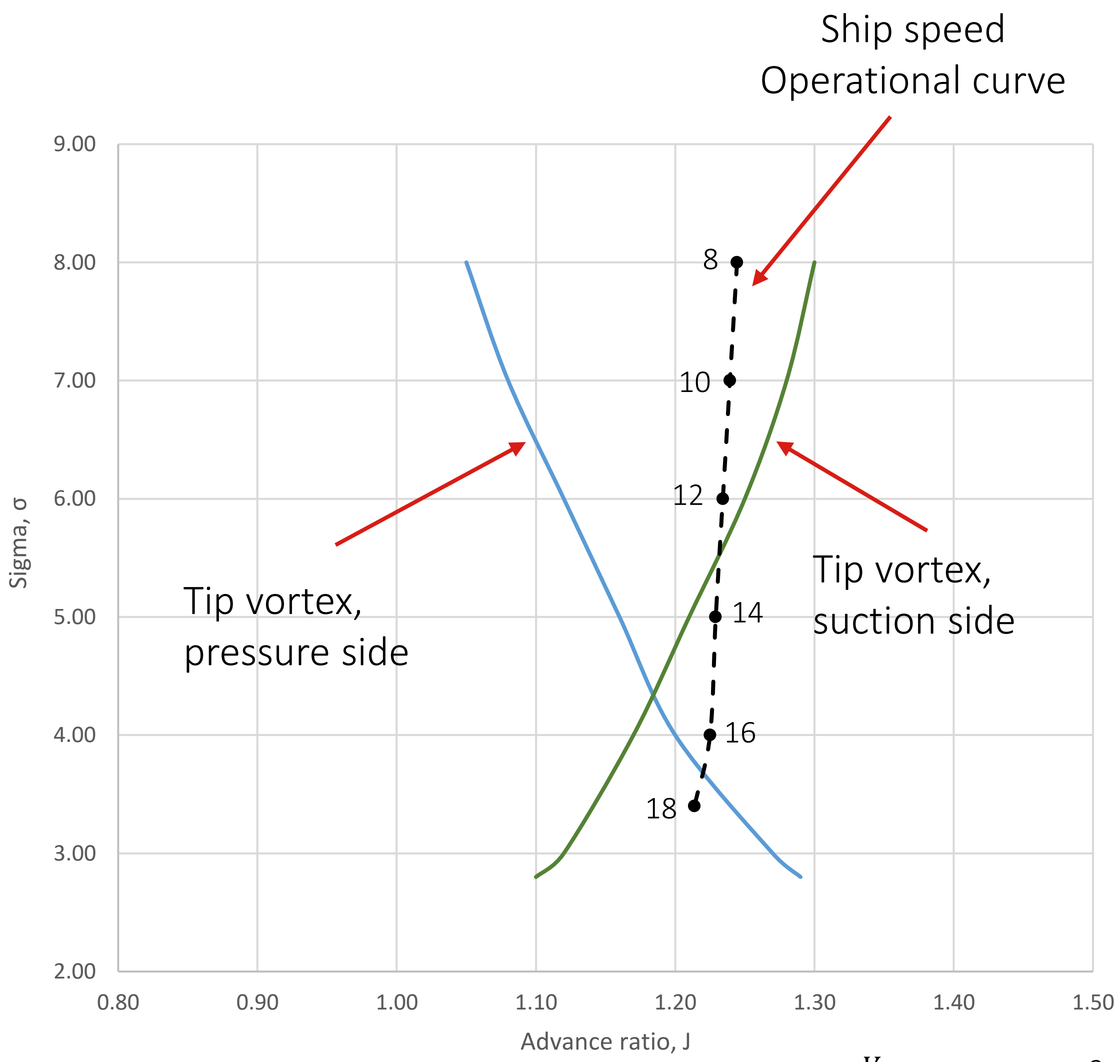
Cavitation Inception Speed (CIS)

- ❑ Cavitation “bucket diagram”
- ❑ Shows where and when the propeller starts to cavitate
- ❑ Where the Operational curve of the vessel intersects any of the limit curves → cavitation inception
- ❑ Tip vortex first type of cavitation that is triggered (in full scale)

Cavitation number:

$$\sigma = \frac{p - p_v}{0.5\, \rho\, {V_A}^2}$$

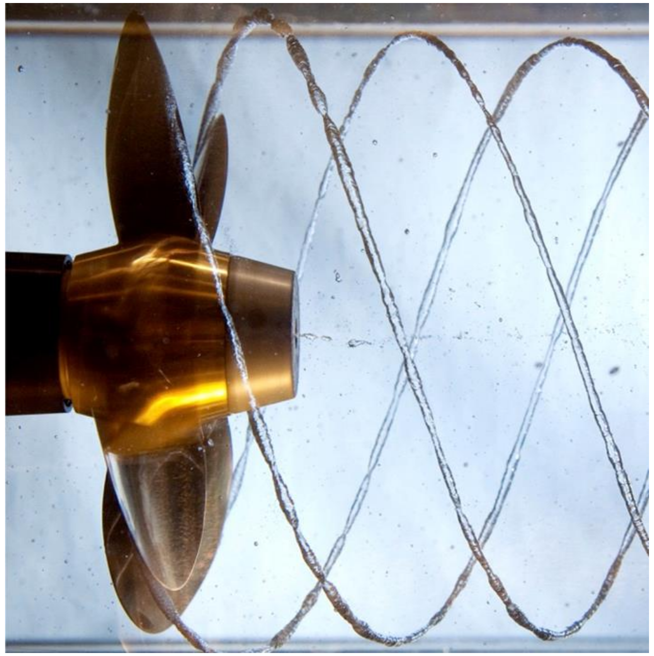




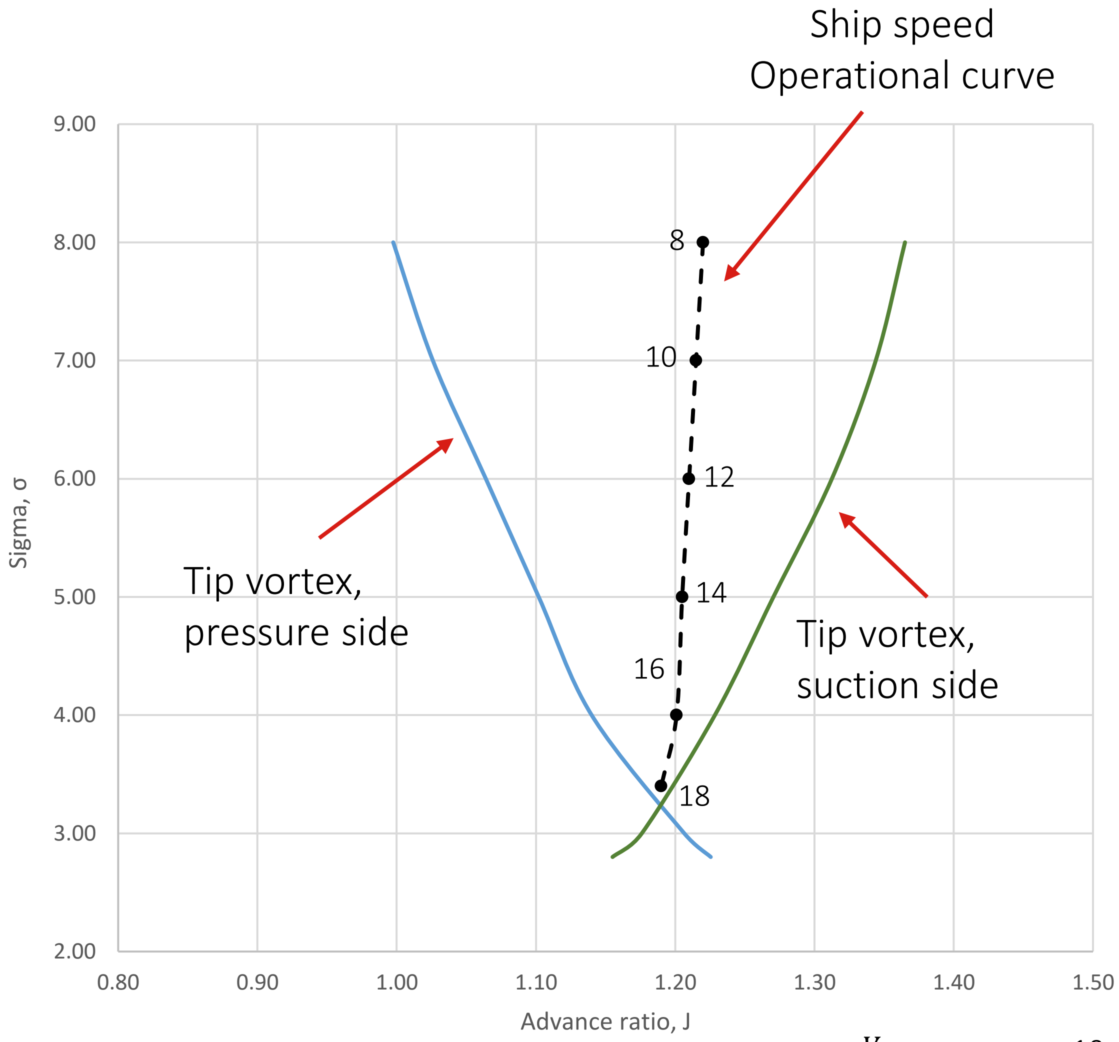
$$J = \frac{V_A}{n \cdot D}$$

Cavitation Inception Speed (CIS)

- ❑ Design objective → deep and wide bucket!
- ❑ Strict noise requirements
  - ❑ A specific cavitation inception speed
  - ❑ Silent-R notation or equivalent
- ❑ Validating model tests needed



Cavitation number:
$$\sigma = \frac{p - p_v}{0.5\,\rho\,{V_A}^2}$$



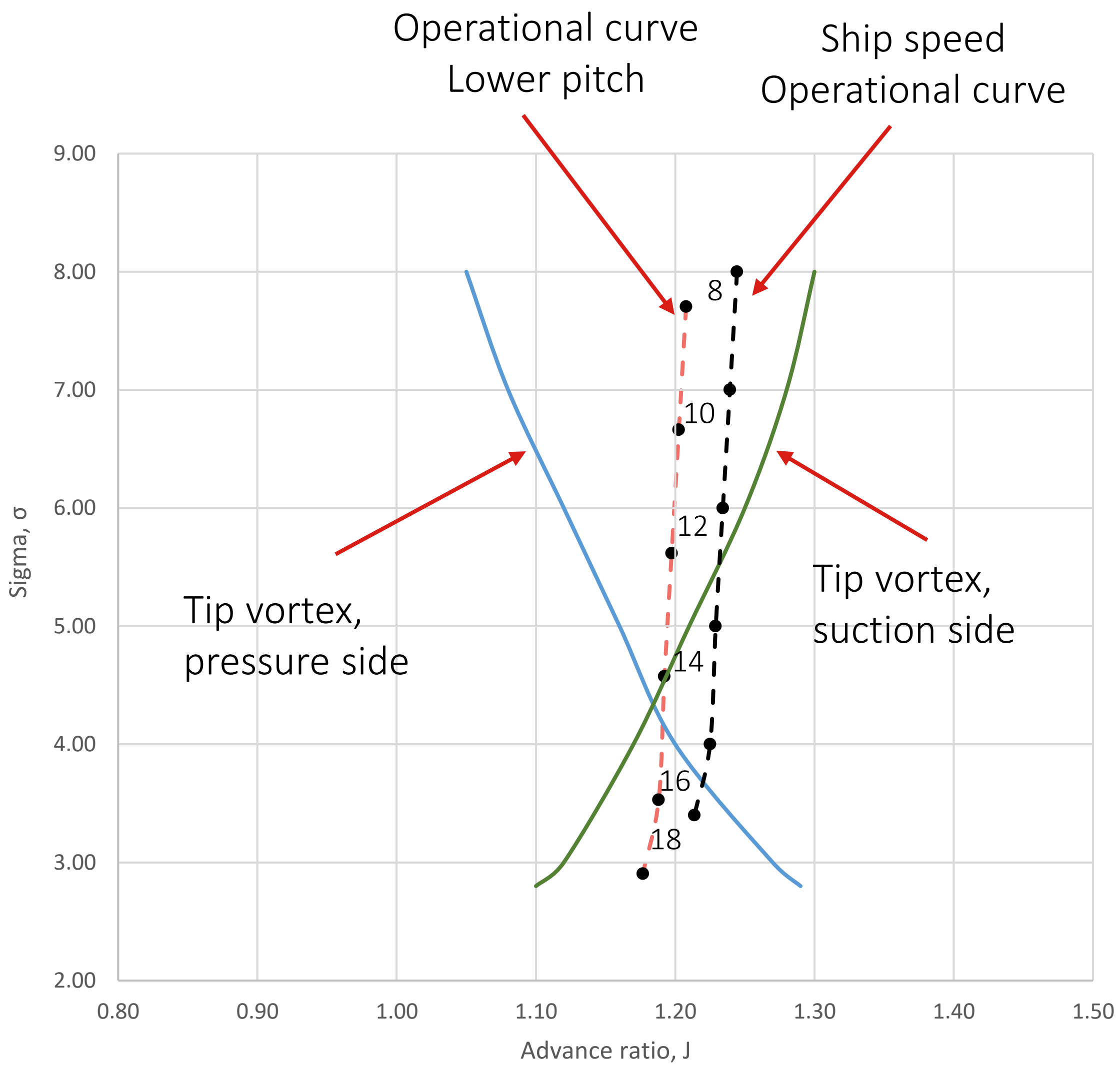
$$J = \frac{V_A}{n \cdot D}$$

CPP vs FPP

- FPP advantages:
  - Smaller hub, little better efficiency

- CPP advantages:
  - Operation profile adjustable in operation by setting the pitch
  - Adjust CIS to current sea state and other variables
  - All other advantages with CPP

(Image only for illustration. Changing pitch also shifts the bucket.)



Design optimalizaion

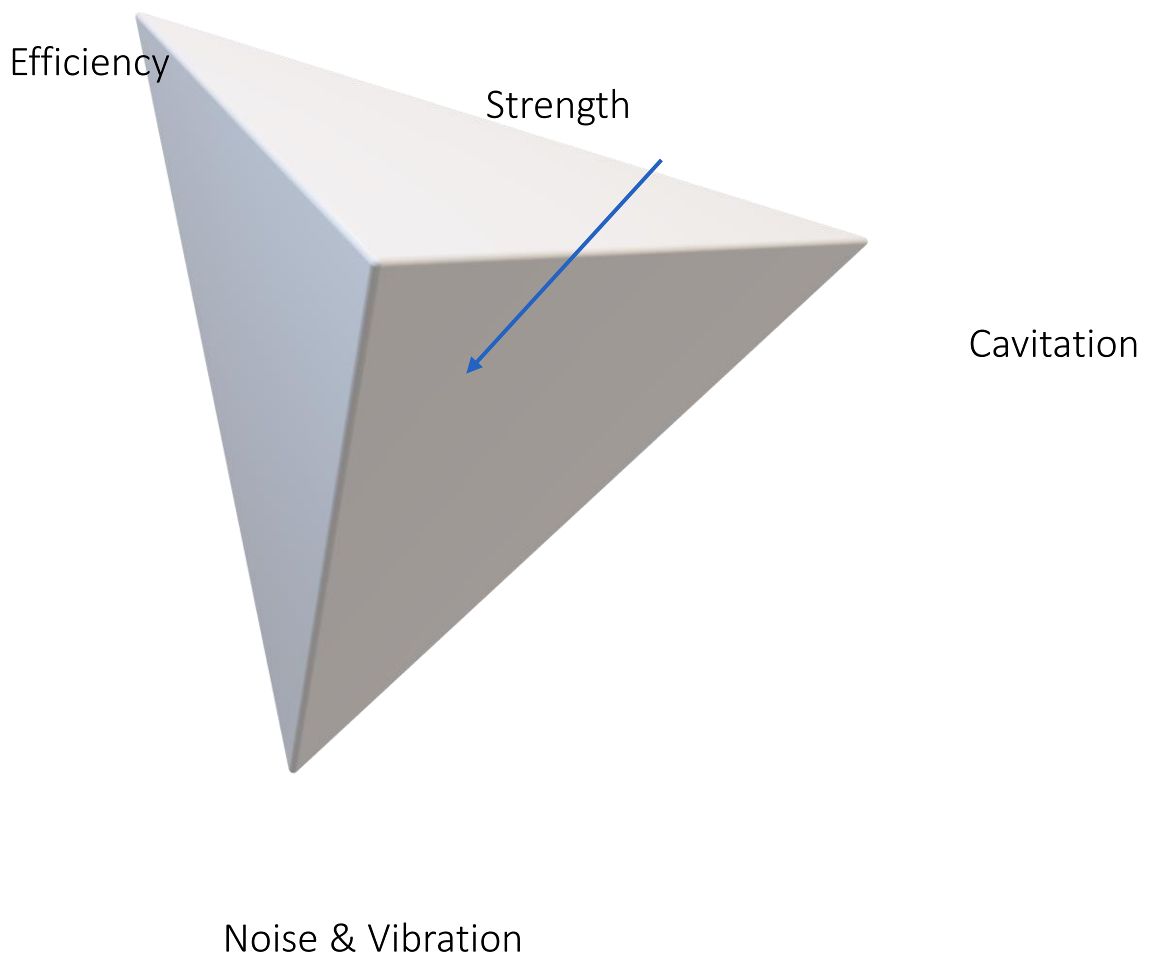
The Great Dilemma

- ❑ High efficiency → low blade area
- ❑ High efficiency → high tip load
- ❑ High efficiency → thin blade
- ❑ High efficiency → fewer blades (3-4)

- ❑ Little caviation → high blade area
- ❑ Little cavitation → thin blade

- ❑ Low noise → low tip load
- ❑ Low noise → more blades (5-6)

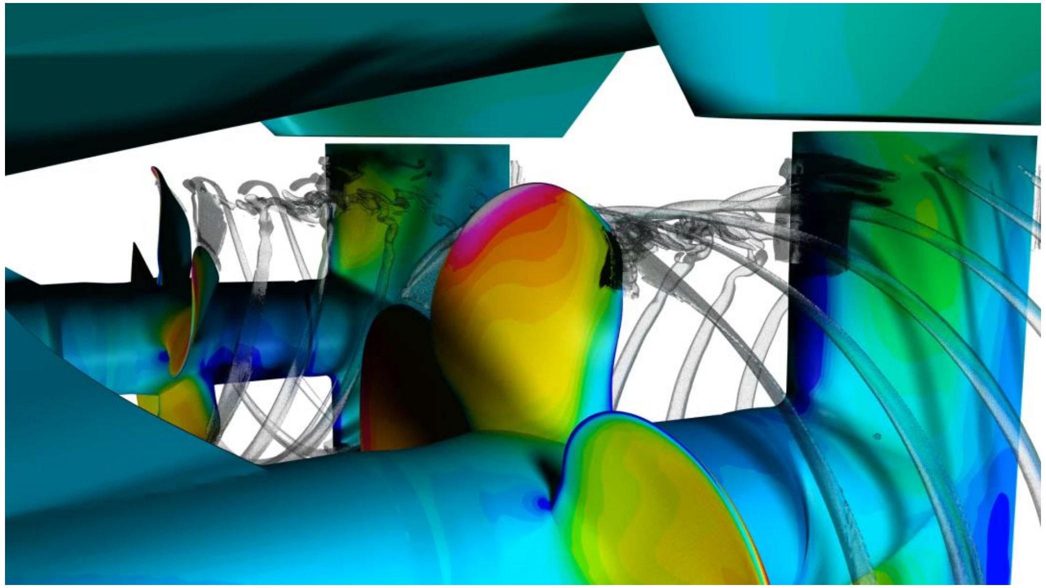
- ❑ High strength (ice) → thick blade

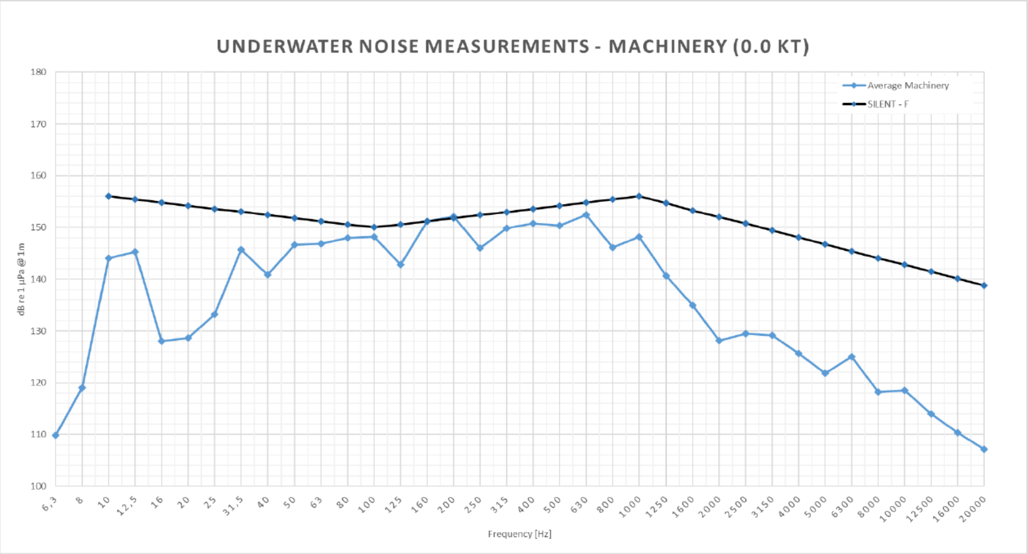


Underwater Radiated Noise (URN)

System design

- A vessel with noise requirements needs to be designed as a system. Cooperation at an early stage important for the best possible result.
- Hull design influences wake
- Wake influences cavitation
- Cavitation and the amount of cavitation influences levels of URN
- Inboard noise could contribute significantly to total URN budget





System integration and hydrodynamic optimisation

Kongsberg Maritime can offer optimization such as bracket design to enhance the wake (flow into propeller). Performance comes from capability of analyzing, optimizing and designing a system.

Using internal software for optimization of propulsor, rudder and hull. (Hullprop)

- Increasing propulsive efficiency and reducing pressure pulses
- Reducing fuel cost and lower emissions. (Carbon footprint?)
- Improving cavitation performance and lowering under water radiated noise (URN)

Underwater Radiated Noise (URN)

Refrences and market change

- The number of commercial vessels built each year with a notation related to URN is increasing
- Some of the most strict classification URN requirements demands ”navy type” design philosopy
- Commercial projects gives Kongsberg the possibility to obtain full scale data, that could be shared and used in our research
- The capability to be able to predict URN in an early stage of ship and propulsion system design is a differentiator

Vessel name	**MS MARJATA**
IMO	9648659
Design	LMG; Research & Explor.
Yard	STX OSV Langsten, H.777
Owner	FLO – Norway
Delivery	2013
Type	Twin Screw Promas
Propeller	CPP
Material Hub	NiAl Bronze
Material Blade	NiAl Bronze
Notation	Silent R
Service Speed	18.0 Knots

Vessel name	**REV OCEAN**
IMO	9840037
Design	Vard 6 16, Research exploration
Yard	Vard Brattvaag, H.884
Owner	Rev Ocean
Delivery	2019/20
Type	Twin screw Promas
Propeller	5 bladed CPP 102A, Dia 3.8 m
Material Hub	NiAl Bronze
Material Blade	NiAl Bronze
Notation	Silent R
Service Speed	17.0 Knots

Vessel name	**BELGICA**
IMO	9871294
Design	UT 844 WP, Oceanographic
Yard	Freire Shipyard, H.723
Owner	Government of Belgium
Delivery	2019/20
Type	Twin screw Promas
Propeller	5 bladed FPP, Dia 3.3 m
Material Hub	NiAl Bronze
Material Blade	NiAl Bronze
Notation	Silent R
Service Speed	14.0 Knots

Vessel name	**SIR DAVID ATTENBOROUGH**
IMO	9798222
Design	UT 851, Research
Yard	Cammell Laird, H.1390
Owner	NERC
Delivery	2017
Type	Twin Screw Promas
Propeller	5 bladed CPP 157A, Dia 4.5 m
Material Hub	NiAl Bronze
Material Blade	Stainless Steel
Notation	Silent R
Service Speed	13 Knots

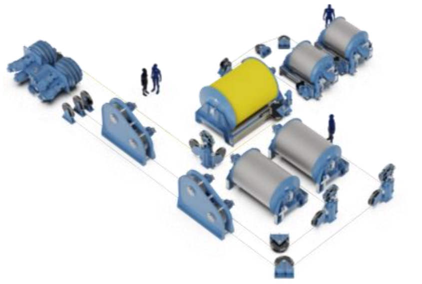
Vessel name	**-**
IMO	-
Design	
Yard	Damen Schelde Naval Shipb
Owner	Australian Antarctic, environm
Delivery	
Type	Twin Screw
Propeller	4 bladed CPP 194A, Dia 5.65 m
Material Hub	NiAl Bronze
Material Blade	Stainless Steel
Notation	Silent R
Service Speed	16 Knots

Oceanography

Polar Challenges related to deck machinery

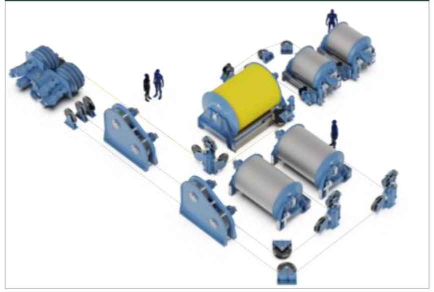
Cable Traction Control Units

Fibre Rope Handling Systems



Traction winches

Traction Winch Systems

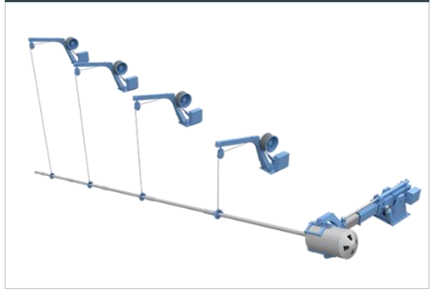


Direct Pull Winches

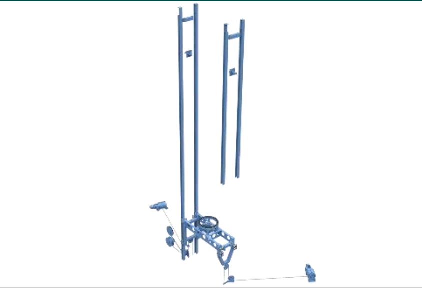
A-Frames

CTD Handling Systems

Corer Handling Systems



Moonpool Handling Systems



Outhauler Units

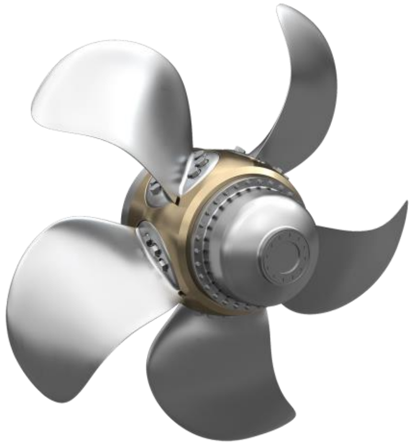
System Solutions

Ctrl Systems & User Interfaces

Polar research ship

Sir David Attenborough – Case Study blade stress

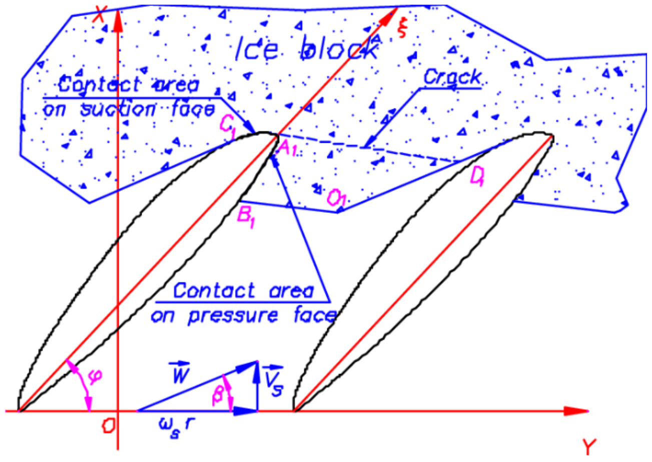
- Twin screw propeller
- 5 bladed CPP, 4.5 m diameter
- Hub: Bronze, size 157A
- Blade: stainless steel
- Polar Class 5
- Notation: Silent R



Task

- Measure blade forces due to ice interaction during continues operation
- Instrumenting spare blade

- Partners: LRS, BAS, Aker Arctic



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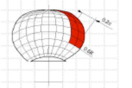
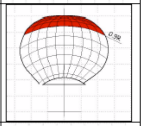
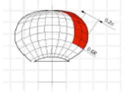
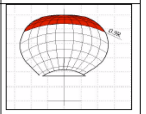
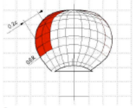
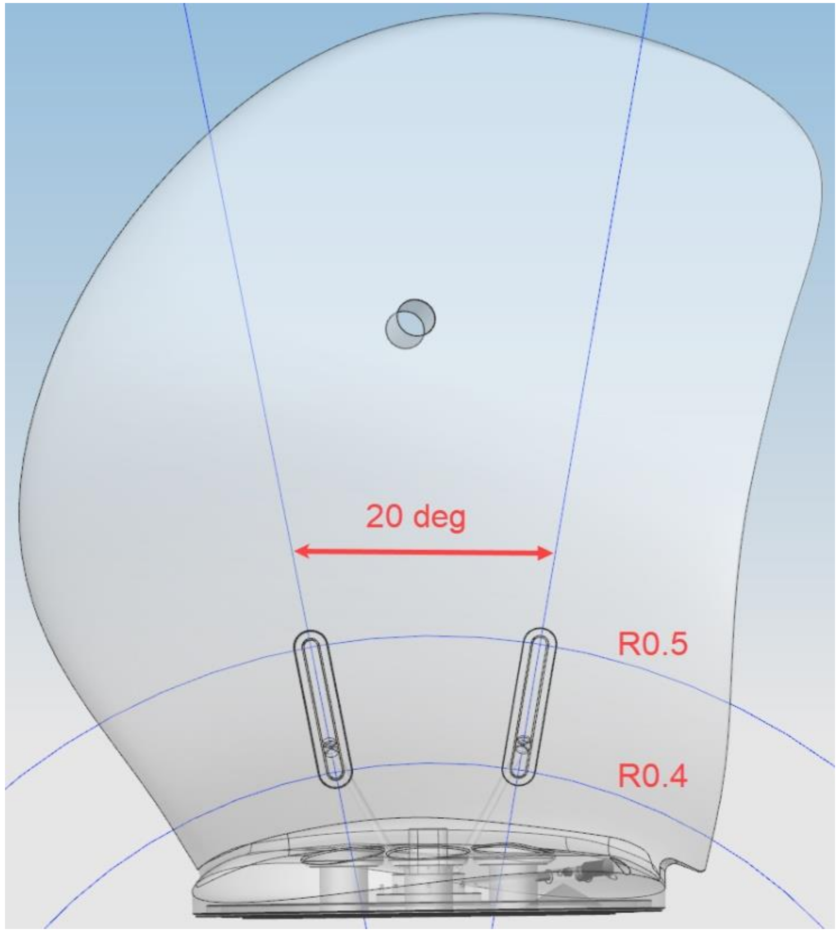
Load case 1	F_b	Uniform pressure applied on the back of the blade(suction side) to an area from 0.6R to the tip and from the leading edge to 0.2 times the chord length.	
Load case 2	50 % of F_b	Uniform pressure applied on the back of the blade (suction side) on the propeller tip area outside of 0.9R radius.	
Load case 3	F_f	Uniform pressure applied on the blade face (pressure side) to an area from 0.6R to the tip and from the leading edge to 0.2 times the chord length.	
Load case 4	50 % of F_f	Uniform pressure applied on propeller face (pressure side) on the propeller tip area outside of 0.9R radius.	
Load case 5	60 % of F_f or F_b which one is greater	Uniform pressure applied on propeller face (pressure side) to an area from 0.6R to the tip and from the trailing edge to 0.2 times the chord length.	 e

Design

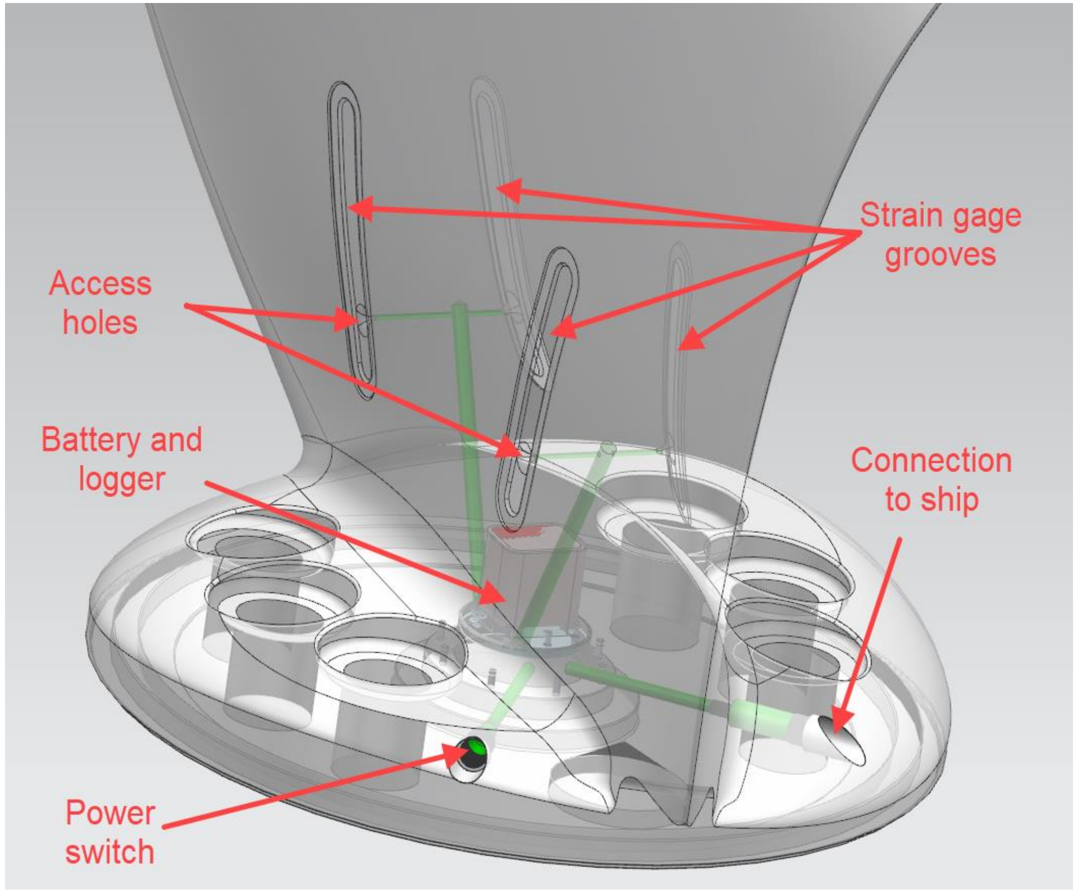
Measurement design for deciding

- Radial position
- Position along the chord
- Magnitude of blade force



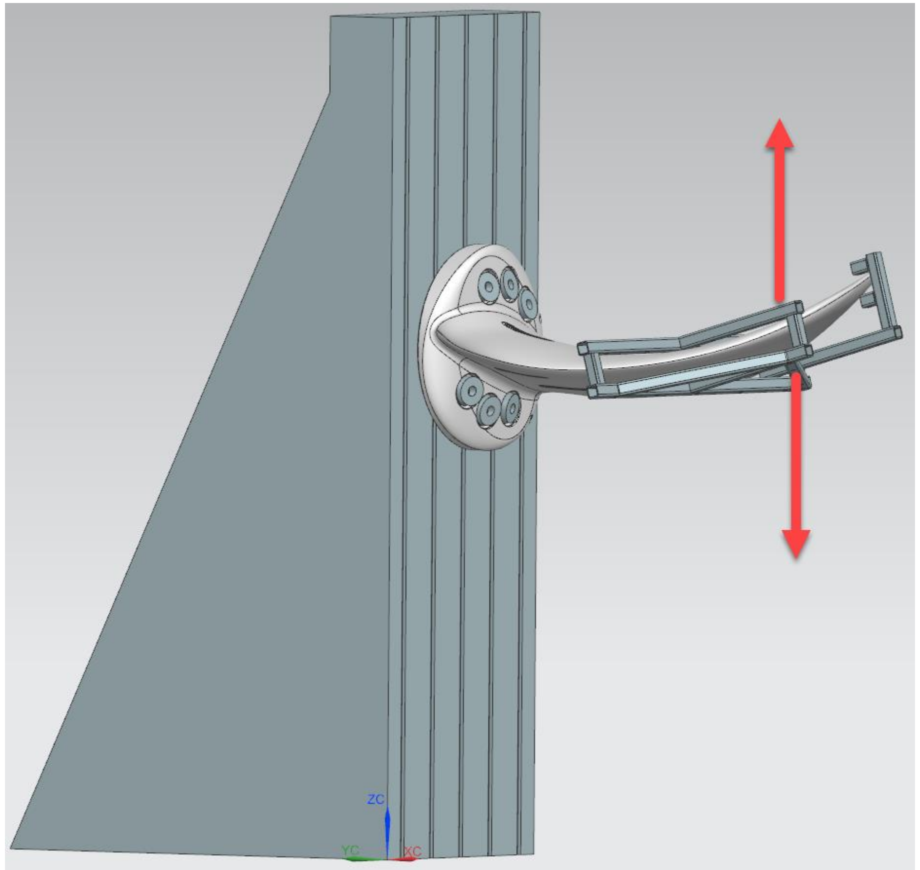
Solution

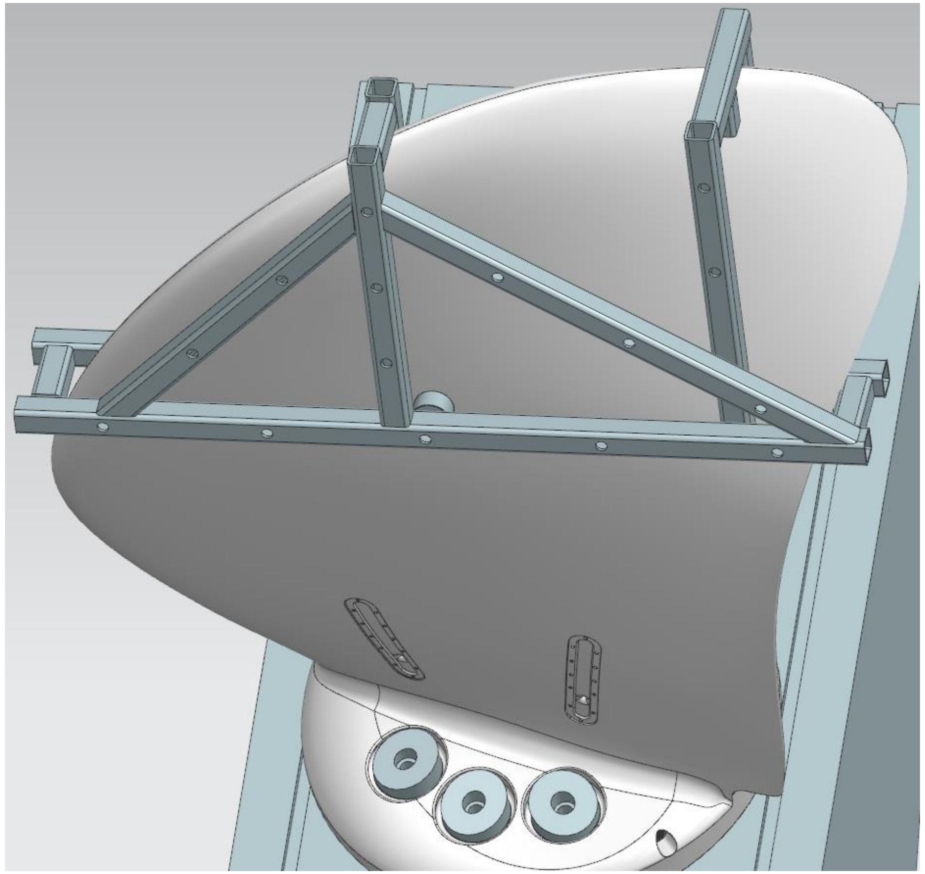
- Strain gauge technique
- Stand alone logger
- Data extraction
- Battery charge



Sir David Attenborough

Calibration





Plan

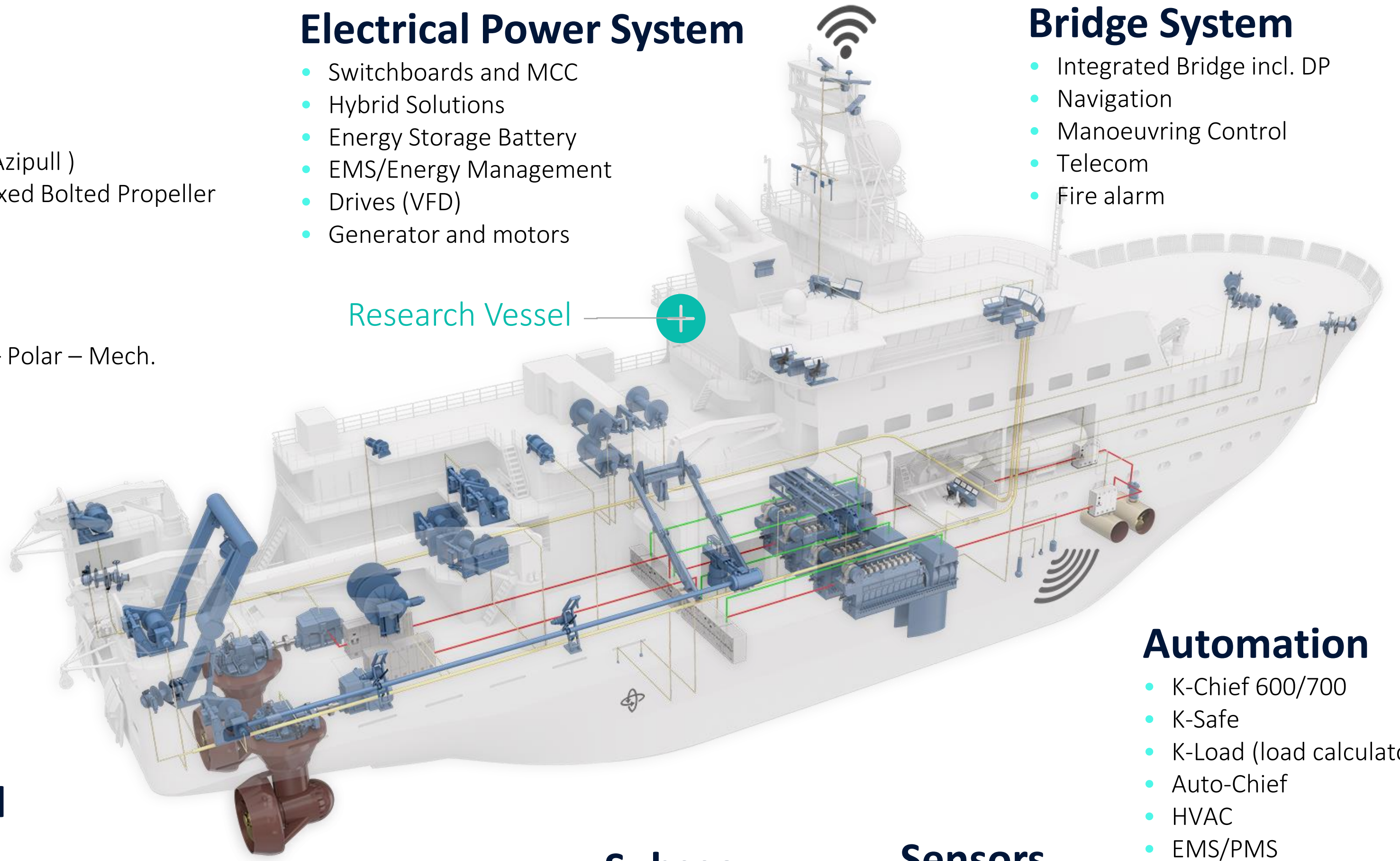
Ice trials winter 2024-2025

Kongsberg the complete supplier for Research Vessel

Propulsion
- Controllable Pitch Propeller
- Rim Drive Azimuth Thruster
- Azimuthing thruster (US and Azipull)
- Adjustable Bolted Propeller/Fixed Bolted Propeller
- Elegance Pod
- ARC Thrusters – Polar Class

Aux Propulsion
- Tunnel Thruster - Rime Drive – Polar – Mech.
- Retractable, UL&ULE –

Electrical Power System
- Switchboards and MCC
- Hybrid Solutions
- Energy Storage Battery
- EMS/Energy Management
- Drives (VFD)
- Generator and motors



Bridge System
- Integrated Bridge incl. DP
- Navigation
- Manoeuvring Control
- Telecom
- Fire alarm

Information Management
- Condition Based Maintenance
- Automation
- Unified Bridge
- Situational Awareness
- Safe data transfer and cloud solutions
- Customised ILS and maintenance plans
- Remote diagnostics
- Predictable maintenance

Deck Machinery
- Oceanographic handling system
- LARS and A-FRAMEs
- Fishery Winches
- Main Winch AHT/TUG
- Missions Bay Handling system
- Anchoring and Mooring Winches

Hybrid/Electric
- Power and propulsion optimization
- Power management
- LV/MV hybrid electrics

Automation
- K-Chief 600/700
- K-Safe
- K-Load (load calculator)
- Auto-Chief
- HVAC
- EMS/PMS

Digital Performance
- Remote Support
- K-IMS / Vessel Insight
- Situational Awareness
- Collision avoidance

Motion Control
- Rudders
- Steering Gears
- Stabiliser NR
- Stabiliser Retractable

Simulation solution
- Digital Twin
- Onshore Training
- Real Time simulation

Subsea
- Sonars
- Echo sounders
- Catch monitoring
- Mesotech products

Sensors
- Navigation Sensor suite incl. MGC
- MBR & Simrad BR 90 FishNet

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