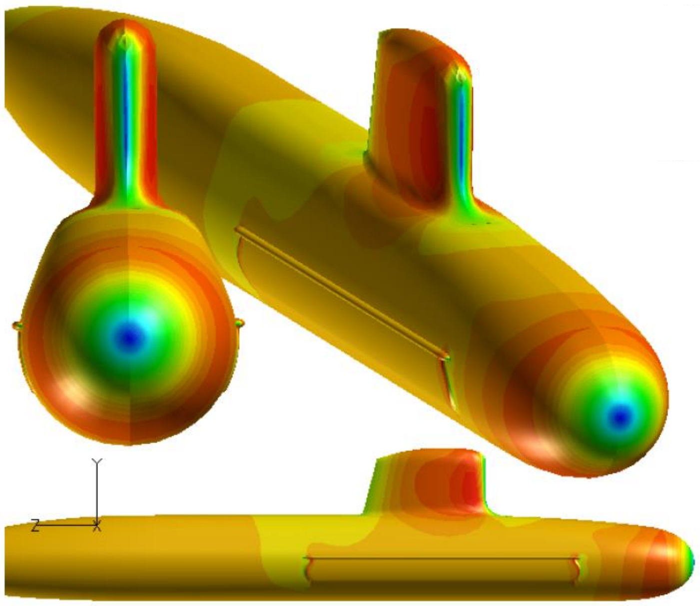
IMPROVING SUBMARINE SONAR ARRAY INTEGRATION FOR OPERATIONAL PERFORMANCE



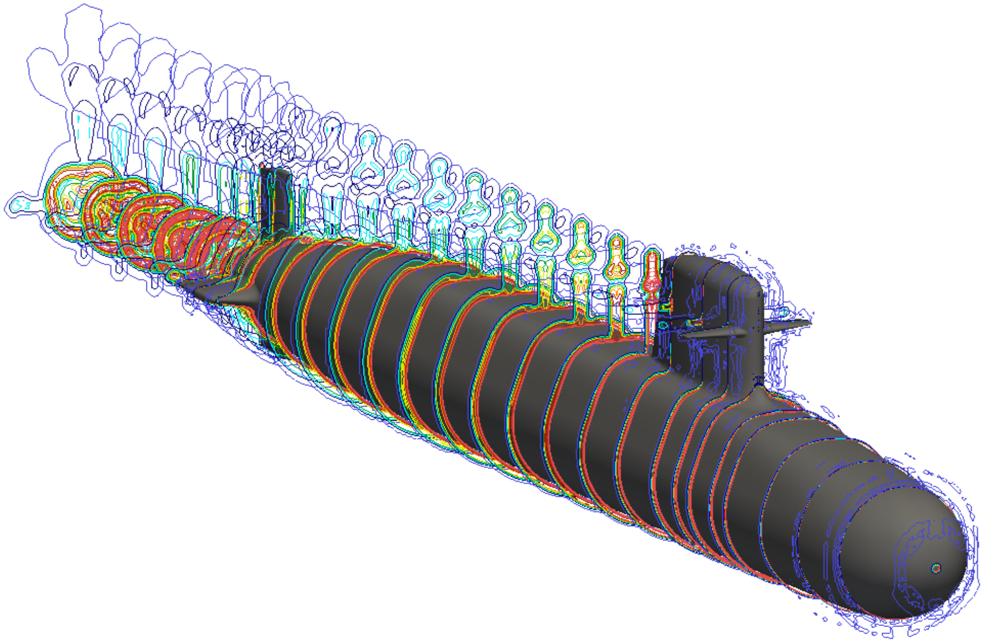
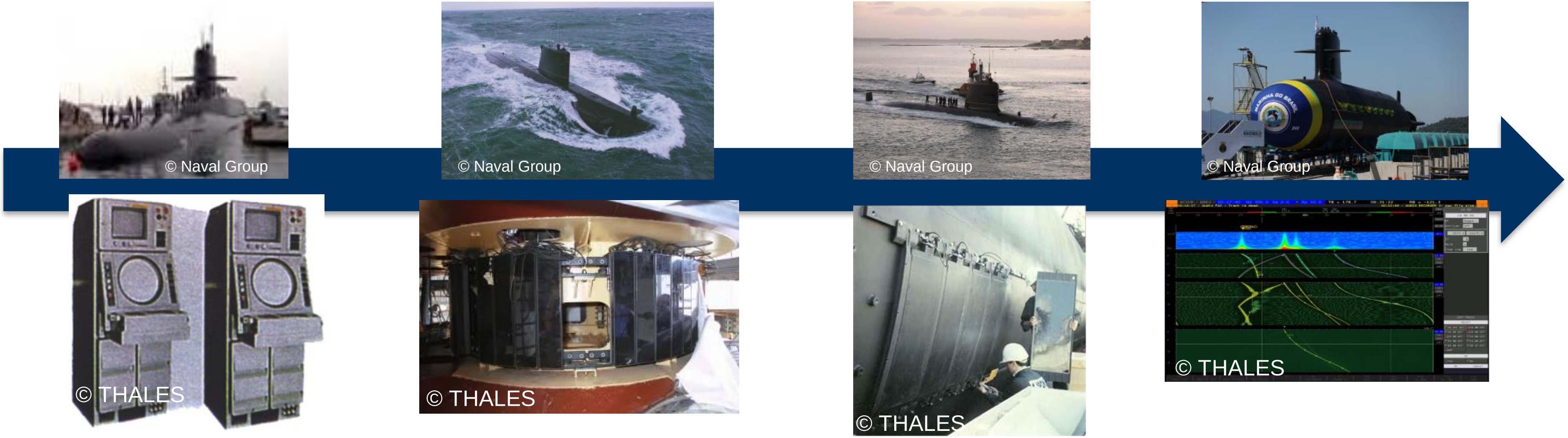


TABLE OF CONTENTS

1. Introduction
2. Offering the best of submarine and sonar performance
3. Description of array and integration constraints
4. Reducing array sensitivity to ambient noise
5. Minimizing self-noise
6. Conclusion

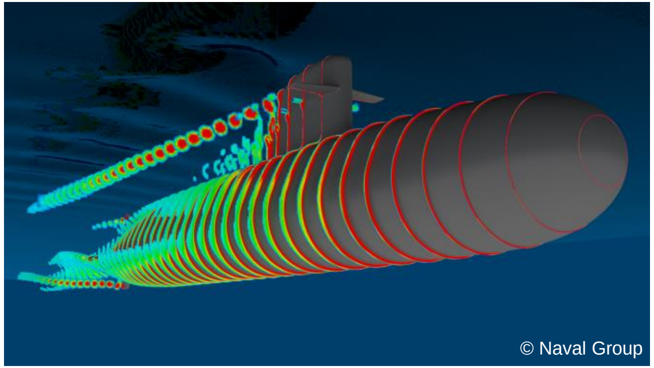
1. INTRODUCTION



- For a submarine, the sonar is the main sensor to detect underwater and surface threats
- During last decades, sonar sensor and processing have been greatly improved, while submarines are getting quieter and stealthier

1. INTRODUCTION

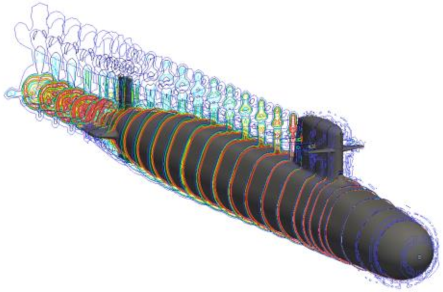
- The final global performance of the sonar remains closely linked to its integration to the submarine
- A strong team-work between sonar designer and submarine designer is mandatory to optimize the integration of sonar arrays in order to maximize their performance



2. OFFERING THE BEST OF SUBMARINE AND SONAR PERFORMANCE

Submarine designer

Submarine knowledge
- noise sources
- hydrodynamics
- structures behavior
- …



Sonar manufacturer

Sonar knowledge
- sensor technology
- electronics
- sonar processing
- …

Common analysis
Common R&D and design studies
Team work

Submarine with optimized sonar performance

3. DESCRIPTION OF ARRAY AND INTEGRATION CONSTRAINTS

SONAR MAIN PERFORMANCE TO ADRESS

- Bearing and elevation coverage in relation with frequency coverage
- Array gain

$$\text{Array Gain} = \frac{4\pi \; S_{urface} \nearrow}{\lambda^2 \searrow}$$

- Maximize signal to noise ratio

$$\frac{Signal}{Ambient\ noise \oplus Self - noise}$$

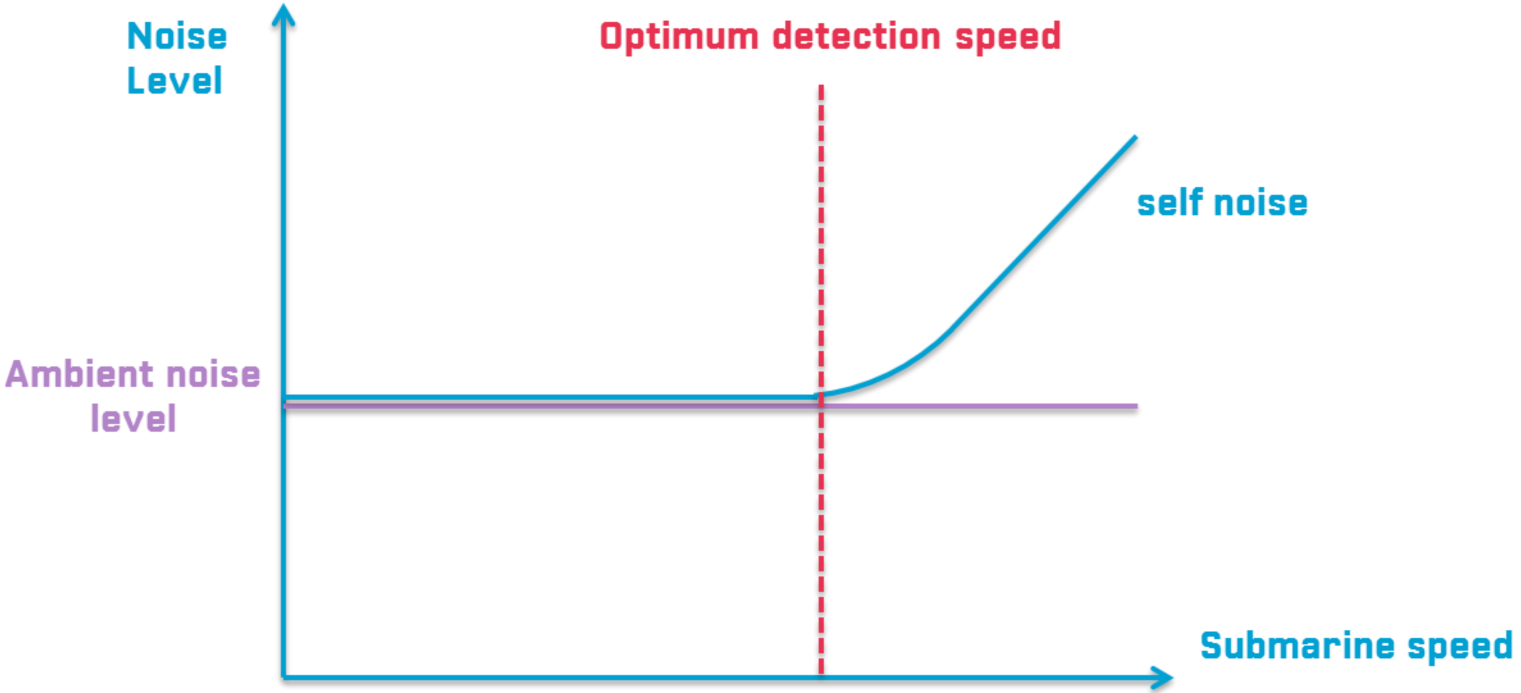
Improve signal detection

Reduce array sensitivity to ambient noise

Minimize self-noise

3. DESCRIPTION OF ARRAY AND INTEGRATION CONSTRAINTS

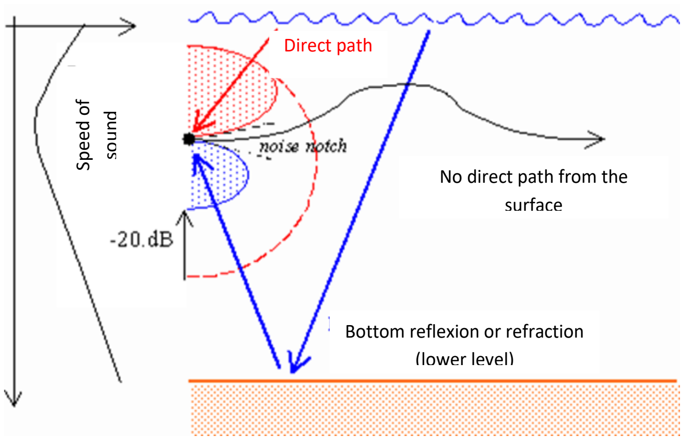
SONAR MAIN PERFORMANCE TO ADRESS

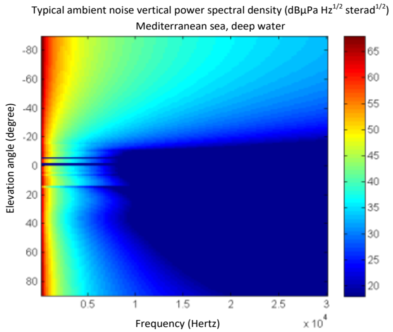


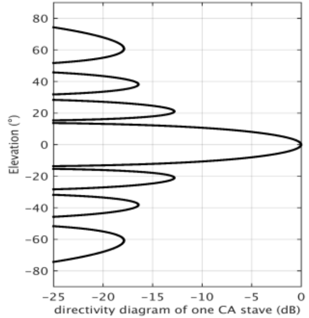
4. REDUCING ARRAY SENSITIVITY TO AMBIENT NOISE

AMBIENT NOISE AND ENVIRONNEMENT

- In array frequency bandwidth most of the ambient noise comes from the sea state.
- Lot of studies have shown that ambient noise is anisotropic in elevation (more noise comes from the surface due to the waves)
- SSK bow arrays usually have a low height due to the lack of room into the bow, thus these arrays have a large elevation beam and so low ambient noise rejection
- By placing the array under torpedo tubes in the lower part of the bow, one can reduce array sensitivity to ambient noise (in beam or coming by secondary beam)





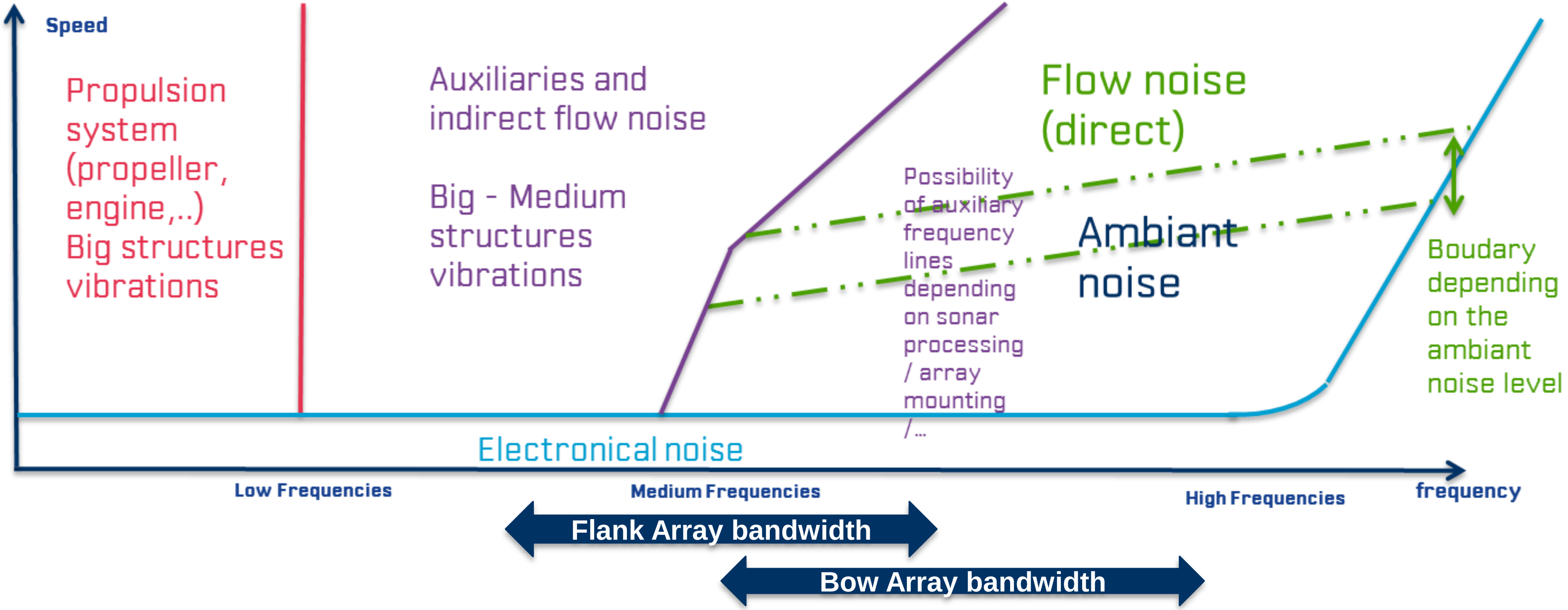


At shannon spatial frequency

5. MINIMIZING SELF-NOISE

UNDERSTANDING SELF-NOISE

At sea measurements and analysis are the key to a good understanding of self noise sources



MINIMIZING SELF-NOISE

To illustrate the impact of self-noise on sonar performance, two submarines (medium size SSK about 2000t) with different shape and array integration have been studied

TYPE A

Hydrodynamic shape not optimized (shape driven by equipement volume)

Cylindrical array above torpedo tubes

Thick flank arrays under dome

TYPE B

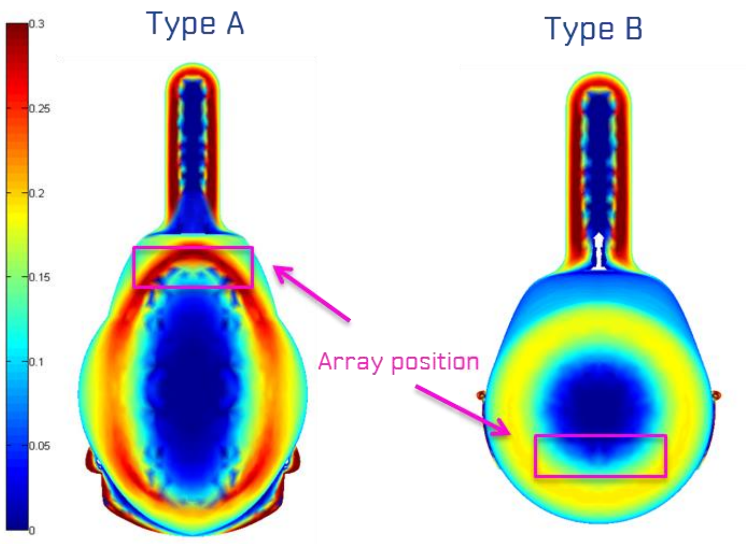
Optimized hydrodynamic shape

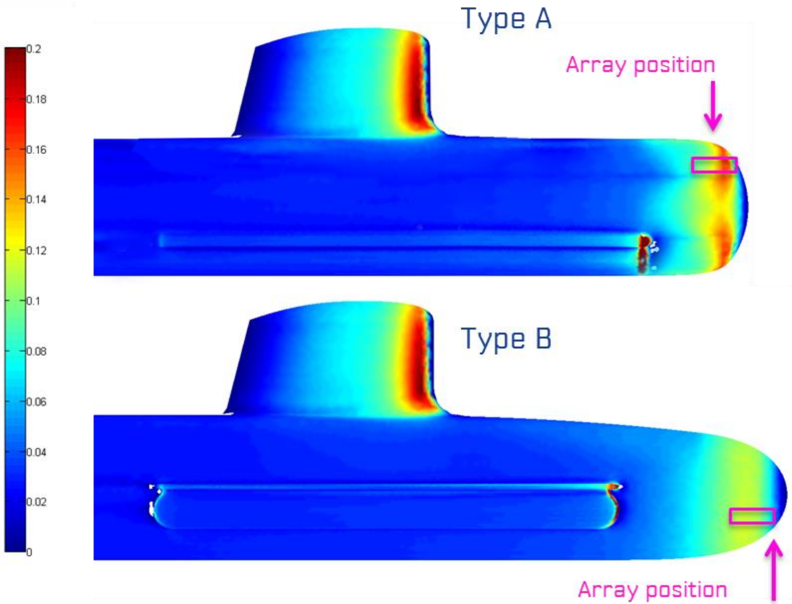
Cylindrical array under torpedo tubes

Thin planar flank arrays flush mounted

MINIMIZING FLOW NOISE
BOW ARRAY EXAMPLE

- The hydrodynamic shape of the bow and the position of the array in it are essential
- Acoustic excitation (Chase autospectrum at 8 kHz and 12 knots and 3 kHz and 8 knots)

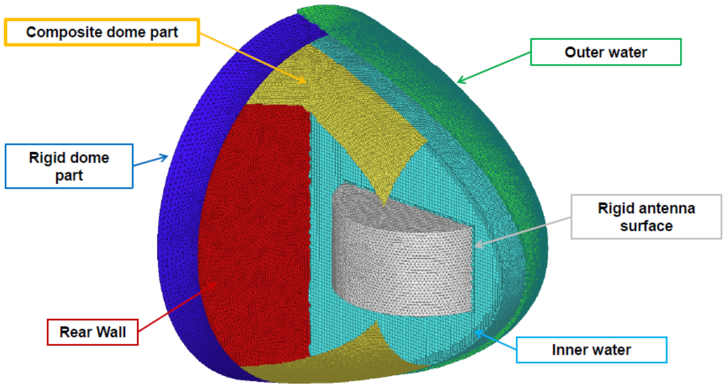


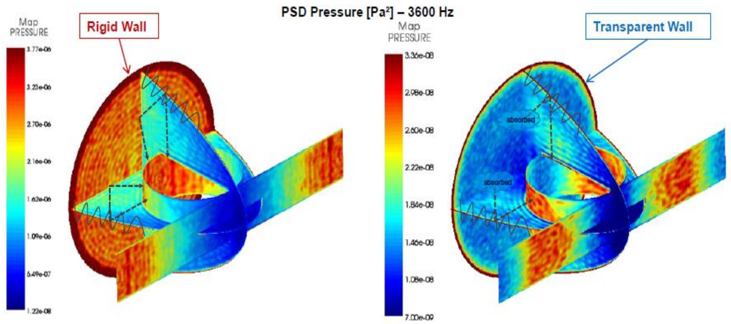


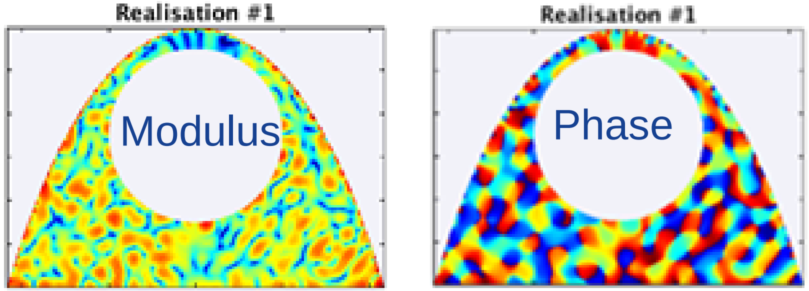
- On Type A submarine the acoustic excitation is much higher than on Type B due to its angular shape

MINIMIZING FLOW NOISE
BOW ARRAY EXAMPLE

- Submarine Designer: Bow geometry ➔ CFD simulation ➔ TBL extraction
- SONAR manufacturer: TBL ➔ Acoustic excitation on bow window ➔ Antenna response
- Difficulties : inhomogeneous excitation & complex transfer function between Bow and Antenna
- ➔ Advanced simulations for optimized integration



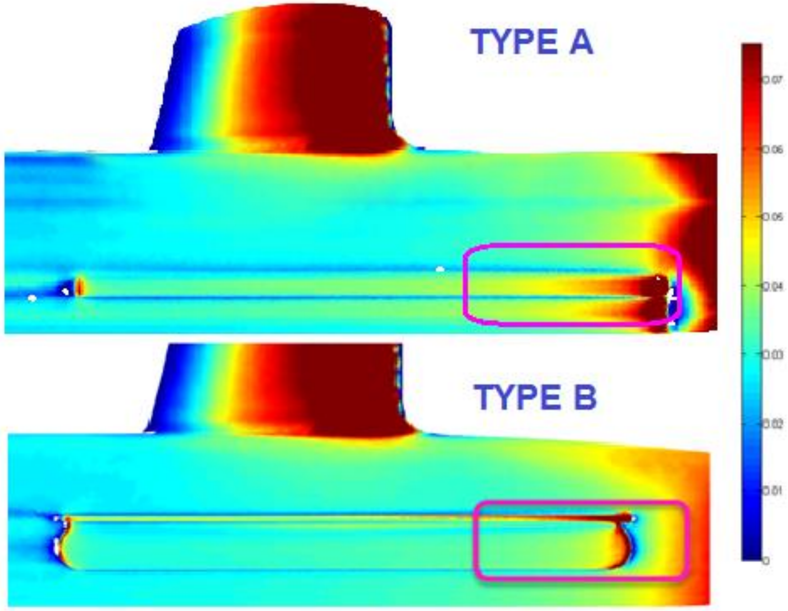




- Stochastic simulation taking into account :
- Elastic window, growing TBL, Bow Cavity, Antenna

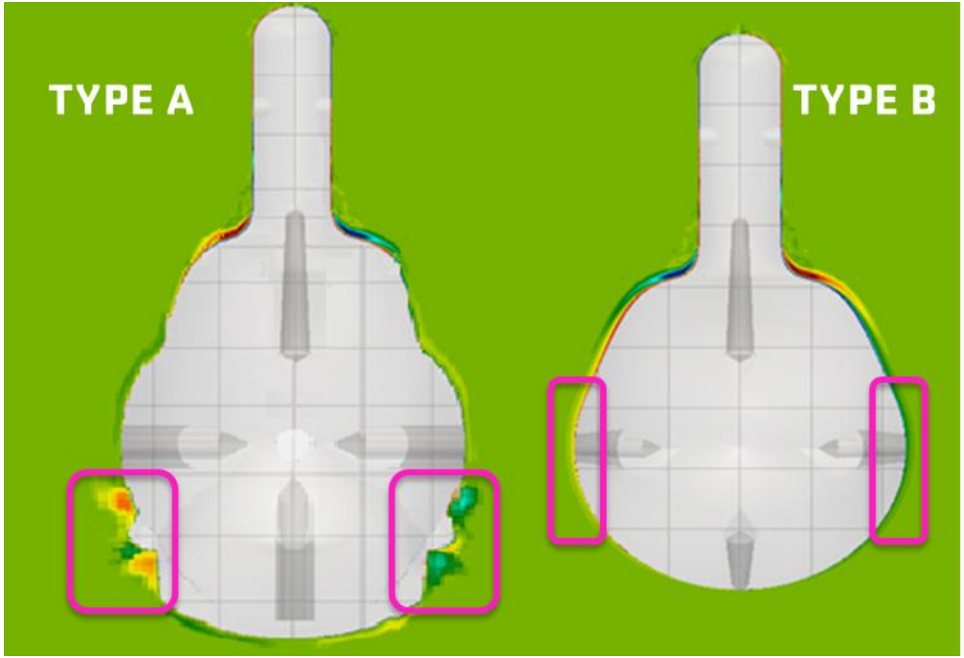
MINIMIZING FLOW NOISE
FLANK ARRAY EXAMPLE

- Thin planar flank array with dedicated fairings to smooth the flow are better
- Chase autospectrum at 800Hz – 8 knots



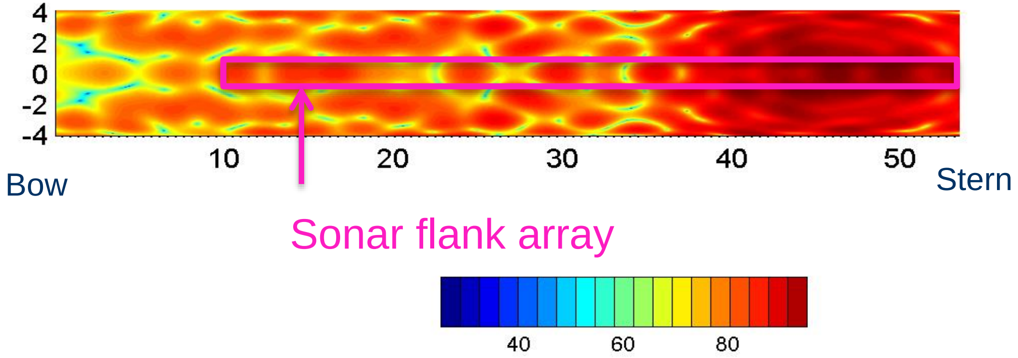
MINIMIZING FLOW NOISE
FLANK ARRAY EXAMPLE

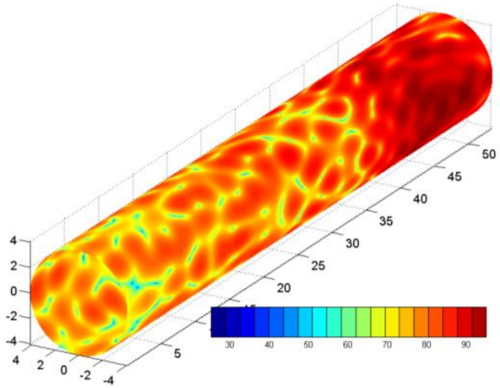
- Angular shapes of flank array fairings shall be prohibited because they generate vortex which are a strong source of noise



MINIMIZING MECHANICAL NOISE
FLANK ARRAY

- Nearfield of pressure (0,2m) computed on a stiffened hull excited by a punctual force at 600 Hz

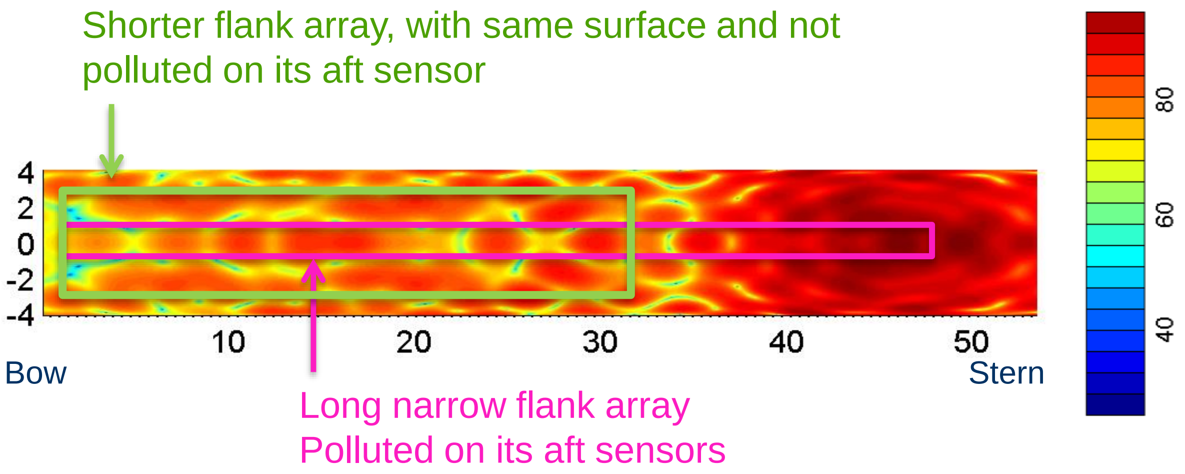




- The radiated nearfield pressure spread much more than the array surface
- Even when using masking material between the array and the hull, the array will still perceive a lot of noise
- To reduce that noise, it is better to well positioned the array in front of less noisy area of the hull and to have a good sonar processing (such as adaptive beamforming)

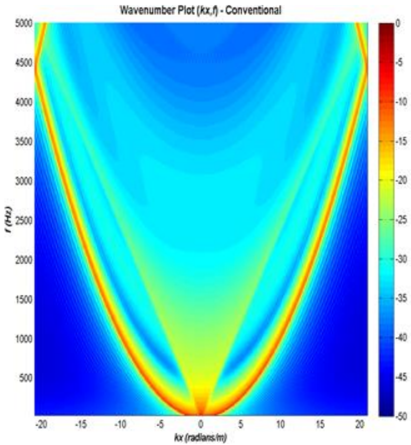
MINIMIZING MECHANICAL NOISE
FLANK ARRAY POSITIONNING

- The array performance is driven by its surface (and not only its length)
- By keeping it identical, it is possible to make the array shorter but higher to optimize its position on the hull and avoid noisy area (such as the aft sector where the propulsion is)

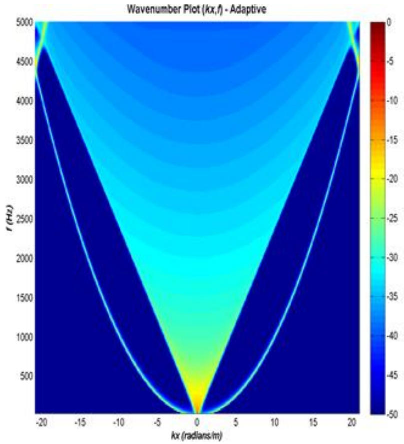


MINIMIZING SELF-NOISE WITH ADAPTIVE BEAMFORMING
MECHANICAL NOISE – FLANK ARRAY

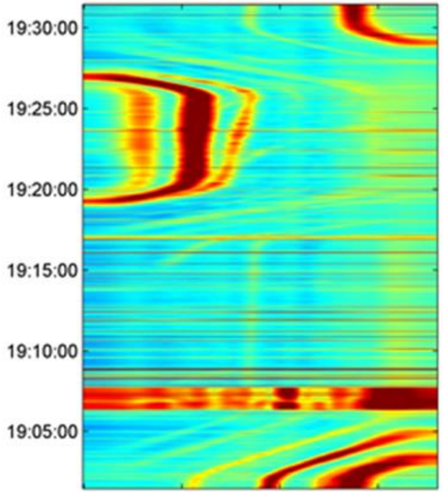
- Adaptive beamforming provides effective reduction of correlated noise
- Correlated mechanical noise is very well reduced by adaptive beamforming



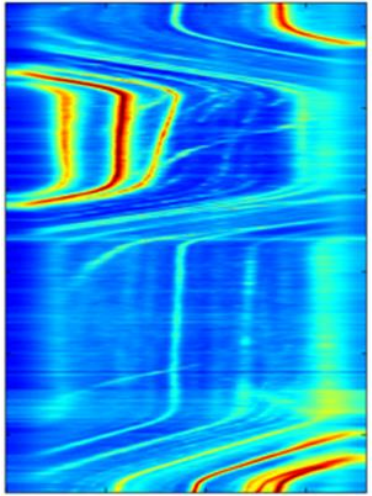
Conventional Beam-Forming



Adaptive Beam-Forming



Conventional Beam-Forming



Adaptive Beam-Forming

6. CONCLUSION

CONCLUSION

Only a **strong teamwork** between **sonar designer** and **submarine designer** allows getting the best detection performance of the integrated sonar suite

Some recommendations

Smooth hydrodynamic shape

Well positioned bow array considering self-noise and ambient noise (lower part of the bow)

Thin planar flush mounted flank array with great surface

Smooth hydrodynamic fairings

Positioned in a quiet area

Tilted downwards to reduce sensitivity to ambient noise

NAVAL GROUP

THALES