MARIN

BETTER SHIPS, BLUE OCEANS


Saturn

Developing Solutions for Underwater Radiated Noise

# Balancing energy efficiency and underwater radiated noise reduction of ships

Frans Hendrik Lafeber, Johan Bosschers, Thomas Lloyd, Evert-Jan Foeth, John Huisman

# Greenhouse gas emissions

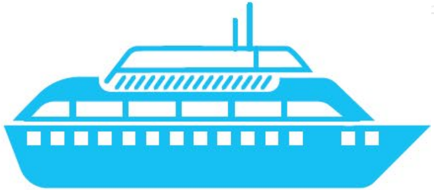
INTERNATIONAL
MARITIME
ORGANIZATION

- IMO Greenhouse Gas Strategy:
  - uptake of zero and near-zero GHG fuels by 2030 (at least 5%)
  - reduce $CO_2$ emissions per transport work in 2030 by 40% compared to 2008
  - net-zero GHG emissions close to 2050

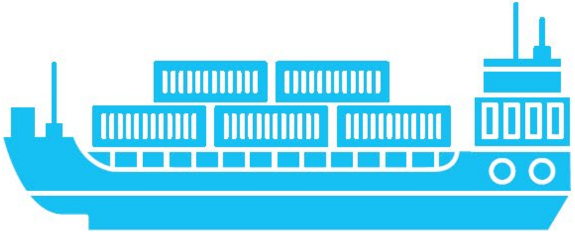
# Greenhouse gas emissions

## EEDI

ENERGY EFFICIENCY DESIGN INDEX
IMPROVING THE TECHNICAL
PERFORMANCE OF NEW BUILD SHIPS



## EEXI

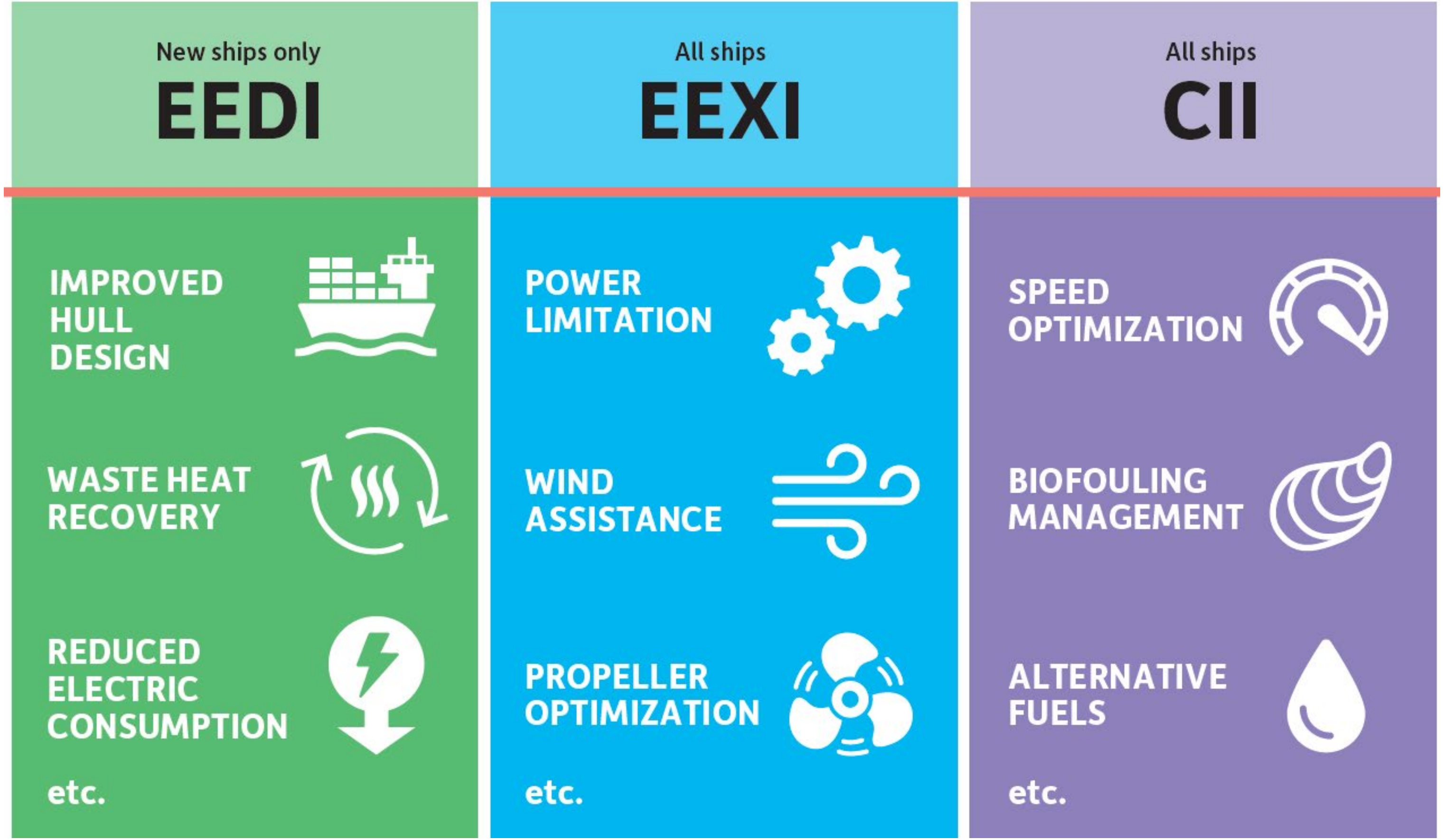


ENERGY EFFICIENCY EXISTING SHIPS INDEX IMPROVING
THE TECHNICAL PERFORMANCE OF EXISTING SHIPS

## CARBON INTENSITY INDICATOR (CII RATING)


IMPROVING THE OPERATIONAL PERFORMANCE OF EXISTING SHIPS

# EEXI / EEDI / CII



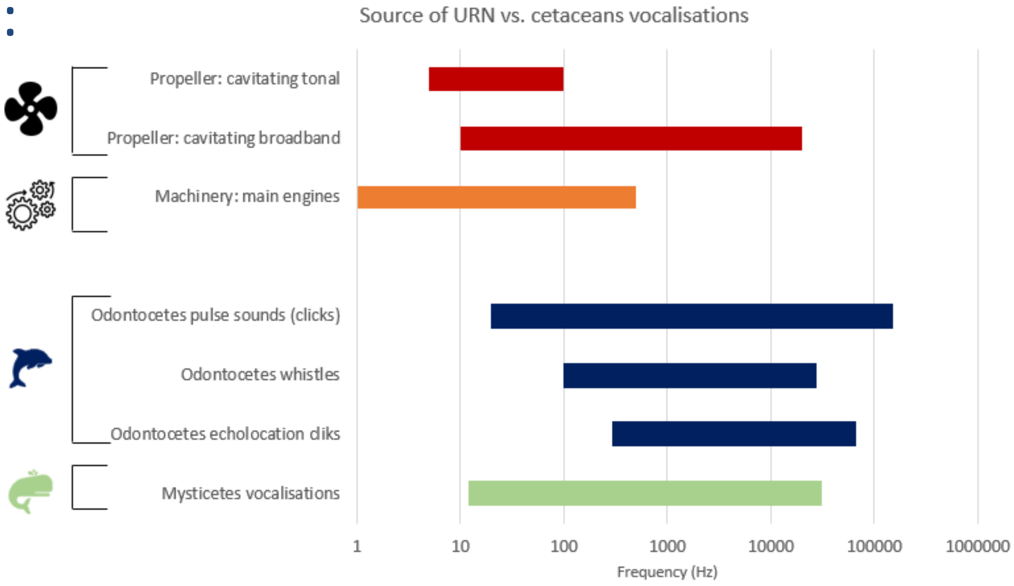

*Source: https://www.imo.org/en/MediaCentre/HotTopics/Pages/EEXI-CII-FAQ.aspx*

# URN from ships: impact on marine life

- Growing evidence of impact of underwater radiated noise (URN) of ships on marine life

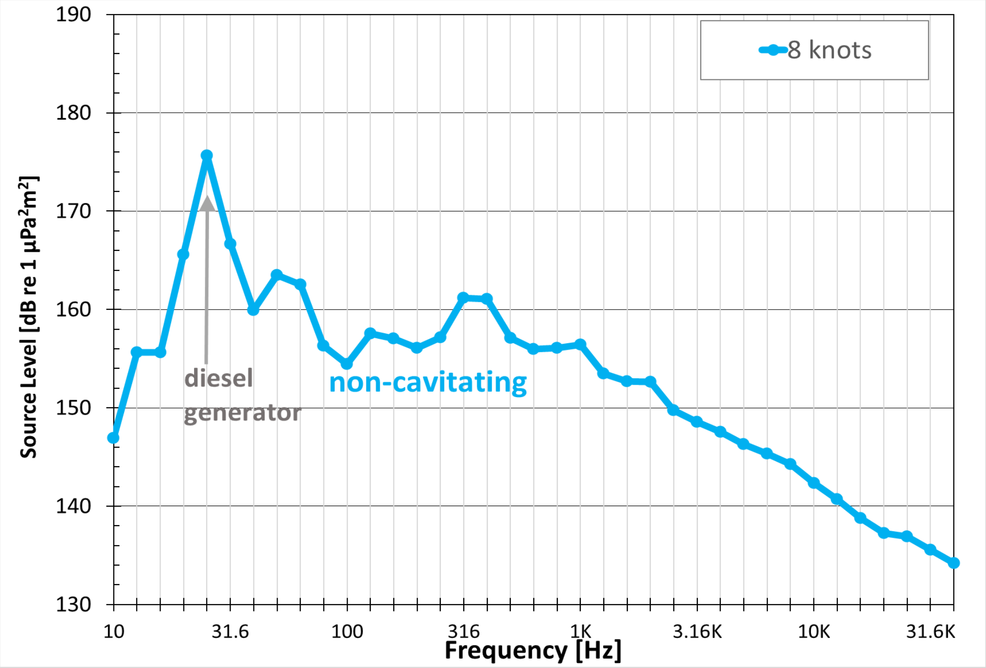
- Masking of sounds used for:
  - Communication
  - Hunting
  - Navigation

- Physical damage:
  - Hearing loss

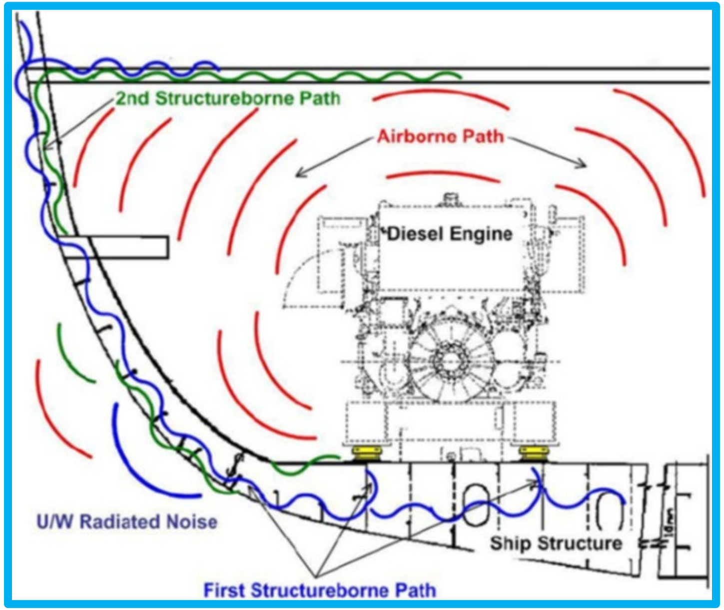



*Source: Cruz, E. Lloyd, T., Bosschers, J., Lafeber, F.H., Vinagre, P. Vaz, G. (2021). Study on inventory of existing policy, research and impacts of continuous underwater noise in Europe*

# URN from ships: sources

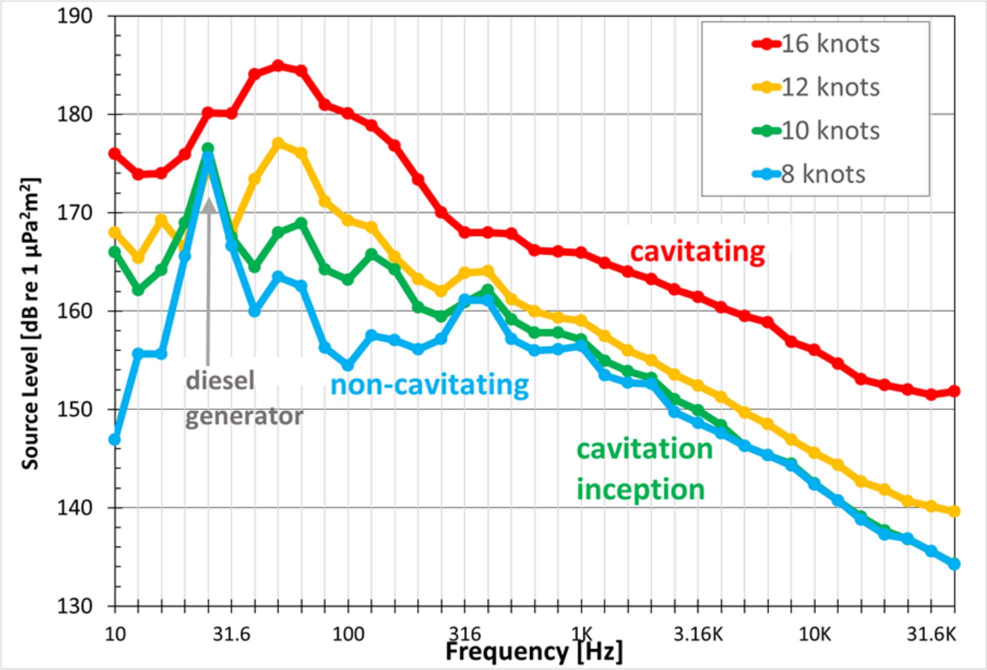



*Source: Arveson & Vendittis (2000) 173 m cargo vessel*




*Source: Spence and Fischer, 2017*

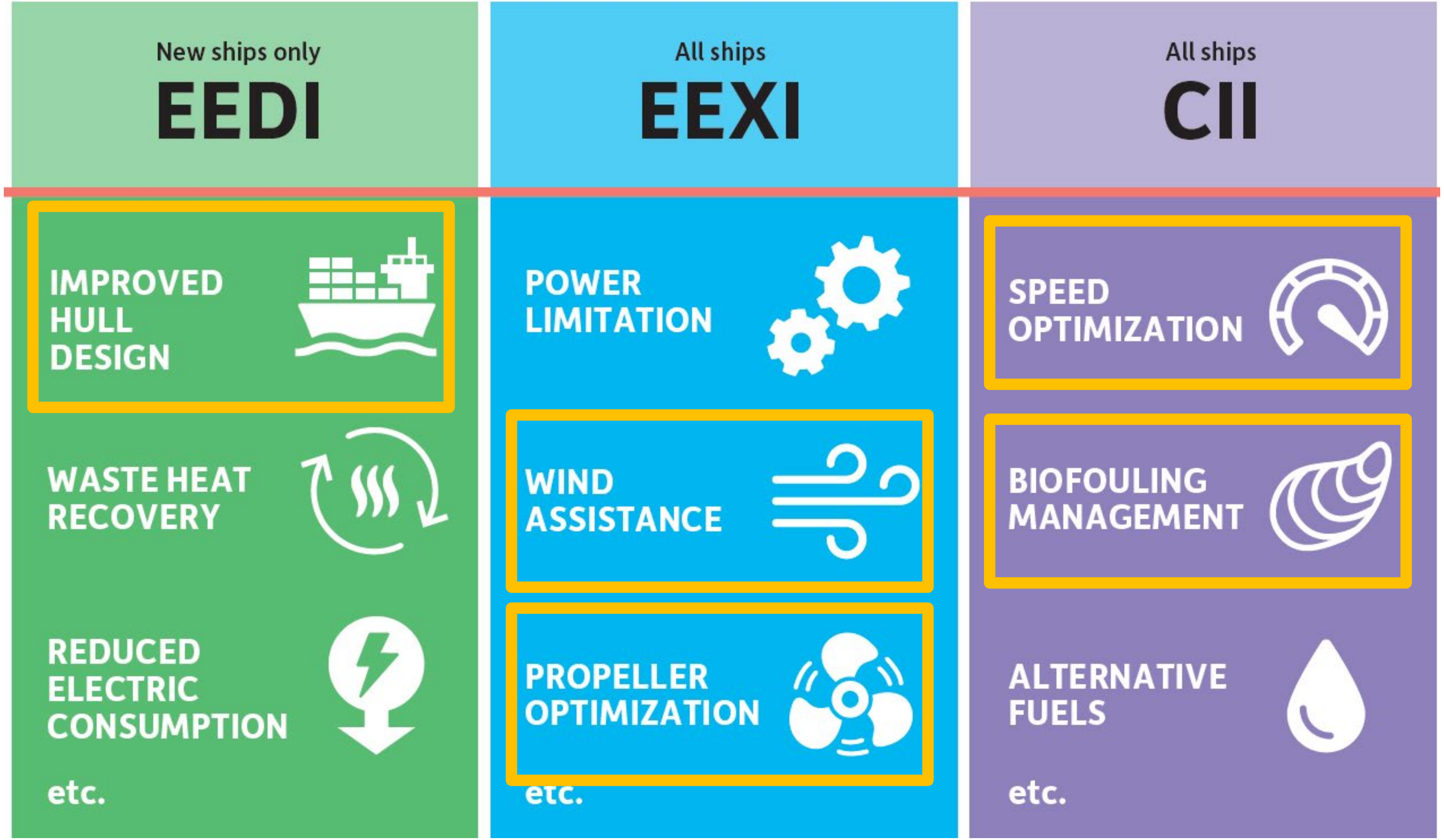
# URN from ships: sources




*Source: Arveson & Vendittis (2000) 173 m cargo vessel*

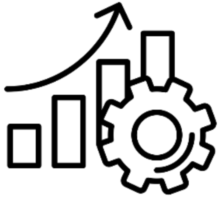
# URN from ships: regulations, incentives and class rules

# Energy efficiency and URN reduction

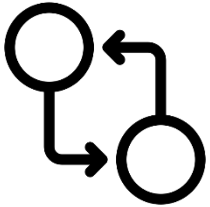



*Source: https://www.imo.org/en/MediaCentre/HotTopics/Pages/EEXI-CII-FAQ.aspx*

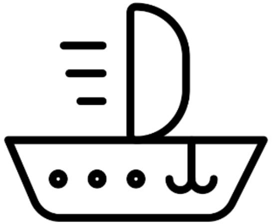
# Example of mitigation measures



- Optimise the hull design
  - Minimise resistance
  - Optimise propeller inflow
- Optimise the propeller design
  - Trade-off efficiency and noise reduction

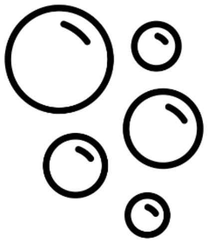


- Change the propulsor concept
  - Pumpjet, trochoidal propeller, etc.



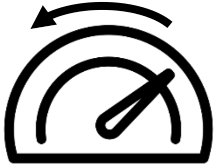
- Use wind-assistance
  - Reduce required thrust

# Example of mitigation measures



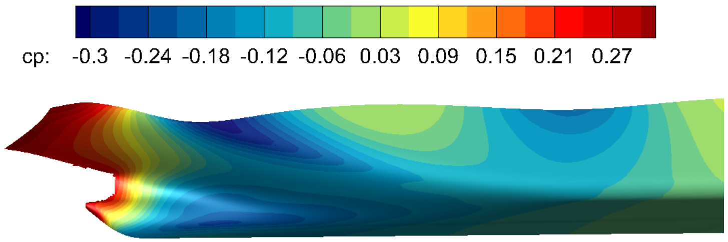
- Inject air bubbles:
  - Air lubrication to reduce resistance
  - Around hull against machinery noise (“Masker system”)
  - Into the cavitation (“Prairie-like system”)

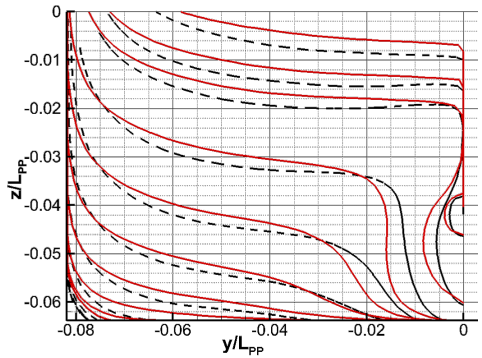
- Clean the hull and propeller
  - Minimise required thrust



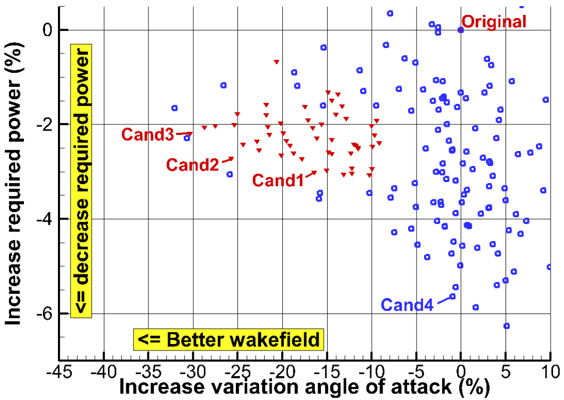
- Reduce speed
  - Minimise required thrust
  - On-board monitoring for real-time advice

# Hull form optimisation

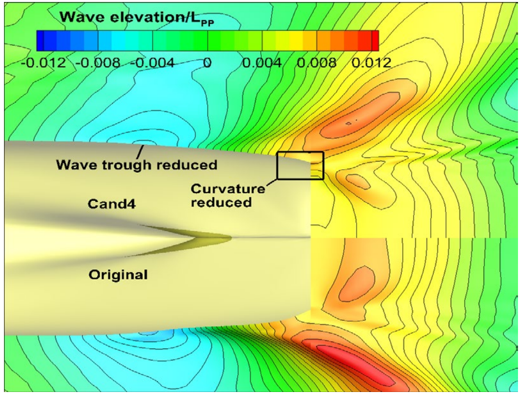


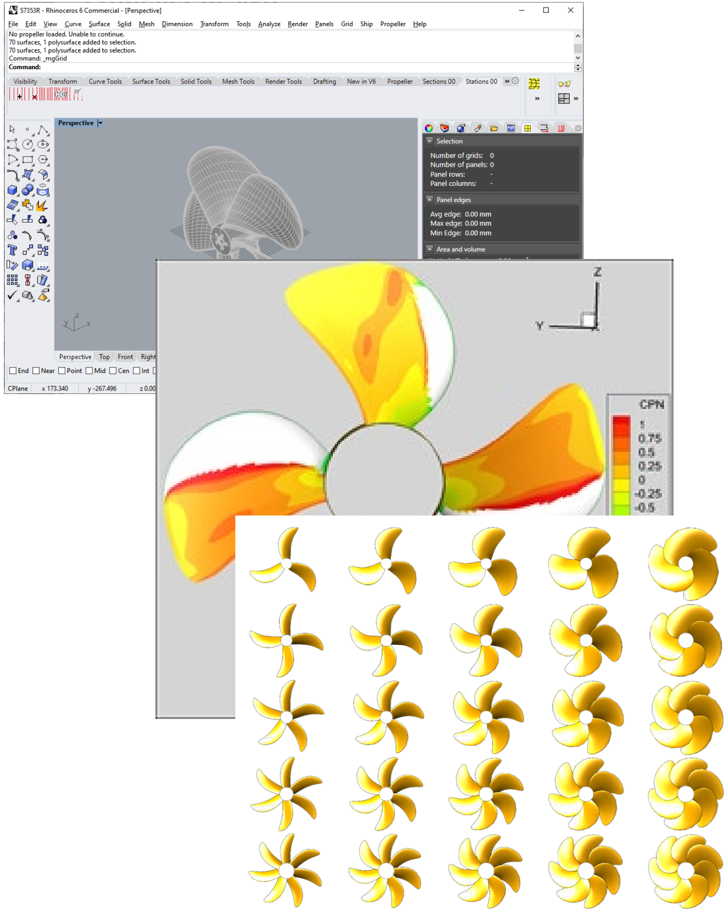

Calculate flow for >100 hull shapes

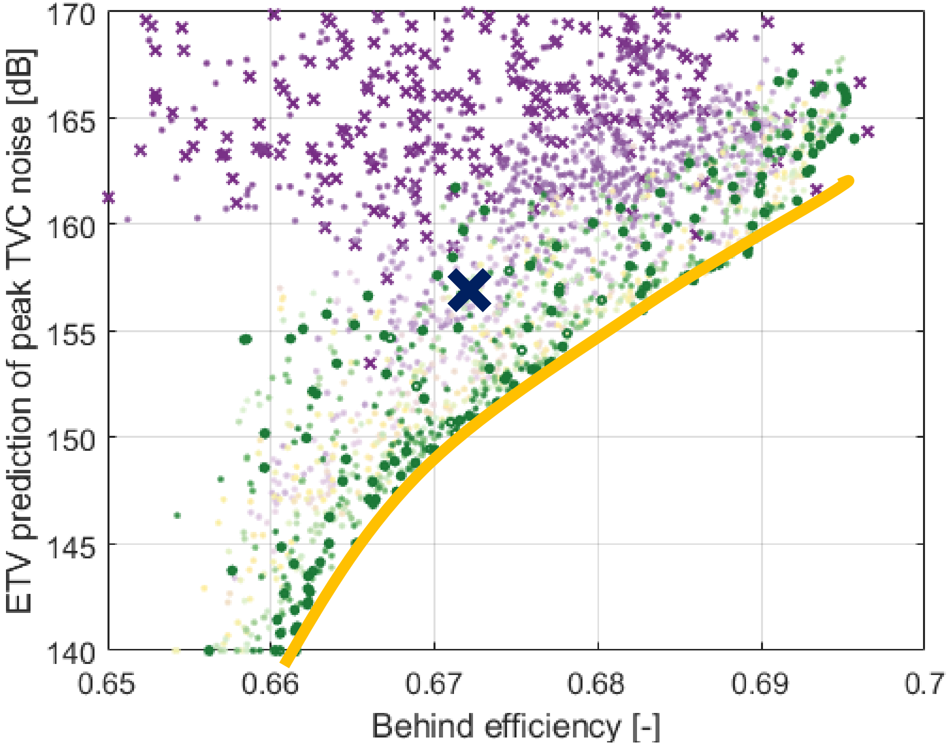



Analyse and determine optimal compromise



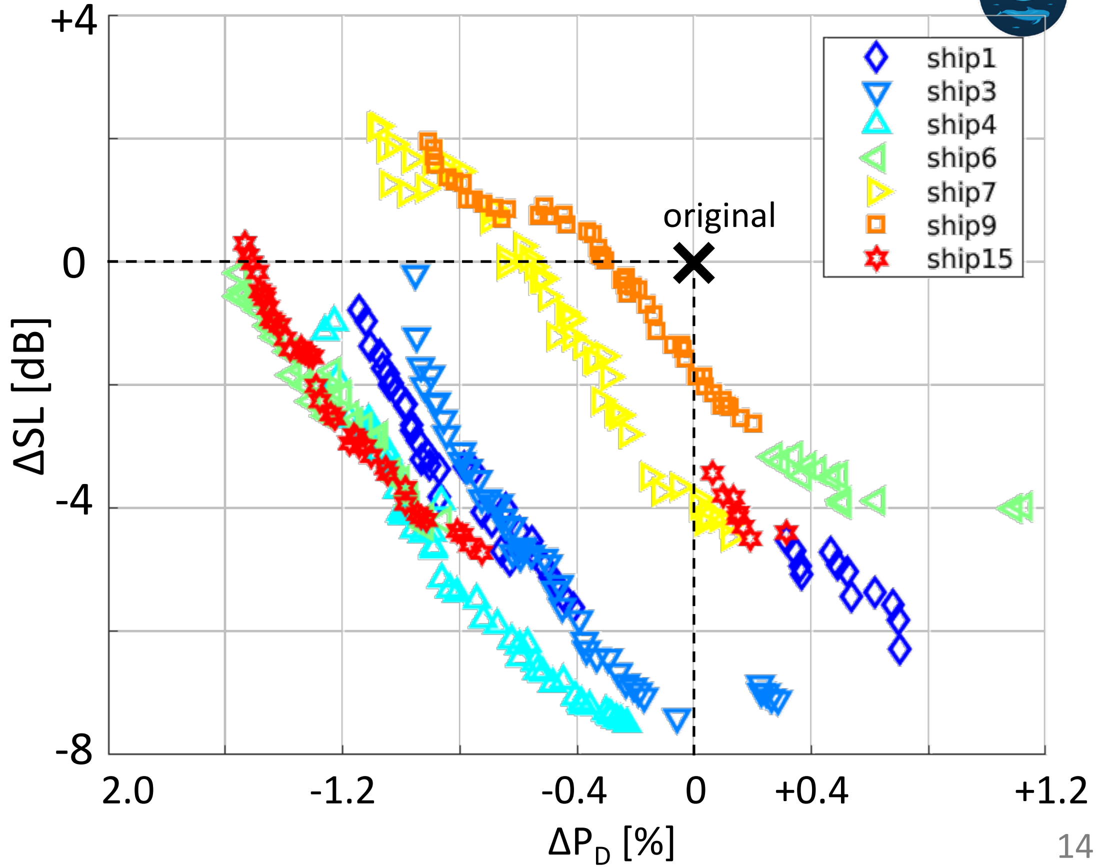
# Propeller design



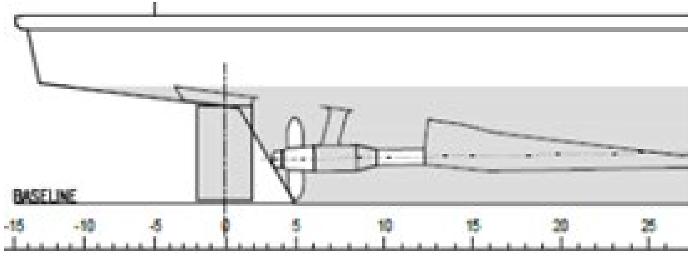


# Integrated hull & propeller design

- Traditionally:
  - optimise hull form for resistance
- Integrated aproach:
  - optimise hull form and propeller *simultaneously* for efficiency and URN



# Change propulsion concept (SATURN WP4)

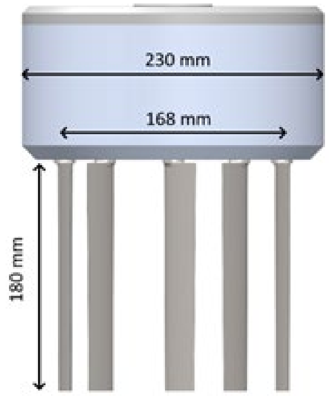
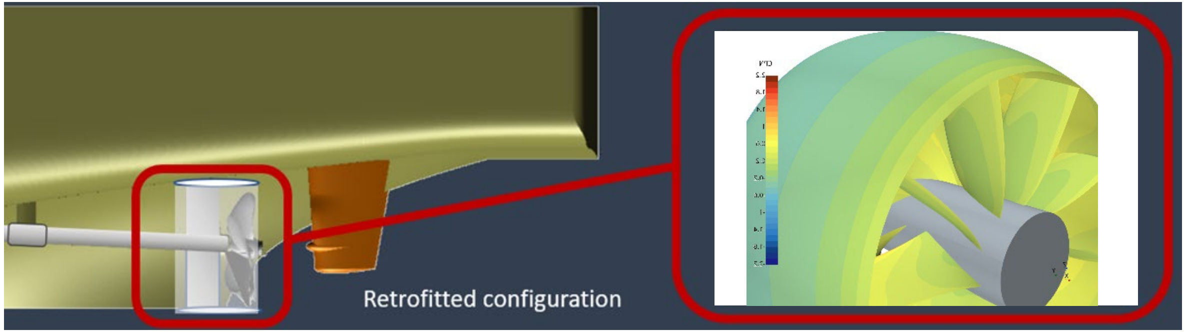



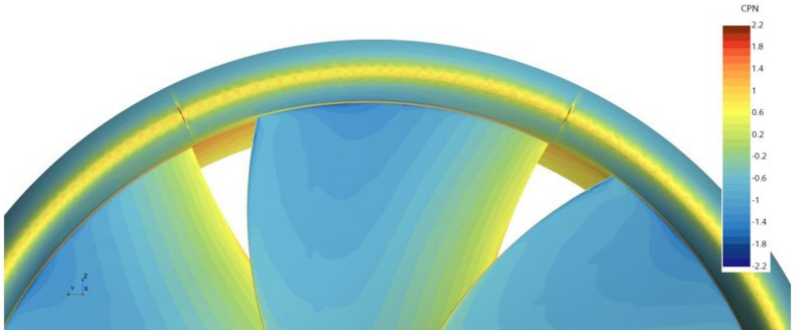

Figure 2 : Drawing of the ADV propeller, with main dimensions.


NAVAL GROUP

SIREHNA NAVAL GROUP

# Change propulsion concept (SATURN WP4)

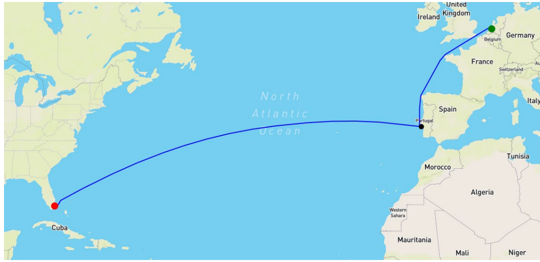



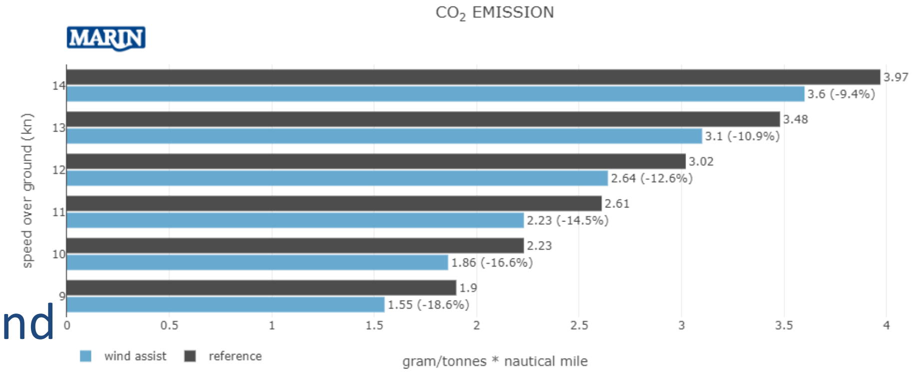




- Suppresses cavitation on rotor
- Improves efficiency +2% in comparison with existing propeller

# Wind assistance

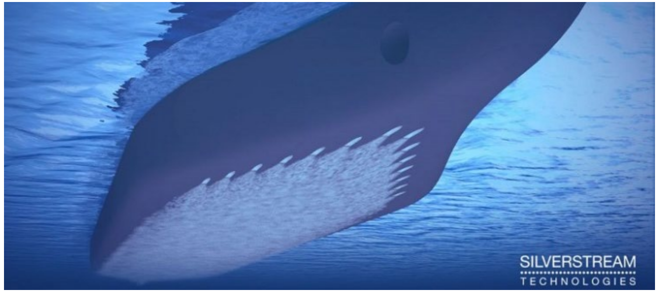
- Wind assistance reduces thrust delivered by propeller
  - Reduced cavitation (reduced noise)
  - Reduced GHG emissions
- Additional complexity in propeller design:
  - Oblique inflow into propeller due to sailing at a drift angle
  - Propeller works has multiple design conditions
  - Consequences thereof on efficiency and noise currently being researched



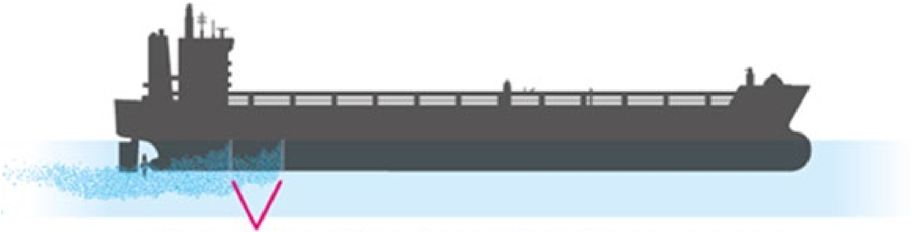
# Air injection

- Air lubrication
  - Various studies show around 5% reduction of fuel consumption



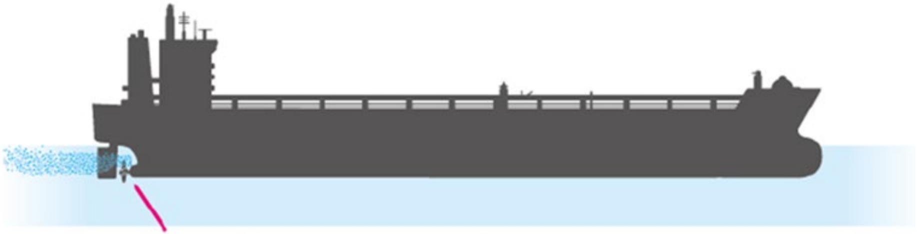

*https://www.silverstream-tech.com/*

- Along the hull to reduce machinery-induced URN:
  - Masker system



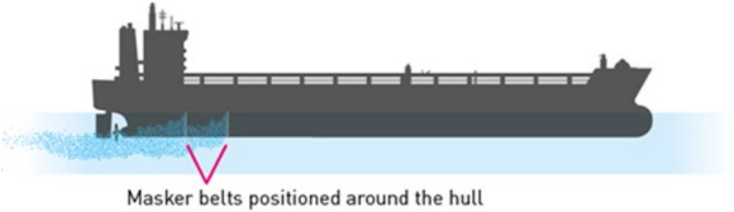
Masker belts positioned around the hull

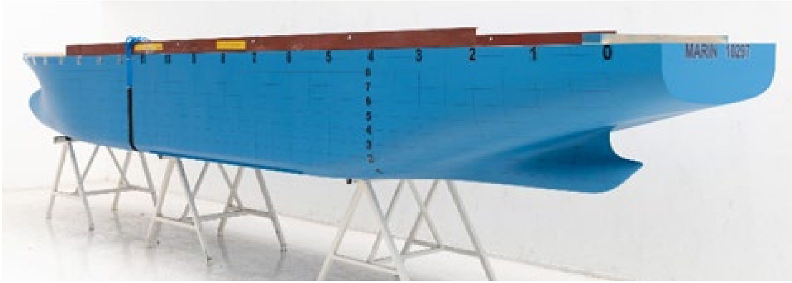
- Into the propeller disk to reduce cavitation-induced URN:
  - Prairie-like system

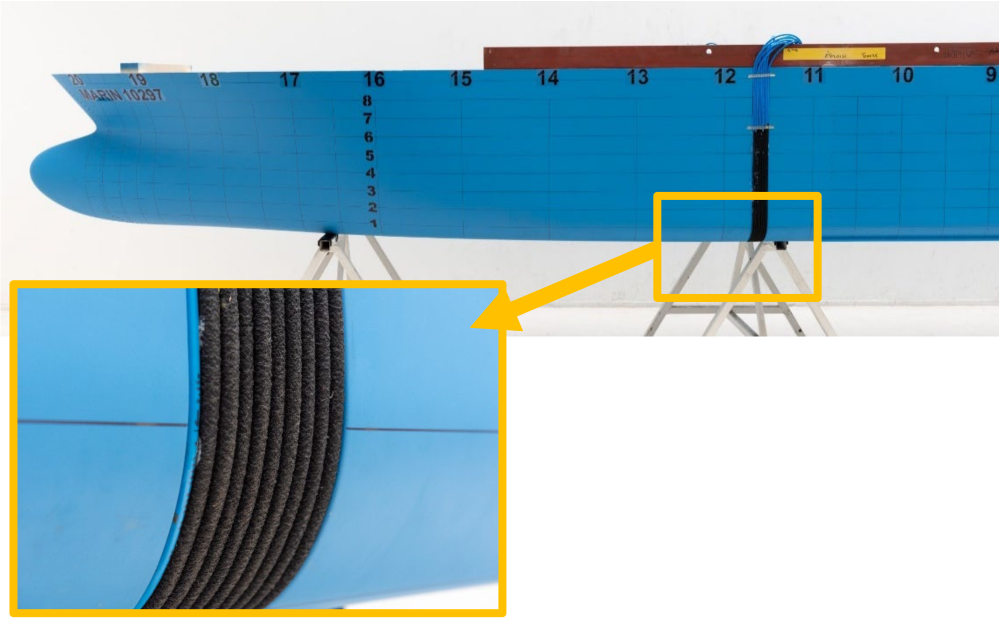


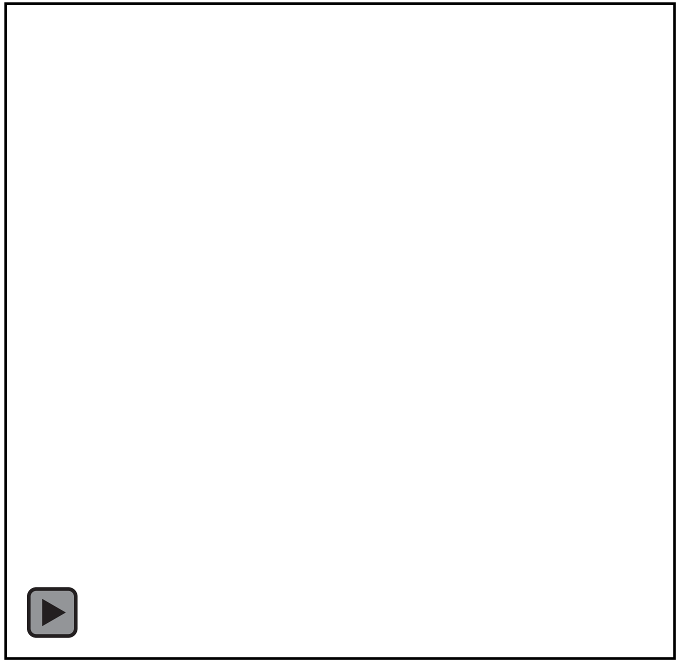
Bubbles injected in propeller inflow

# Air injection: Masker system (SATURN WP4)

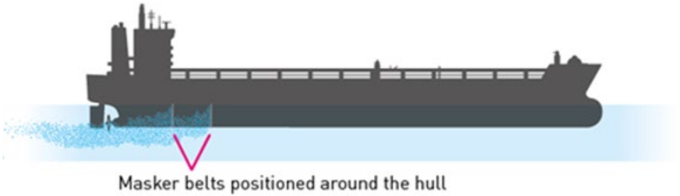


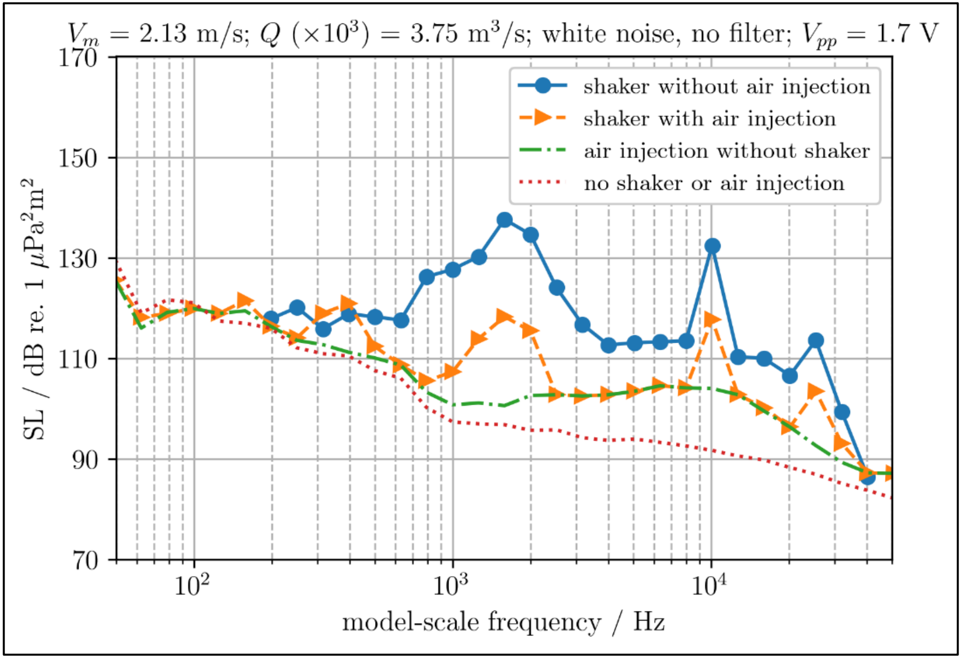



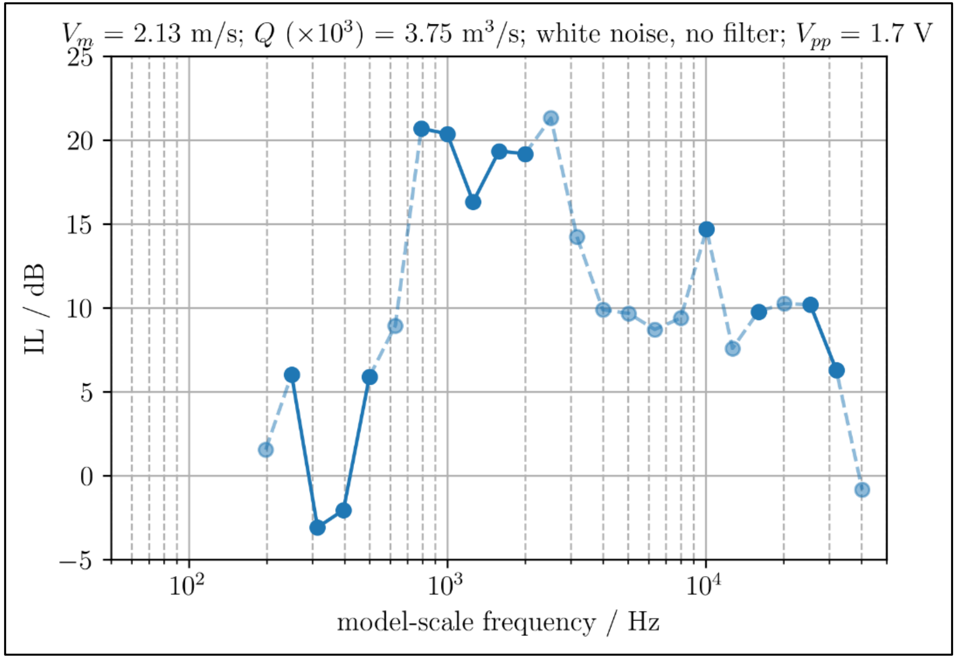




# Injection: Masker system (SATURN WP4)

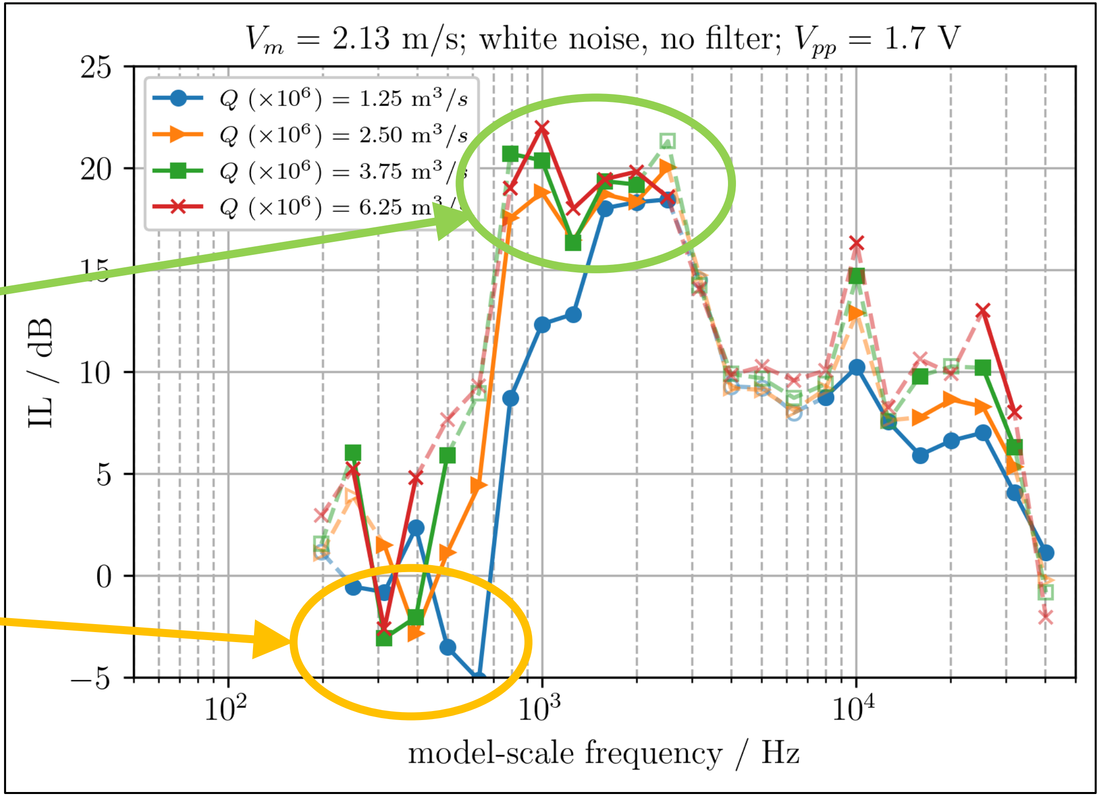


# Air injection: Masker system (SATURN WP4)

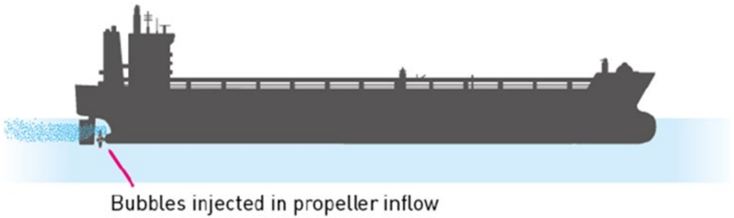
Masker belts positioned around the hull

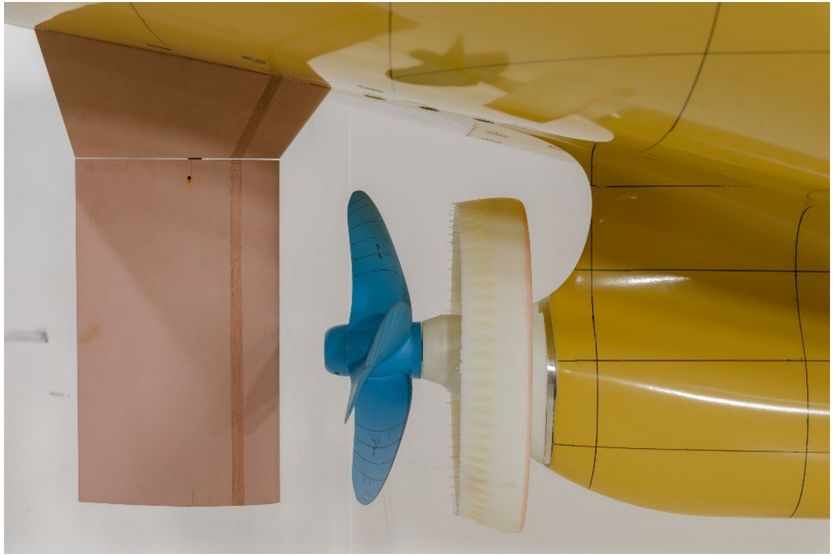


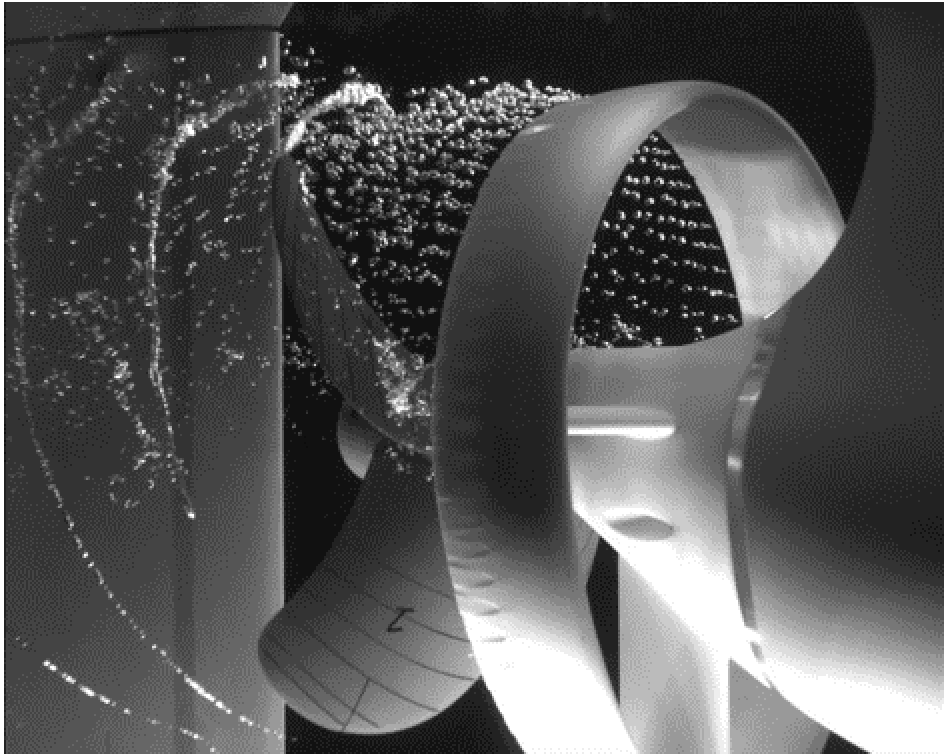

up to 20 dB reduction

sometimes small increase

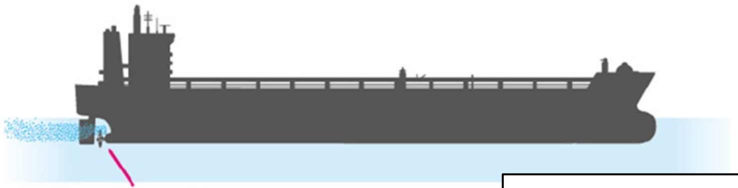
# Air injection: Prairie-like system (SATURN WP4)



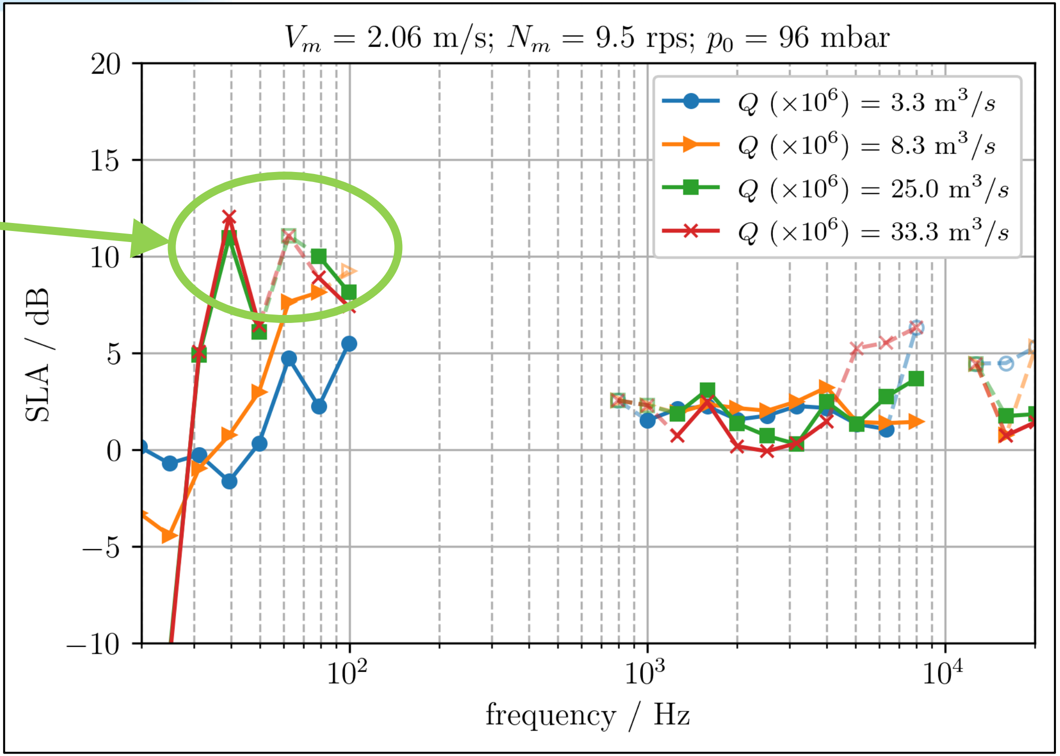





# Air injection: Prairie-like system (SATURN WP4)

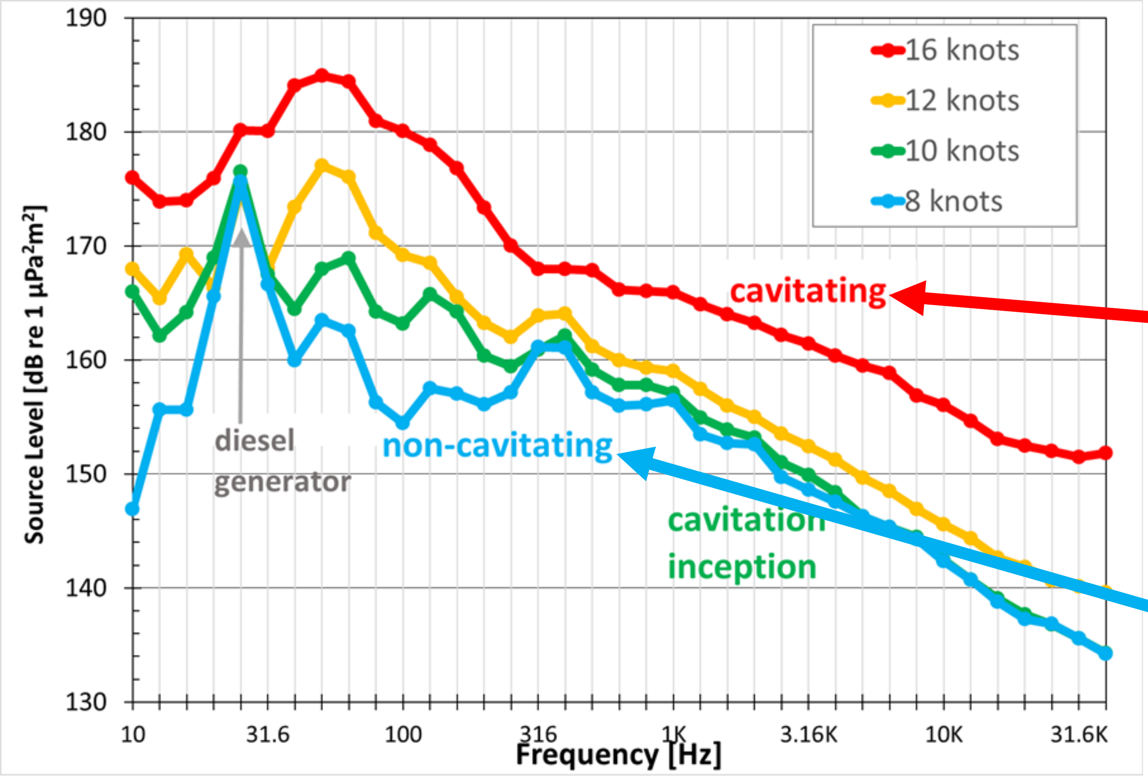


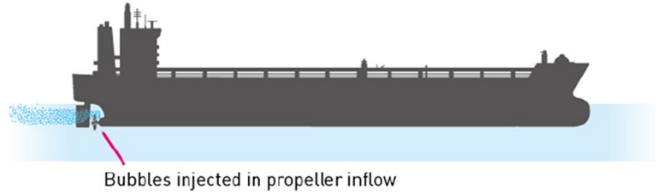

up to 10 dB reduction

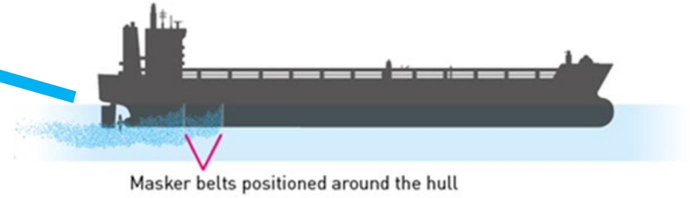



- Small influence of air bubbles on propeller thrust and efficiency

# Application of air injection: 173 m cargo vessel



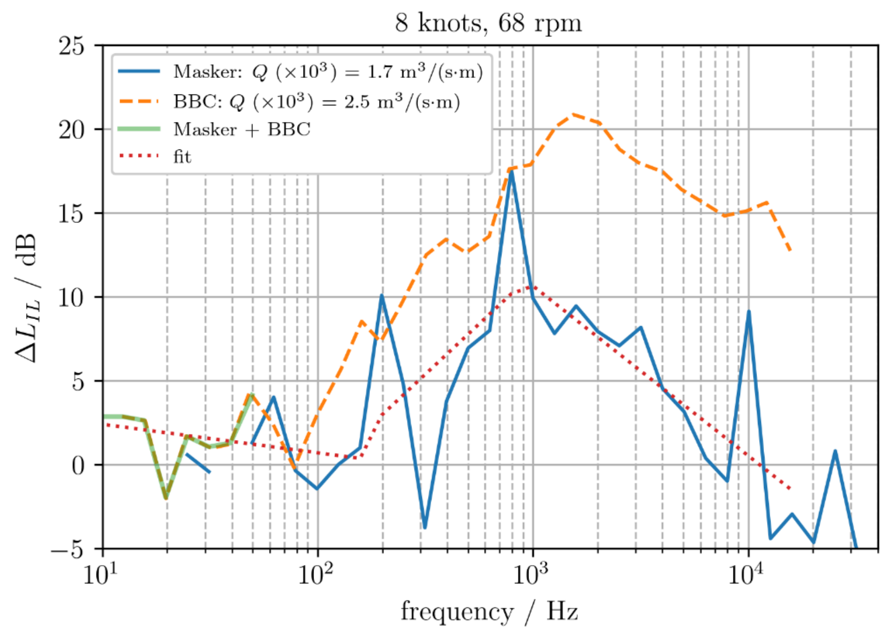



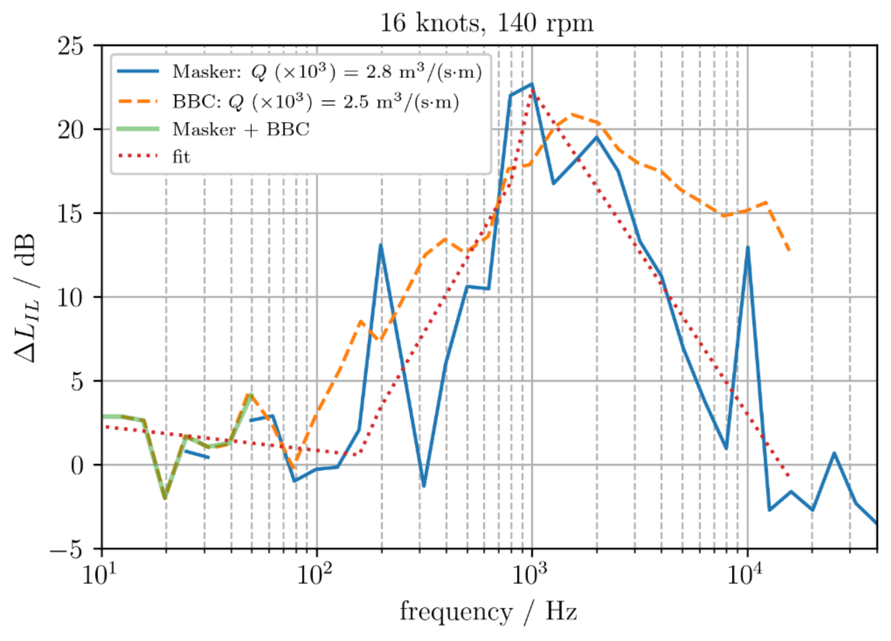




*Source: Arveson & Vendittis (2000) 173 m cargo vessel*

# Application of air injection: 173 m cargo vessel

- Insertion loss due to Masker system

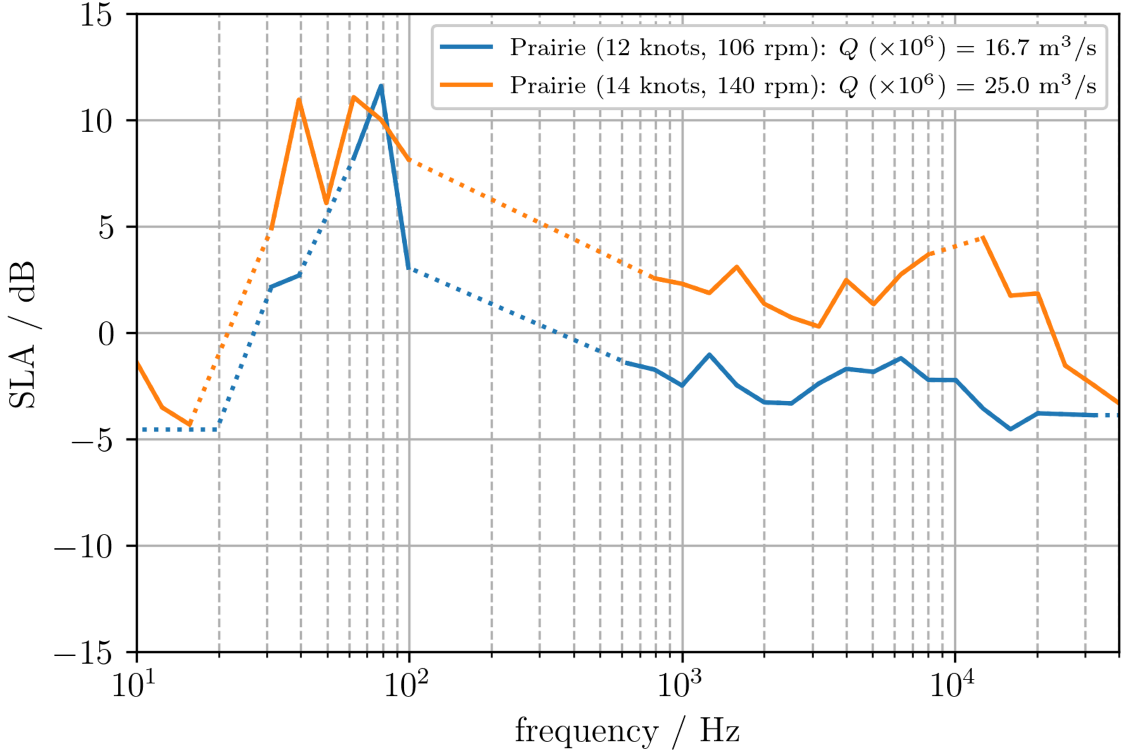



*Big Bubble Curtain data: M.A. Bellmann (2014). Overview of existing Noise Mitigation Systems for reducing Pile-Driving Noise*

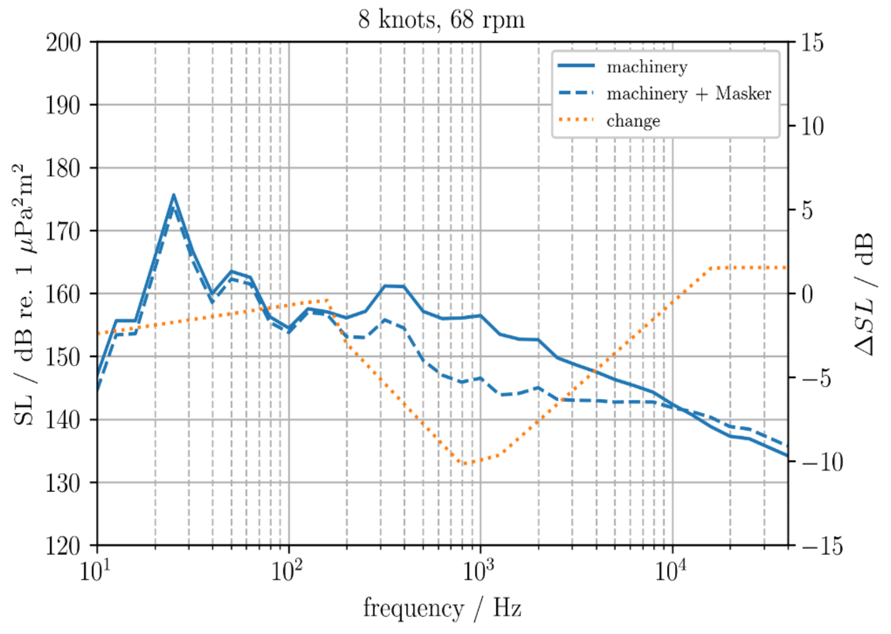
# Application of air injection: 173 m cargo vessel

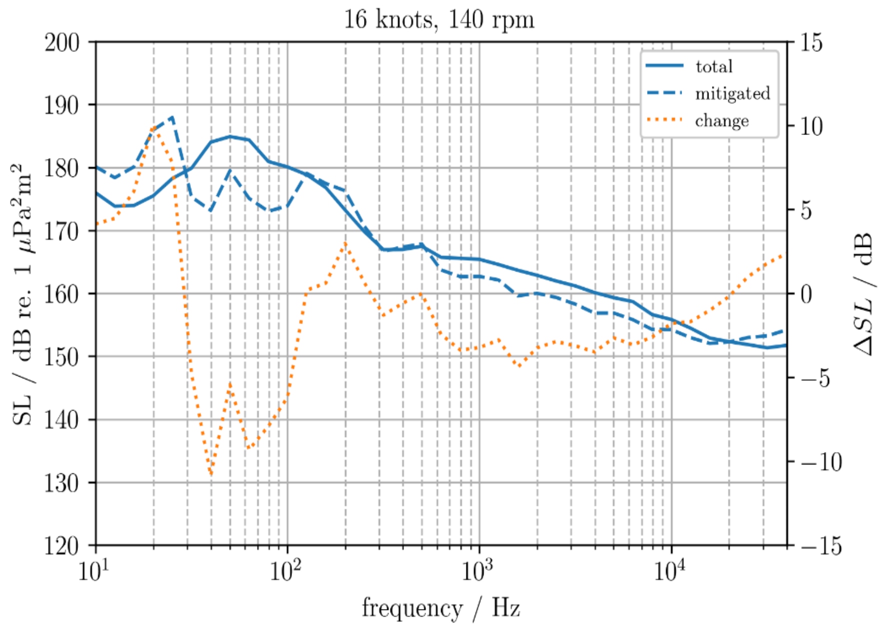
- Source level attenuation due to Prairie-like system



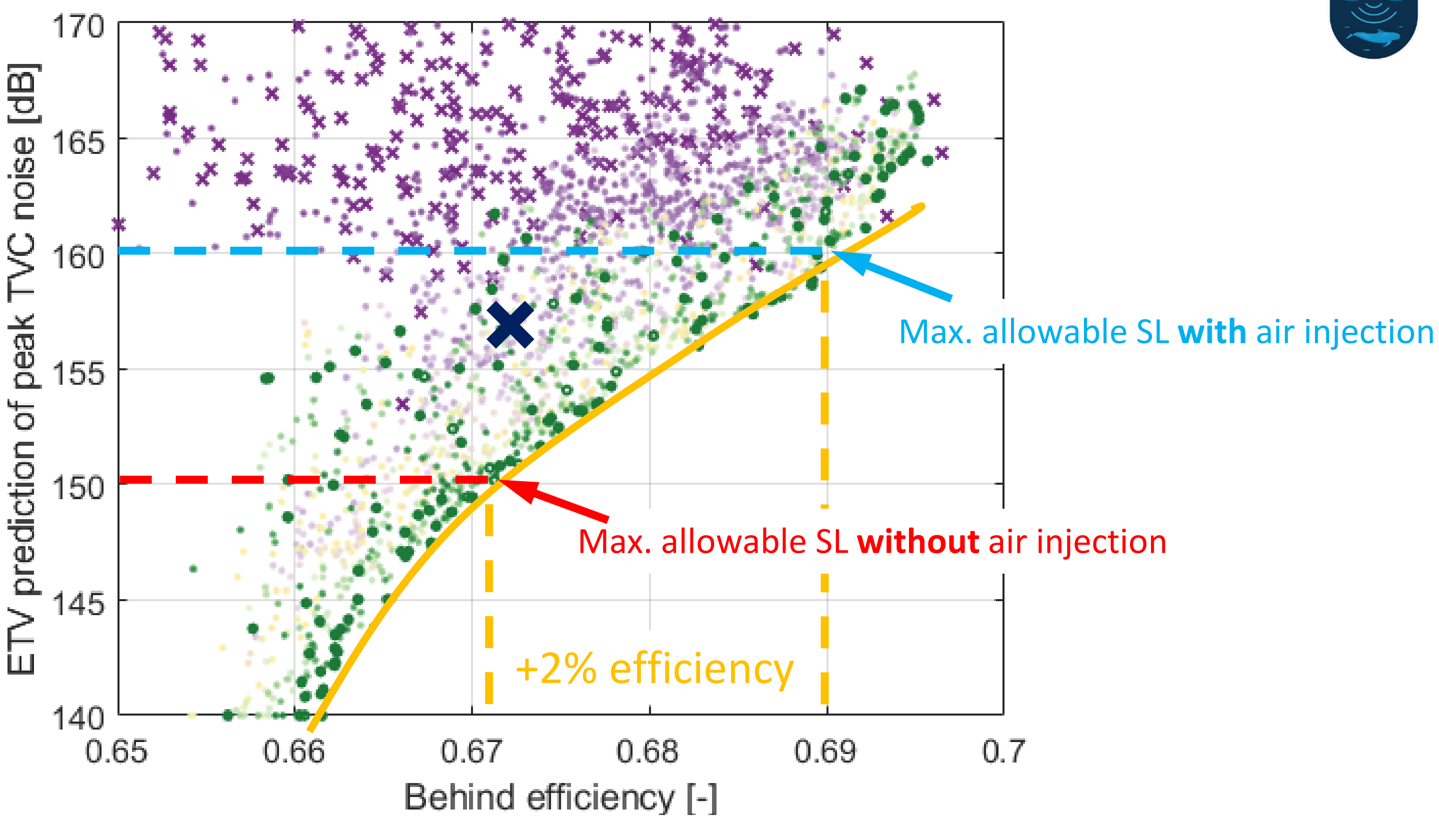
# Application of air injection

- Resulting noise levels



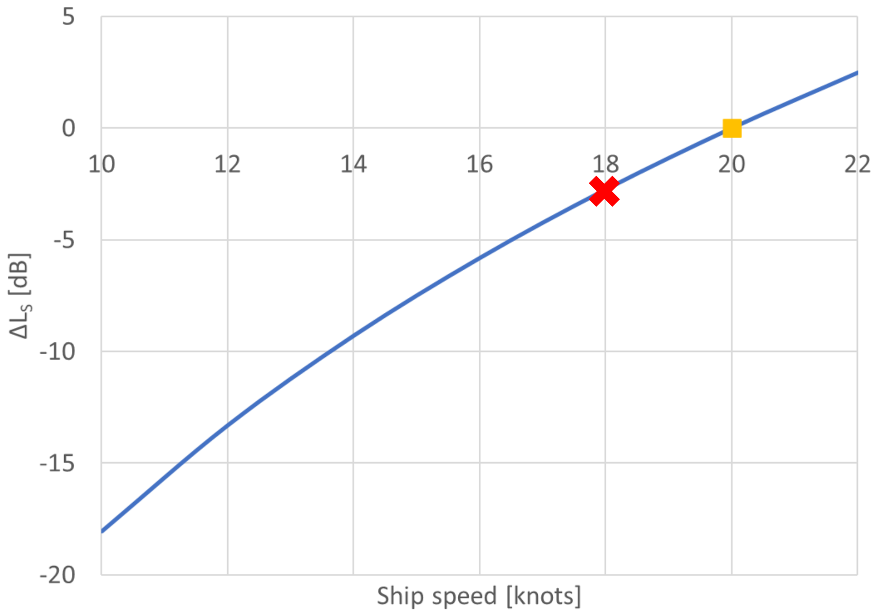



# Prairie-like system: influepropeller design



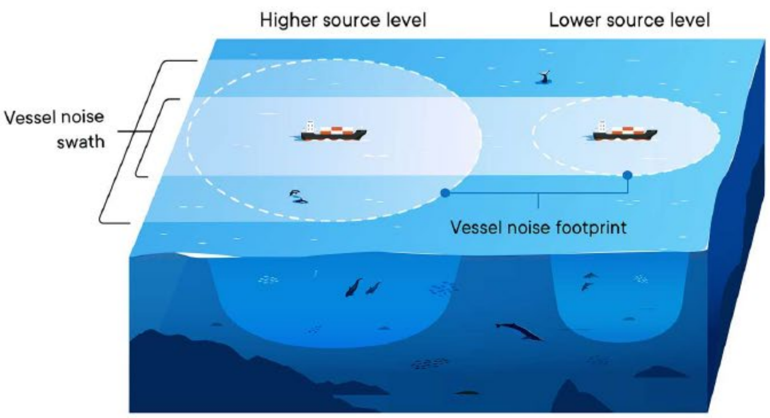
# Effect of speed reduction on URN and GHG emissions

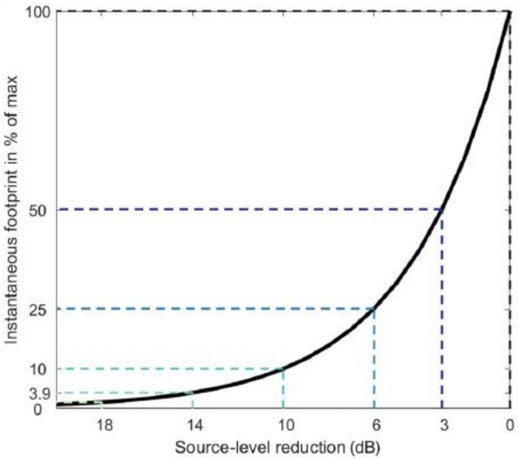
- Speed reduction very effective against URN
  - JOMOPANS-ECHO model*
- 10% speed reduction yields:
  - 3 dB noise reduction
  - 13% GHG emission reduction**
  - Some studies state 30% GHG emission reduction
- Big step in noise reduction:
  - Reduce speed to cavitation inception speed (CIS)
  - CIS not in JOMOPANS-ECHO model




** MacGillivray & De Jong (2021)*
*** Faber et al. (2017)*

# Effect of speed reduction on URN (SATURN WP3)



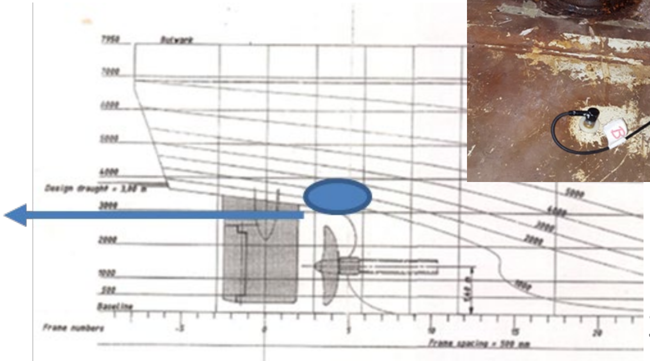

*Source: Findlay et al. (2023). Small reductions in cargo vessel speed substantially reduce noise impacts to marine mammals*

- 25% speed reduction:
  - Source-level reduction of 6 dB:
    - 50% reduction in the swath
    - 75% reduction in the instantaneous acoustic footprint
  - Transit time increased by 25%
- Net reduced noise impact: footprint deceases more than transit time increases

# Cavitation URN estimation by onboard sensors

- How slow is slow enough?
- Onboard monitoring to estimate URN real-time
- Tested on RV Pelagia
- 4 pressure sensors and 4 accelerometers on hull above propeller
- Real-time advice:
  - Reduce speed to reduce noise

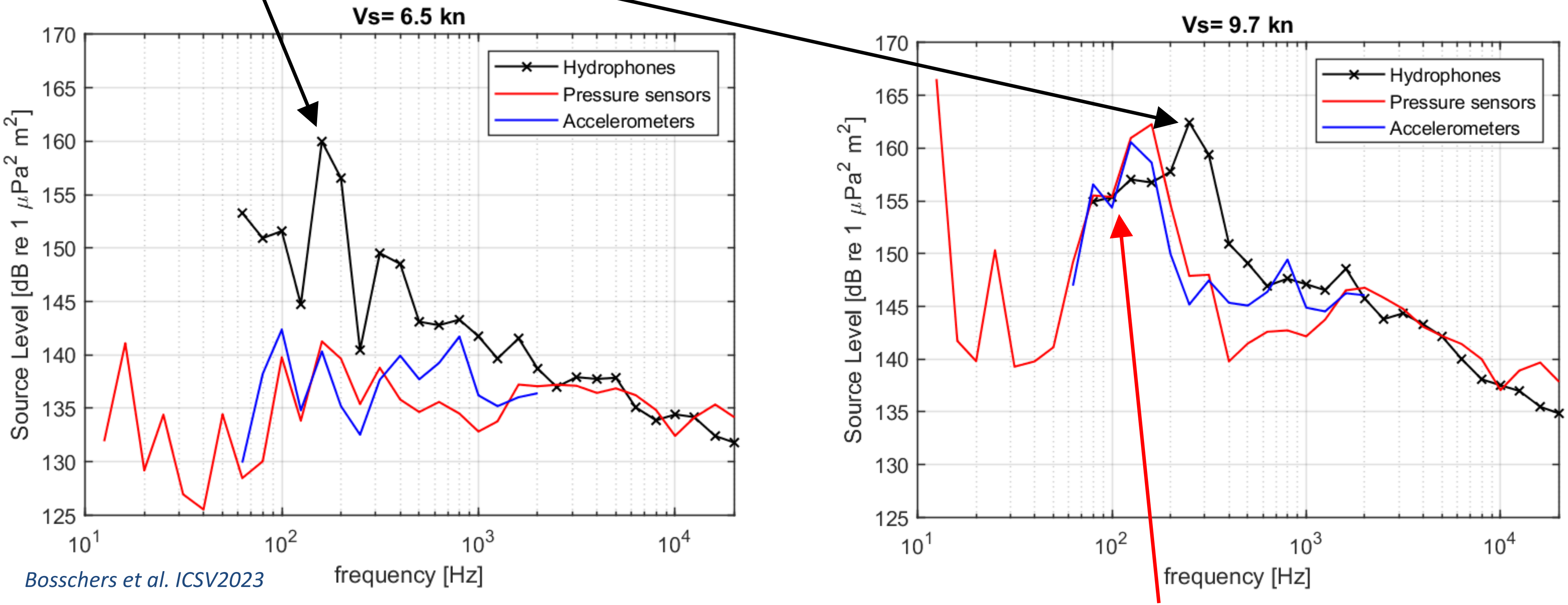

Bosschers et al. ICSV2023



sensors

# Validation of URN estimation by onboard sensors

Peak in URN caused by diesel generator

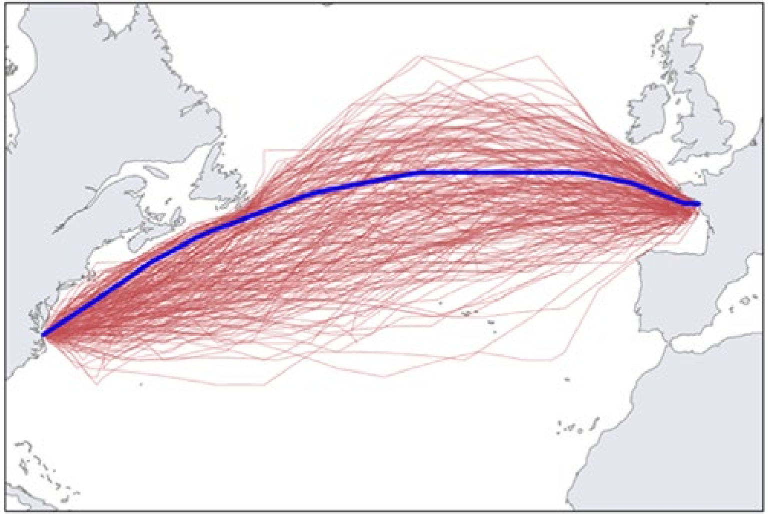



*Bosschers et al. ICSV2023*

Peak in pressures caused cavitation

# Route optimisation

- Optimise route for minimum noise impact:
  - Minimise speed (in areas with sensitive wildlife)
  - Optimal use of wind assistance
  - Just-in-time arrival
  - Try to avoid increasing speed to compensate for slowing down

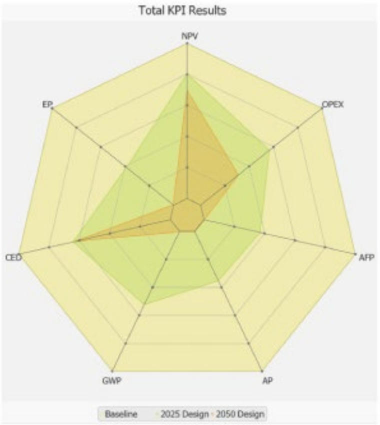


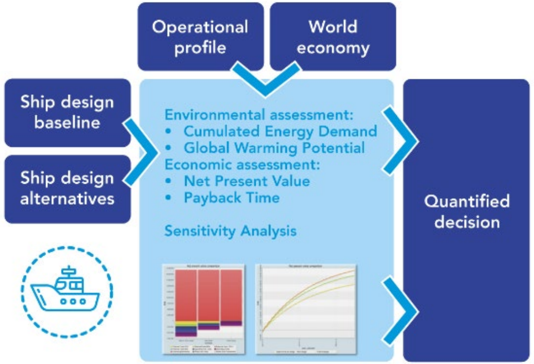
- More ships needed due to speed reduction:
  - Reduced fuel costs compensate operational costs of additional ships

    *Lee et al. (2015)*

# Cost-benefit analysis (SATURN WP4)

- SATURN: Cost-benefit analysis of mitigation solutions
- KPI: Capital costs + operational costs
  - Depends on ship type and operational profile
- KPI: Reduction of impact on marine species
  - Translate change in source levels to change in impact for single ship
- KPI: Impact on energy efficiency
  - Use will be made of LCPA software



# Summary

- To be done
- What are win-win solutions?
  - Speed reduction is a win-win but there is a need to deliver goods on time
  - Technological mitigation measures can help to increase flexibility in ship speed while maintaining acceptable noise and GHG emissions

Saturn
Developing Solutions for Underwater Radiated Noise

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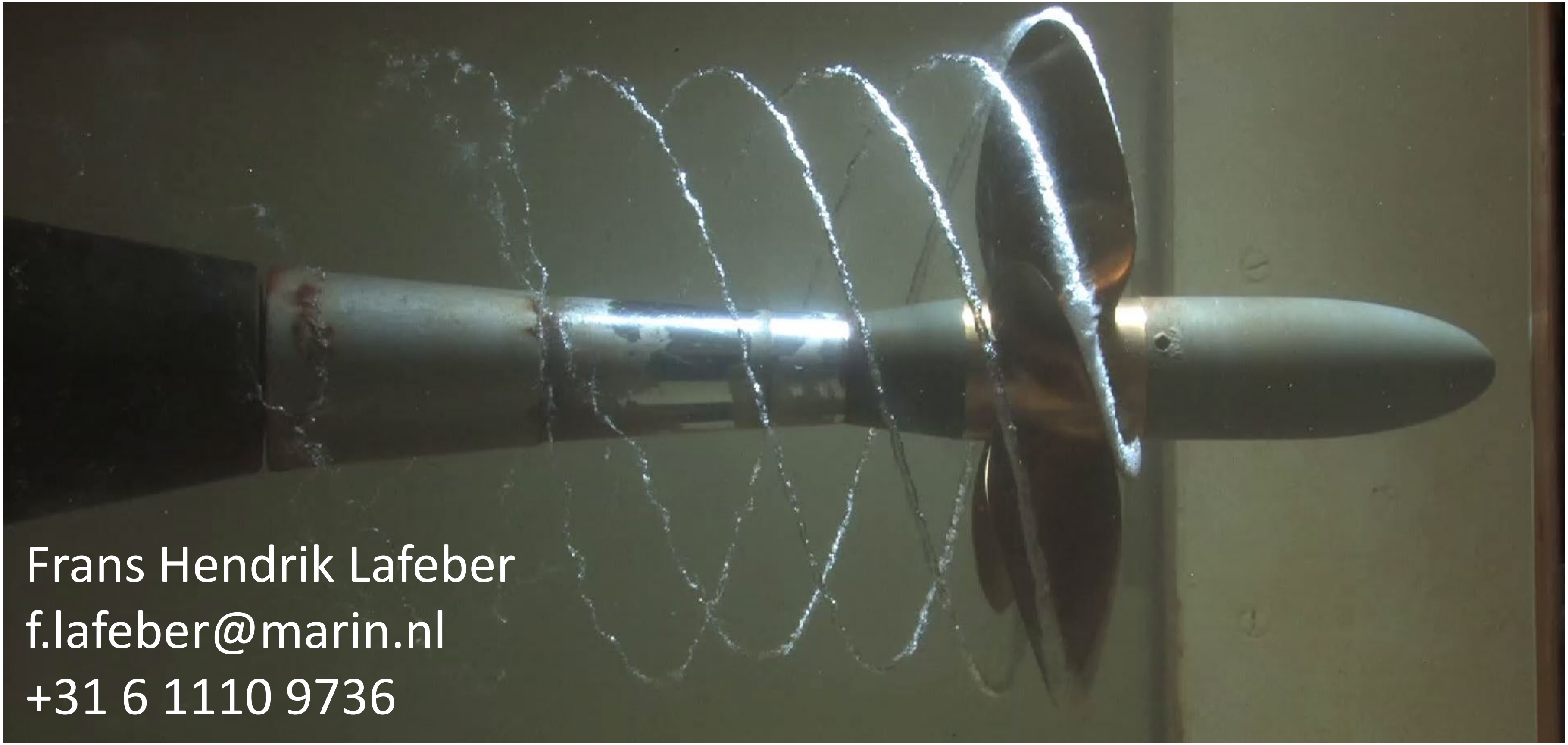
# Thank you



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