Propeller design by optimization

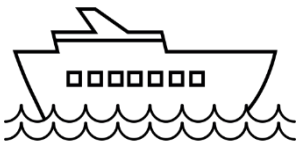
PIAQUO project overview

Main objective is to reduce radiated noise generated by vessels and to adapt it in real-time to ecosystems crossed in order to minimize their impacts on the environment.

GOALS:

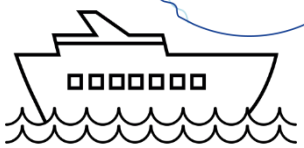
1. **Practical implementation of ship radiated noise reduction using improved propellers**
2. **Practical implementation of ship radiated noise real-time self-estimation and control**
3. **Inducement of virtuous approaches from ship owners to reduce shipping URN**
4. **Adaptation of the maritime traffic according to the real-time state of marine ecosystems**
5. **Setting a broadcasting service for decision making support to reduce shipping noise impact**

PIAQUO Goal 1 overview



Sea trials

Comparison (if possible)



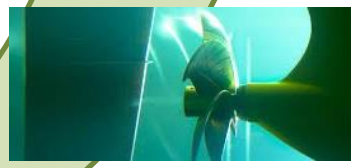
Sea trials

Retrofit (if possible)

Model

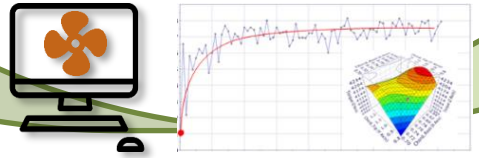
Model tests

Comparison



Model

Model tests



Numerical optimisation

UNIGE ACTIVITIES:
Design by optimisation
Small Passenger boat

Ship characteristics

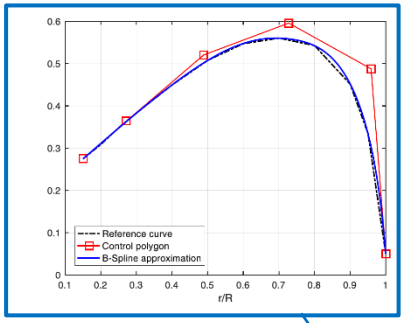
Primero VII

LOA = 27.60 m
Bmax = 6.82 m

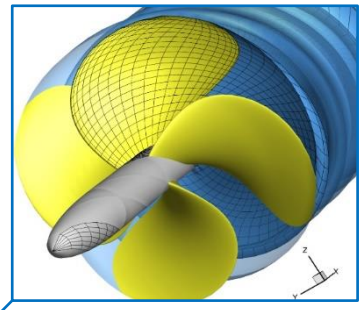
Δ= 76.5 t (full load)
64.5 t (intermediate*)
46.0 t (light)
Vmax = abt.22 kn
(intermediate displacement)
Typical speeds: 10-15 kn

*50% consumables and 250 (over 350) passengers: most common condition, used as design condition

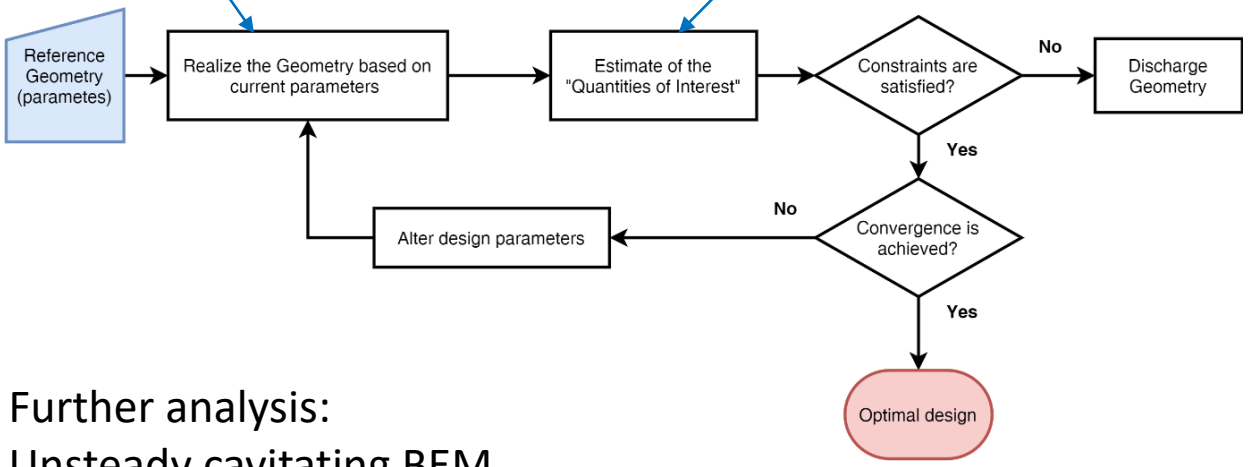
Propellers' design optimizing at the same time noise emission and efficiency



- **Parametric description using B-Splines;**
- **35 free design variables;**

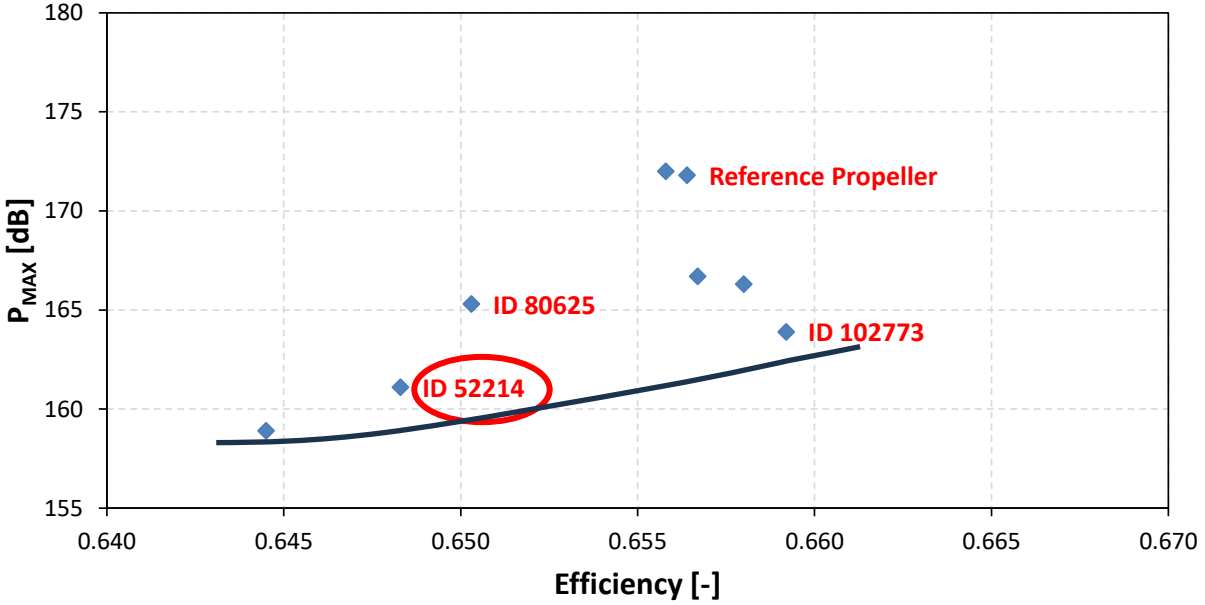


- **BEM for the estimation of QOI;**
- **18 design objectives/constraints at different propeller functioning conditions** (cavitation/boat speed/engine matching)



Further analysis:
Unsteady cavitating BEM
Steady non cavitating RANS
Unsteady non cavitating BEM + ETV

Propellers' design optimizing at the same time noise emission and efficiency



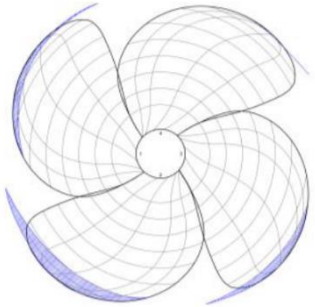
ETV calculations (maximum vortex peak pressure vs propeller efficiency for different propellers)

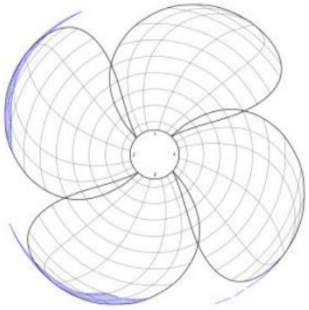
Efficiency and pressure reduction are conflicting objectives, as expected. Some designs are able to reduce noise keeping or slightly improving efficiency.

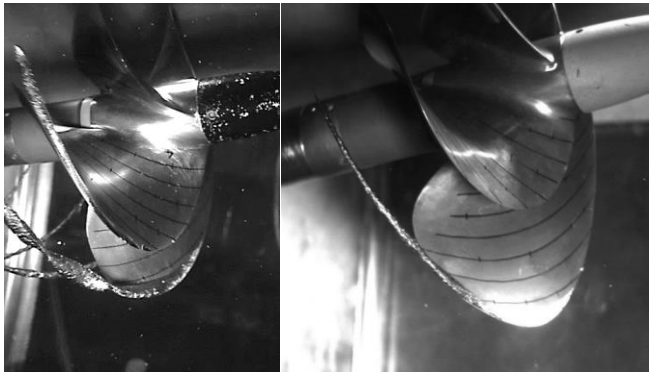
ID 52214 propeller has been chosen in order to emphasize noise reduction for the sake of model and full scale tests, accepting a slight efficiency reduction (about 0.1 kn reduction at constant power for reference configuration @ 400 kW).

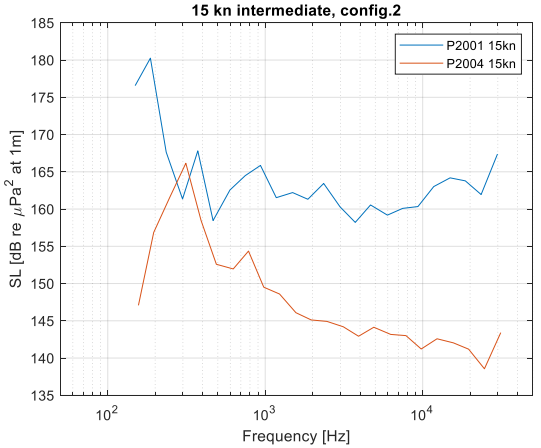
Realization of 2 model test optimized propellers and trials in cavitation tunnel and towing tank

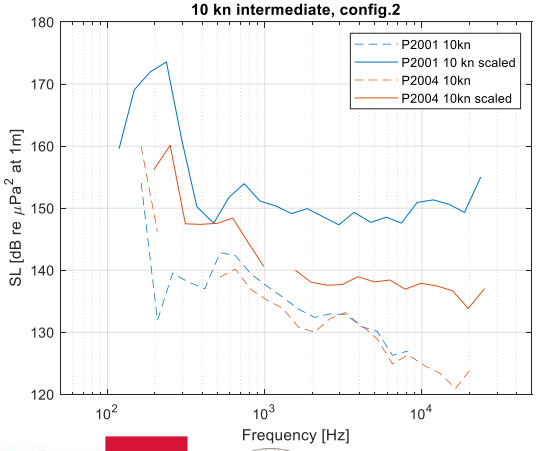
15 kn, intermediate
Reference prop. (P2001) vs Optimized prop. (P2004)

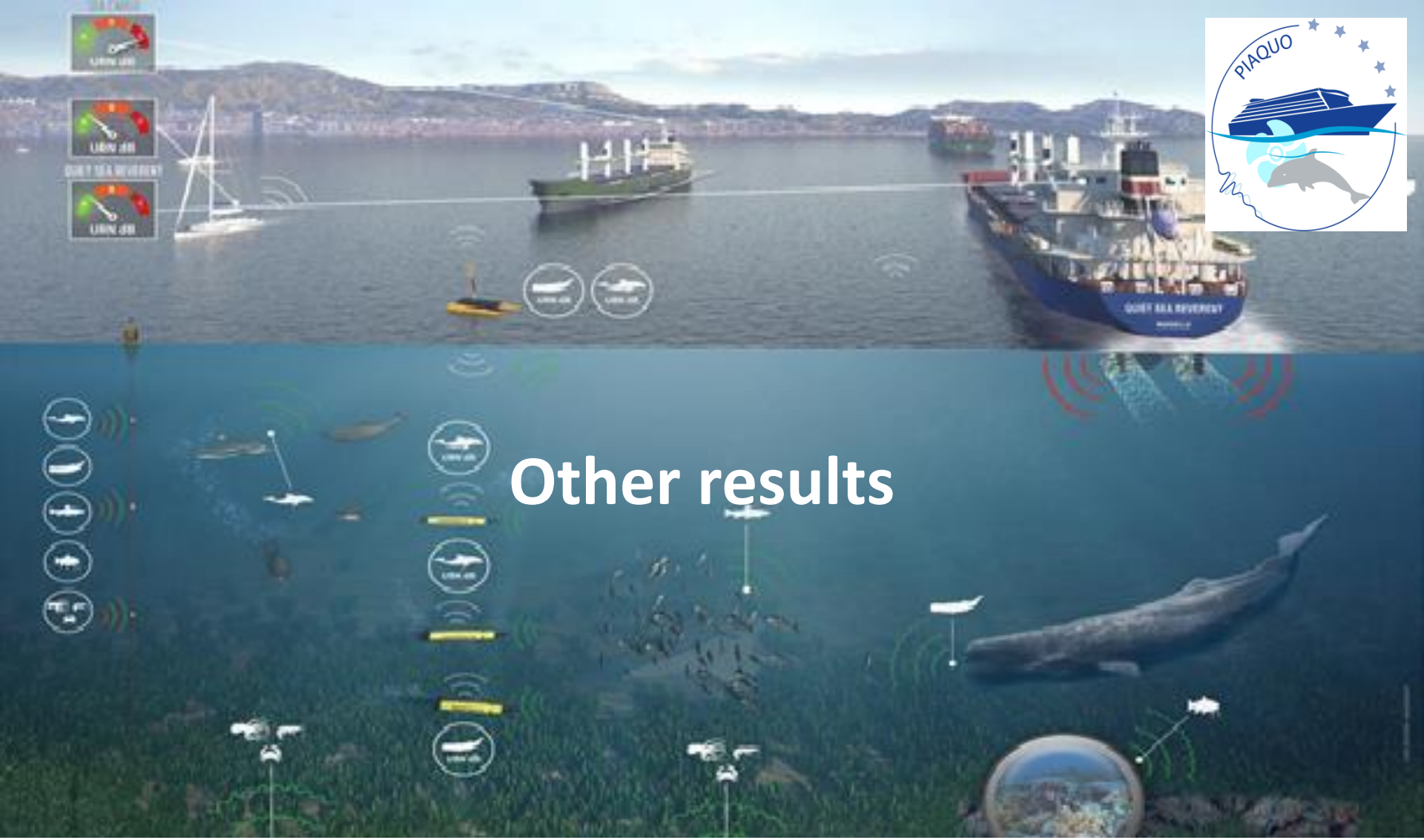










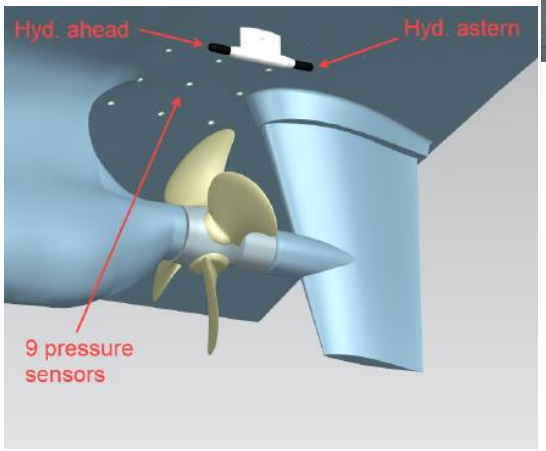


Other results

Ship characteristics

Eurocargo Cagliari

LOA = 201 m
Bmax = 26 m
Δ= abt. 33000 t
22 kn @ 20 MW



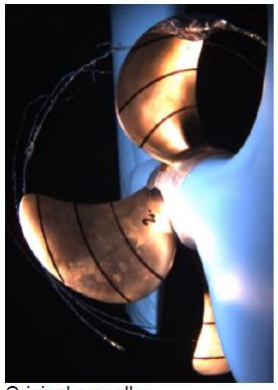
Two propeller designs chosen:

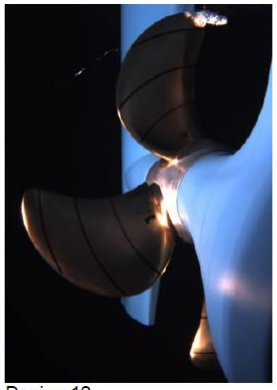
Design 12: same efficiency

Design 15: 1.4% reduction

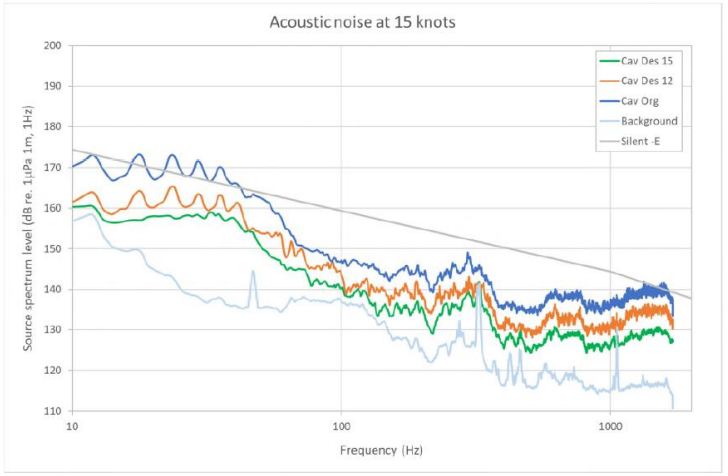
Propeller optimisation

15 kn


Original propeller

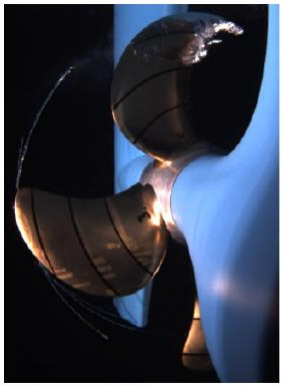

Design 12


Design 15

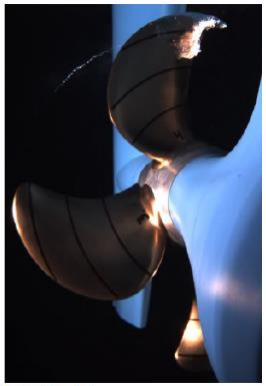


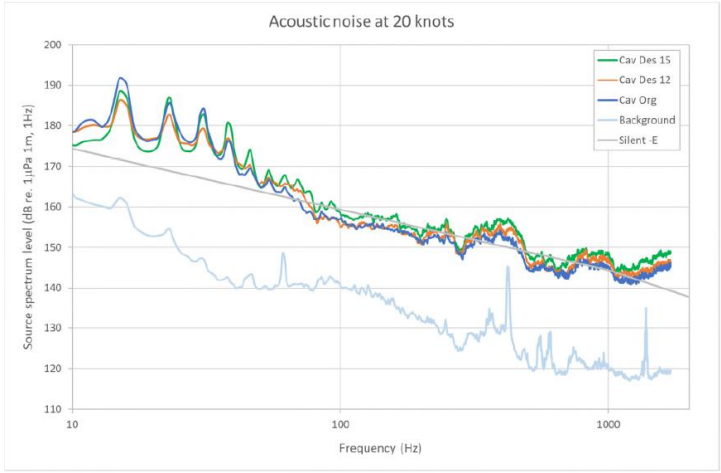
approx. 10 dB in the whole frequency range for des. 15, 5 dB for des. 12

20 kn


Original propeller


Design 12


Design 15



Similar URN

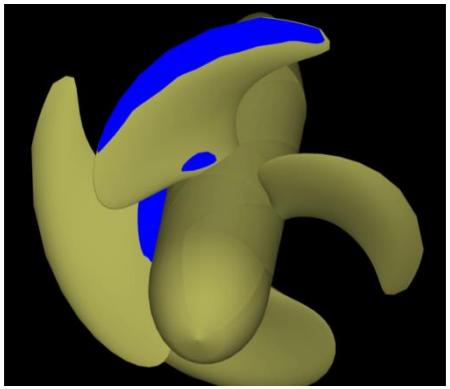
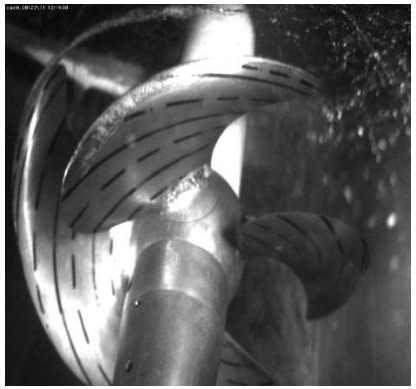
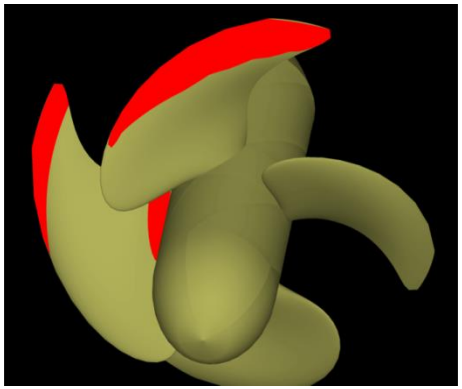
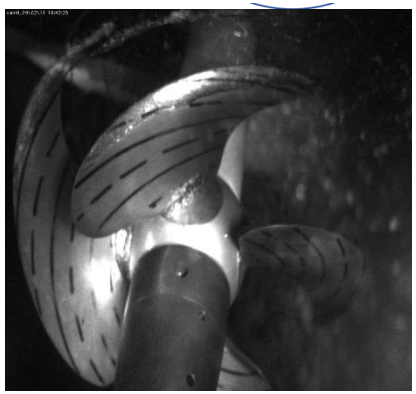
@18 kn reductions up to 40 Hz similar to 15 kn, over 5 dB with des. 15 only

SILENV Project (FP7 project) - Ferry

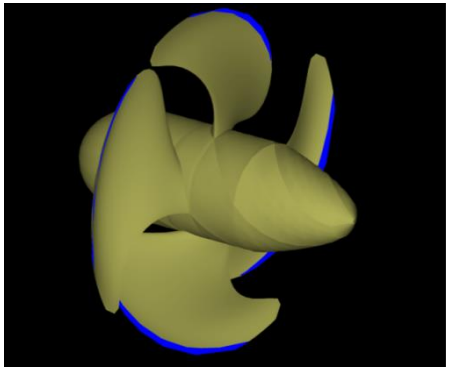
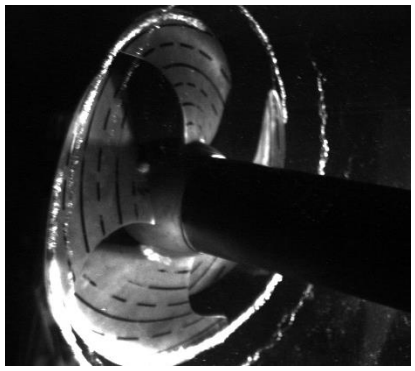
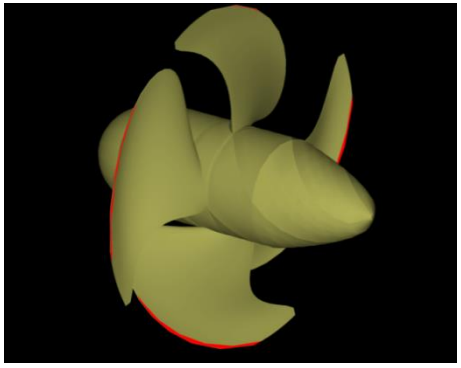
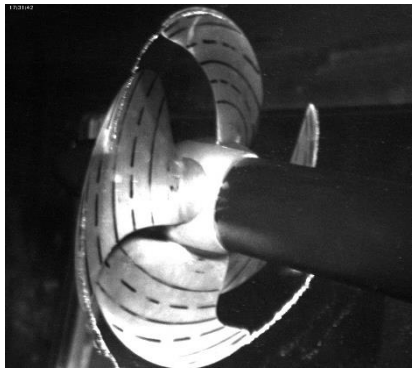
Original

Optimised

Design Pitch

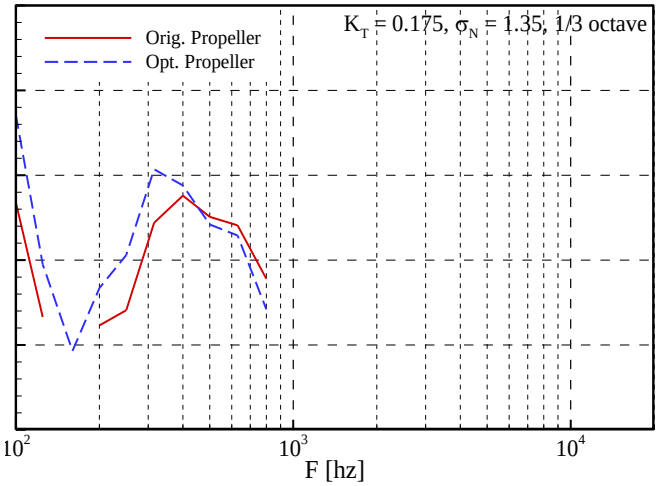





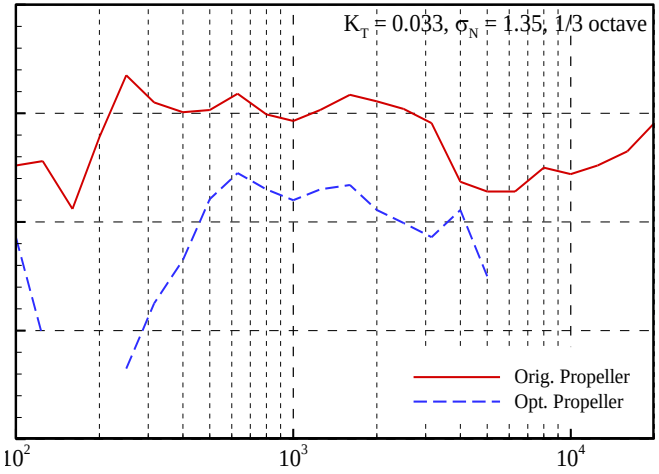
Reduced Pitch

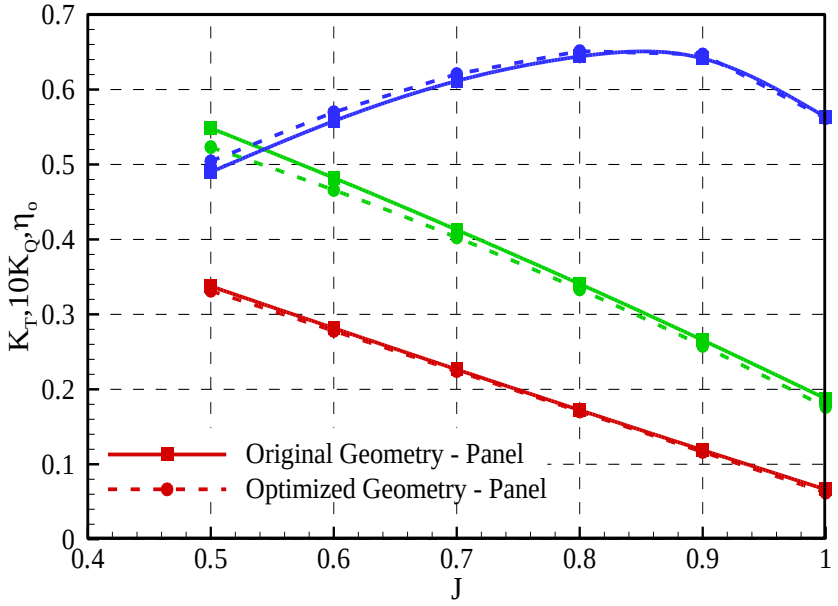





SEVENTH FRAMEWORK PROGRAMME

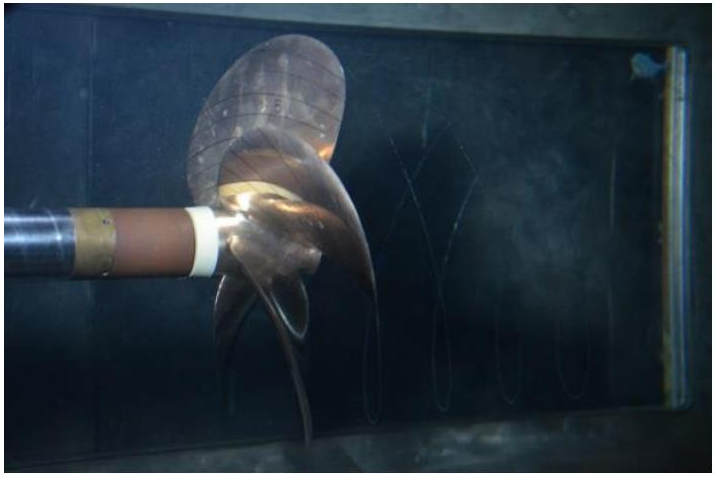
SILENV Project (FP7 project)



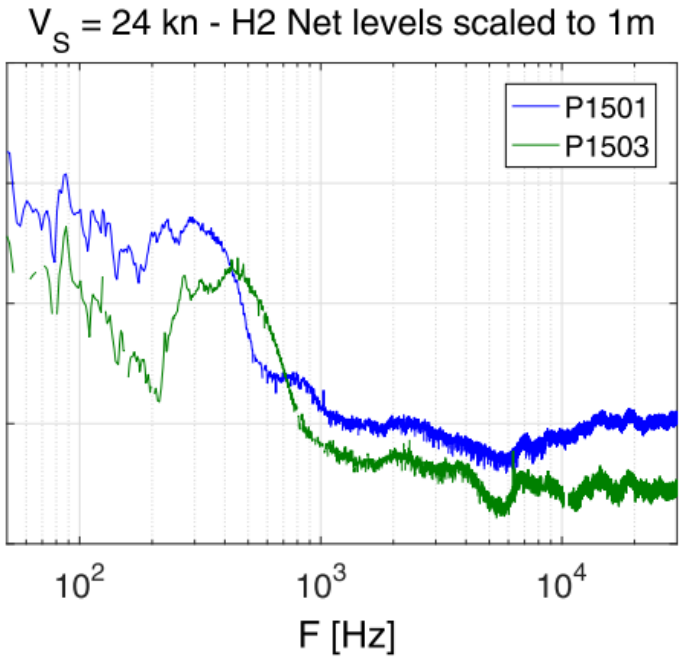




ABC Project (Italian MISE Project) – Leisure Boat



About 1 kn increase @ full scale
(no URN data available)

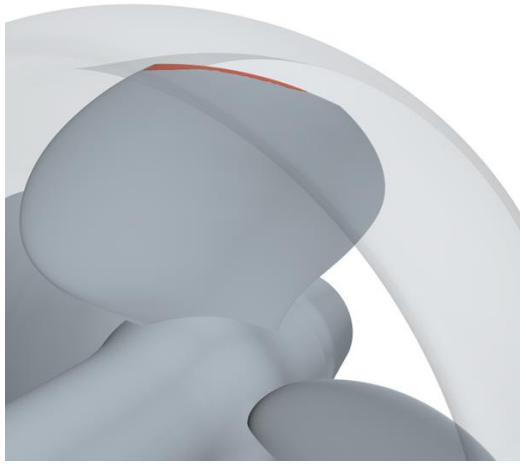


ABC – Advanced Boat Concept
Progetto n. C01/0889/00/X19

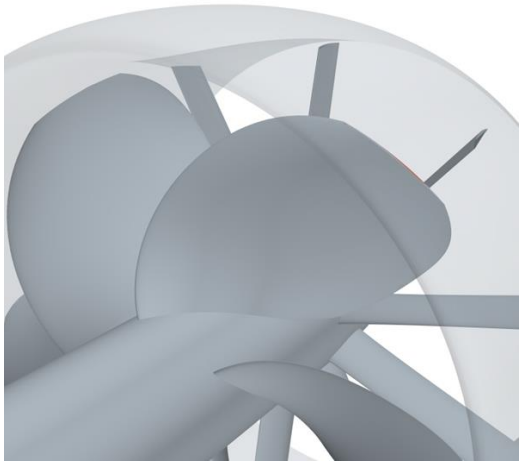
AZIMUT | BENETTI GROUP

Unconventional propulsors

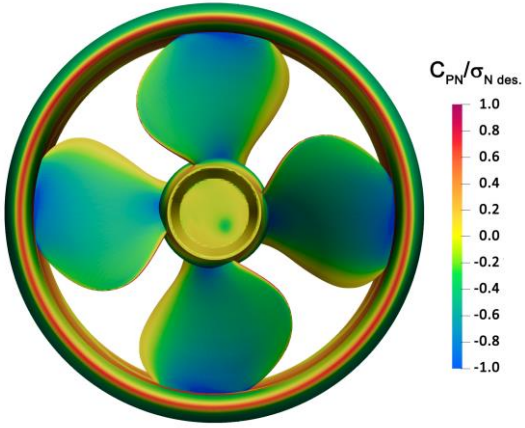
Reference decelerating



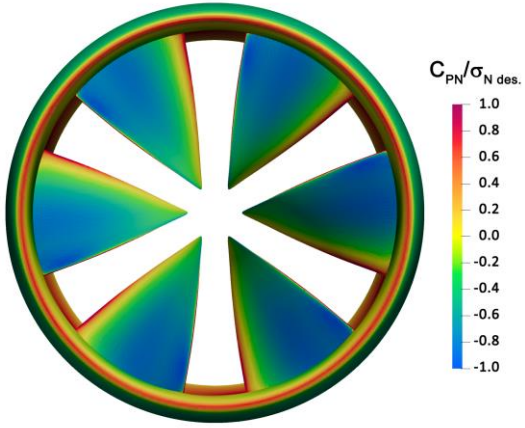
Pumpjet R5/S10



Reference decelerating



RIM-Driven Thruster



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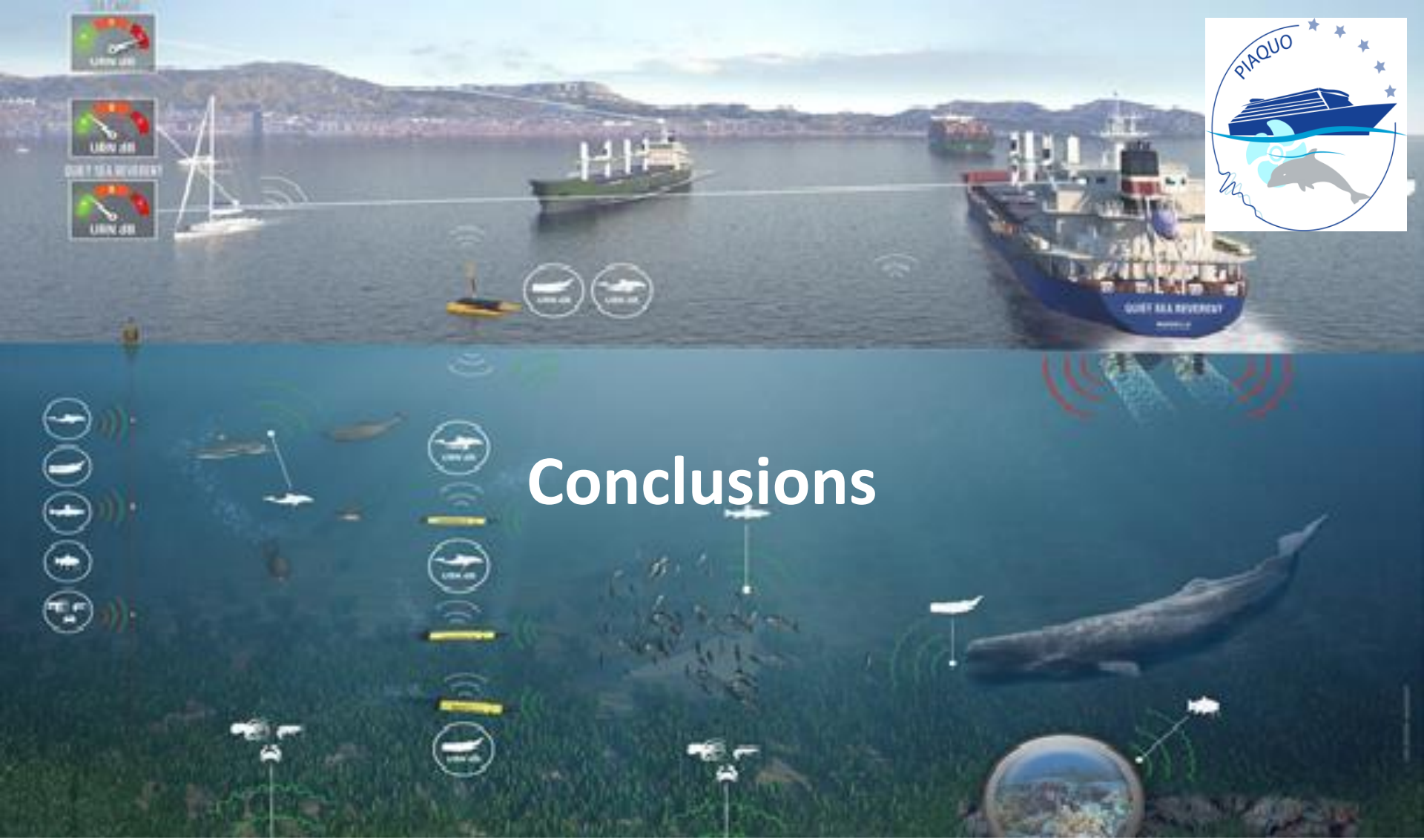


Conclusions

Conclusions

Propeller design by optimisation has proven to be an efficient way of designing propellers with lower URN

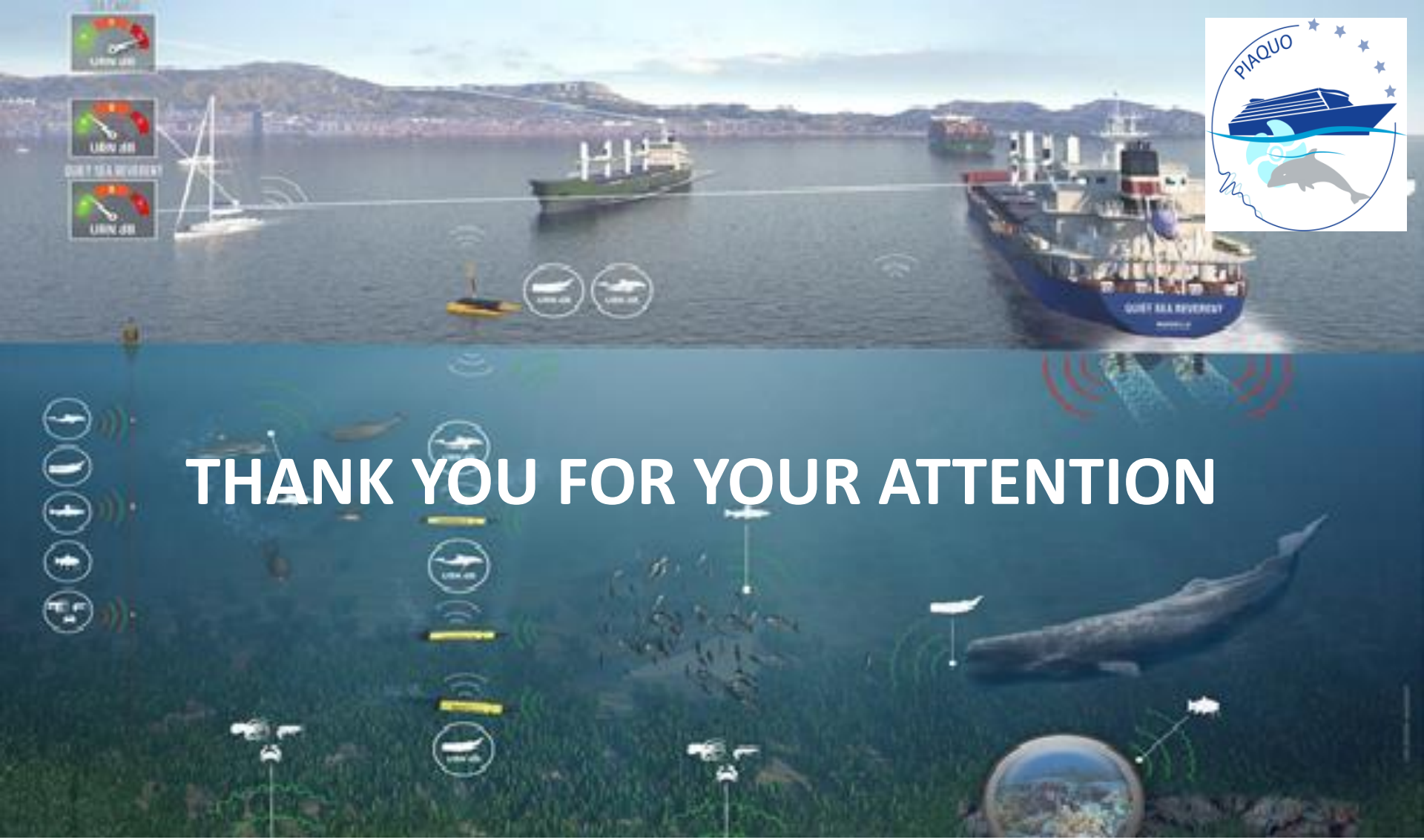
Efficiency increase and Noise reduction are conflicting objectives; even if further analyses and cases need to be considered in order to have a general overview, in a large number of cases a trade-off is possible with URN improvements (5-10 dB) and (at least) constant efficiency

The ship operator has to be deeply involved in the optimisation process to clarify the ship operational profile (speeds of interest); this is of great importance when shipowner and/or route / operating speed change in time during ship life

Cost of propeller design is limited, thus allowing this solution to be viable both for newbuildings and retrofits.

Larger efficiency increases are linked to the whole propulsion plant rather than to the single propulsor (propeller retrofit may be linked to most solutions, allowing to sum advantages).

Unconventional propellers are a possible viable alternative, but still needing further research


PIAQUO
THANK YOU FOR YOUR ATTENTION