UDT
Undersea Defence Technology
13-15 May 2019
Stockholmsmässan, Sweden

Presentation panel:
Deployed & Mobile sensors

Title: Multistatic underwater protection sonar best patterns for harbour and larger critical environments

Authors:
Louis RAILLON
Michel FOUQUET

Multistatic underwater protection sonar best patterns for harbour and larger critical environments

Objective: Fixed Asset protection from UW threats

Approach: Multistatic active specific patterns and collaborative arrangement to secure protection against a given index & speeds threats list.

➔ must provide a thick enough continuous detection barrier for tracking all threats with enough reaction time

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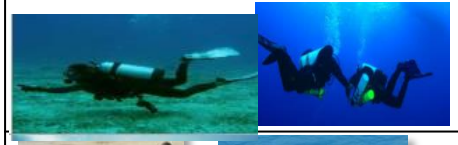
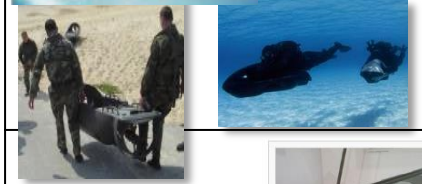
Objective : Detection of wide range of potential threats

	Device / Vehicle	Op. Speed	Autonomy	Distance	TS index
	Closed Circuit Diver (CCD)	< 1,5 kts	4h	6 Nm	> - 25dB
	Open Circuit Diver (OCD)	< 1,5 kts	1h	1.5 Nm	>> -15dB
	Propulsion aid	~ 3 kts	4h	16 Nm	> -15dB
	Swimmer Delivery Vehicle (SDV)	~ 4 to 8 kts ~ 6kts	>4h	>32 Nm	Small/Big -15 to -5 dB
	Unmanned Underwater Vehicle (UUV) (UW drone)	~ 6 kts	Weeks - Months	>100Nm	Small/Big -15 to -5 dB
	Midget Firing range < 2-5 km	< 6 kts	Weeks - Months	>100Nm	> -5 dB

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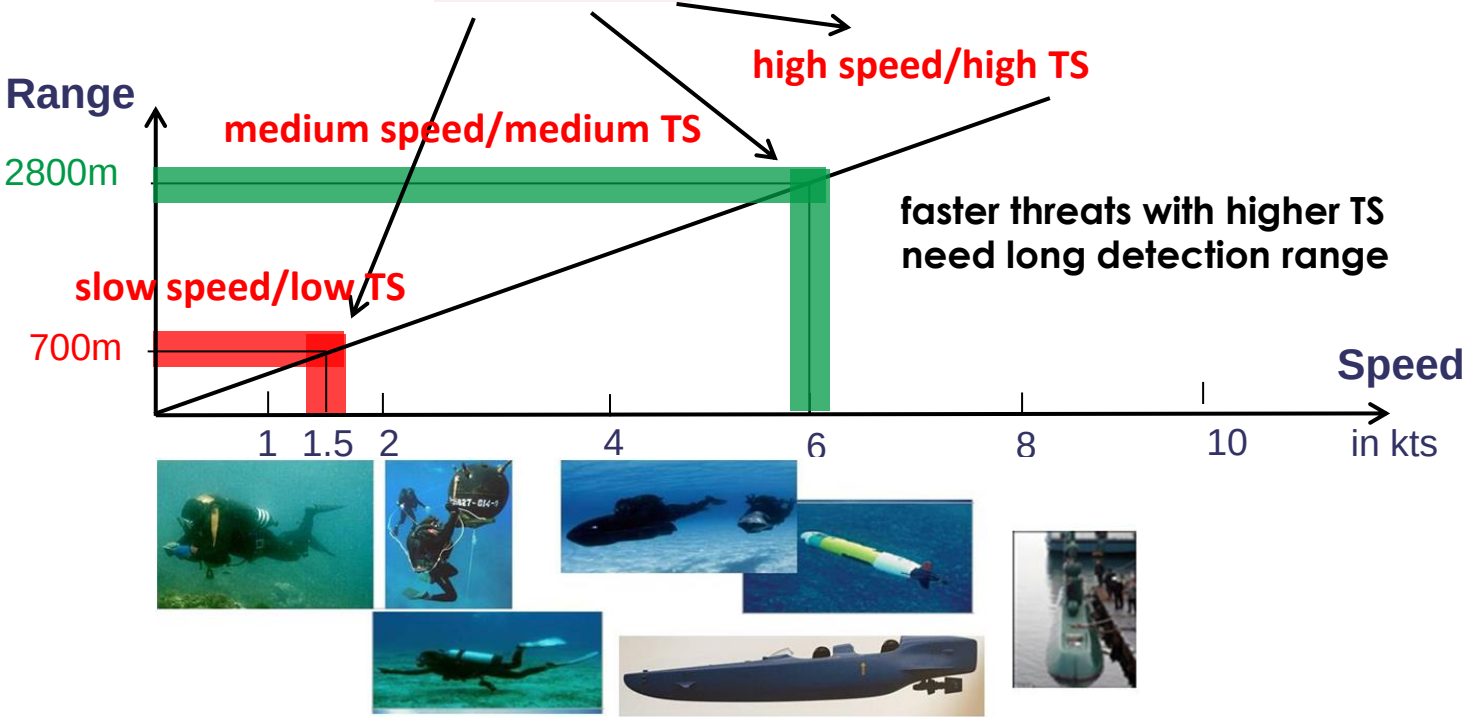
Objective : constant reaction time
➔ Detection range adjusted to threat speeds

Primo-detection 15 minutes before reaching fixed assets



Wide Primo Detection range required to secure constant minimum reaction time

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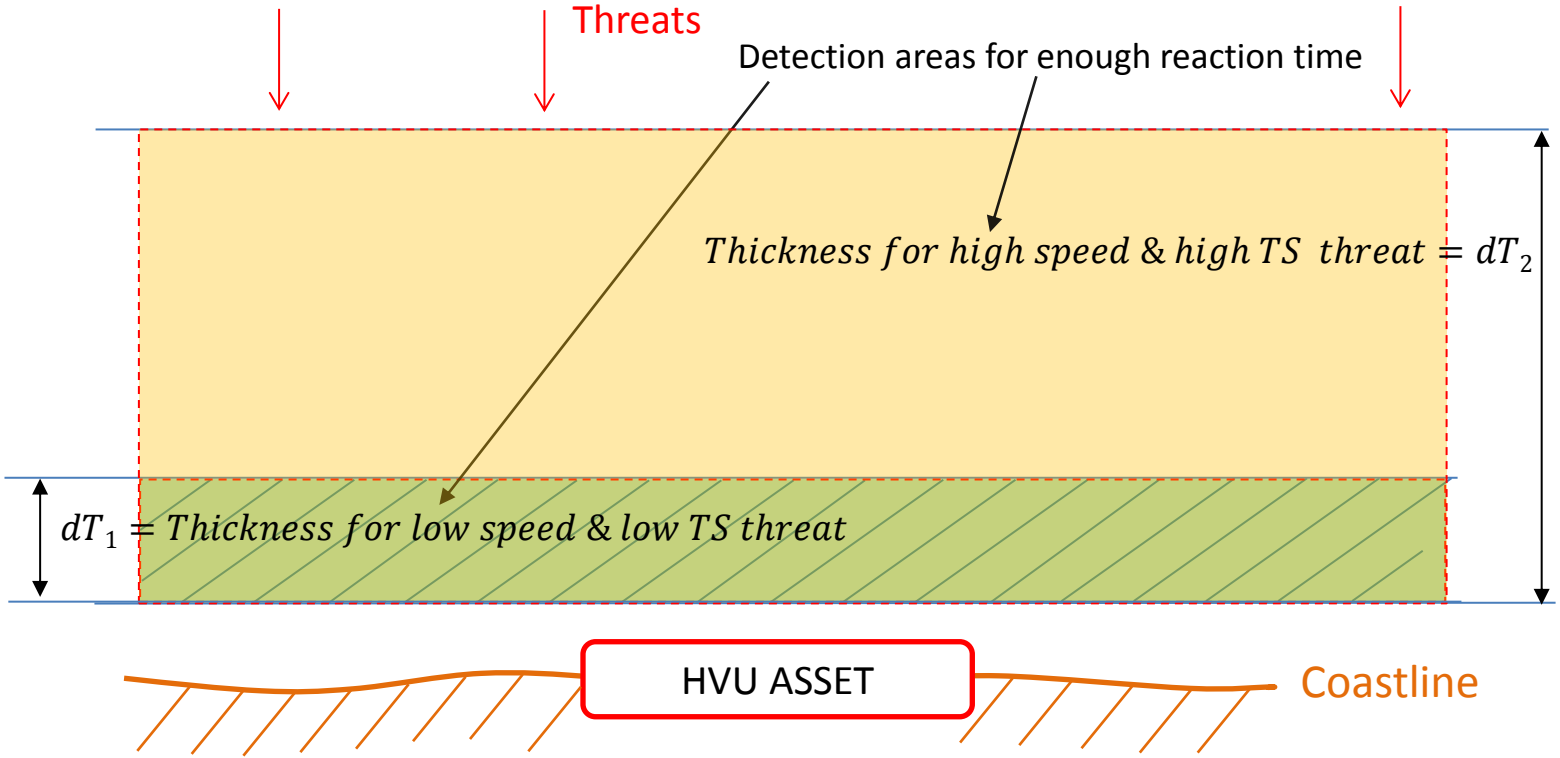
Linear barrier thickness versus threat type for needed reaction time

Threats shall be detected continuously for tracking during reaction time



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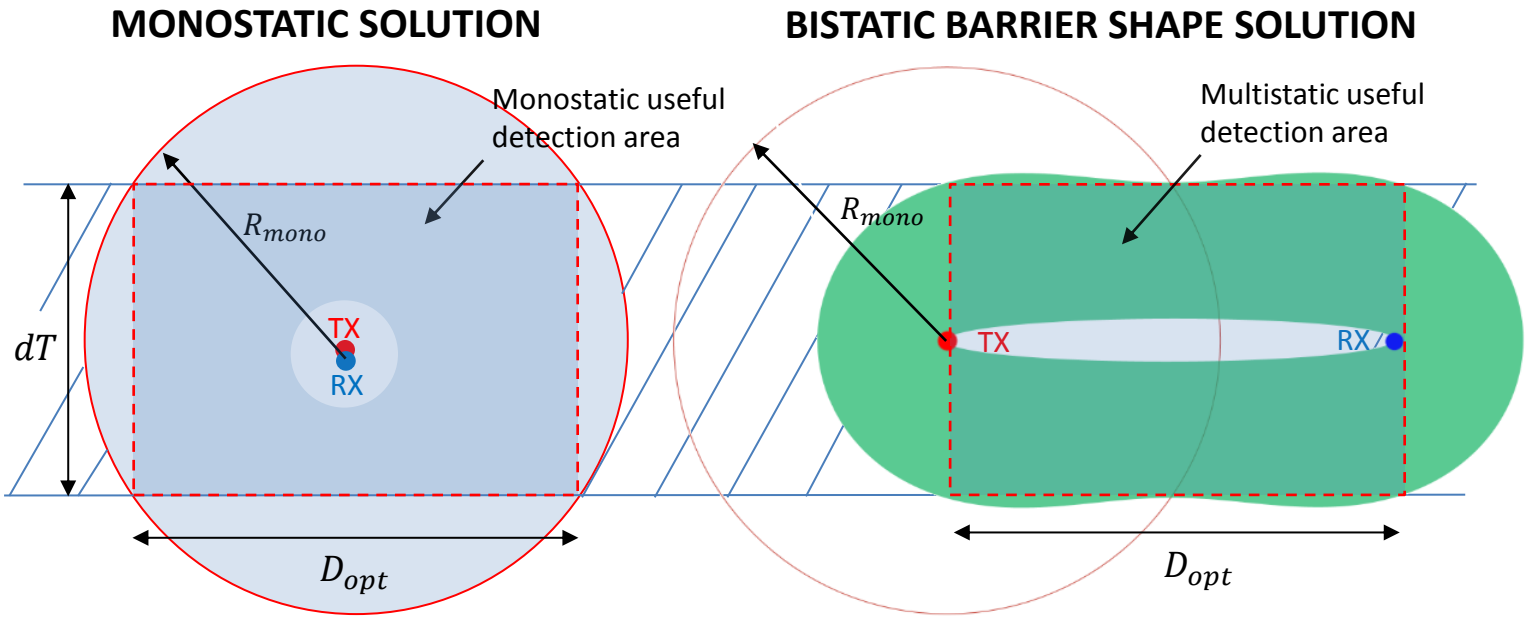
Bistatic optimal TX/RX distance for linear barrier



Hypothesis : Same Tx/Rx characteristics and same Barrier Thickness

$$dT = 2R_{mono}/\sqrt{3}$$

$$Maximum\ bistatic\ detection\ surface\ is\ for\ D_{opt} = \sqrt{8/3}\ R_{mono} \sim 1{,}63\ R_{mono}$$

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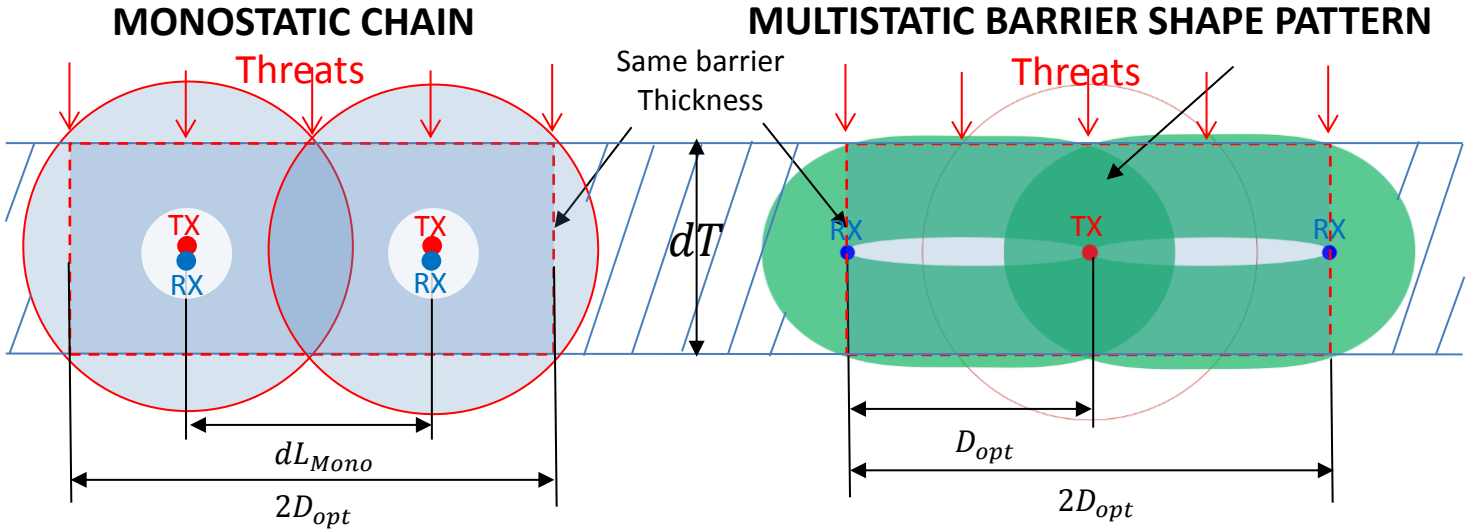
Monostatic versus Multistatic chain for linear barrier



1) Additional monostatic sonar shall be at distance

$dL_{Mono} = \sqrt{8/3}\ R_{mono} = D_{opt}$

➔ Barrier length = $2D_{opt}$

➔ Blanking zone size depends on pulse length

2) Additional RX shall be at distance

D_{opt}

➔ Barrier length = $2D_{opt}$ ➔ **bistatic barrier length is doubled**

➔ Blanking zone size depends on compressed pulse length

Multistatic barrier 1TX/2RX equivalent to 2 monostatic sonars barrier 2TX/2RX

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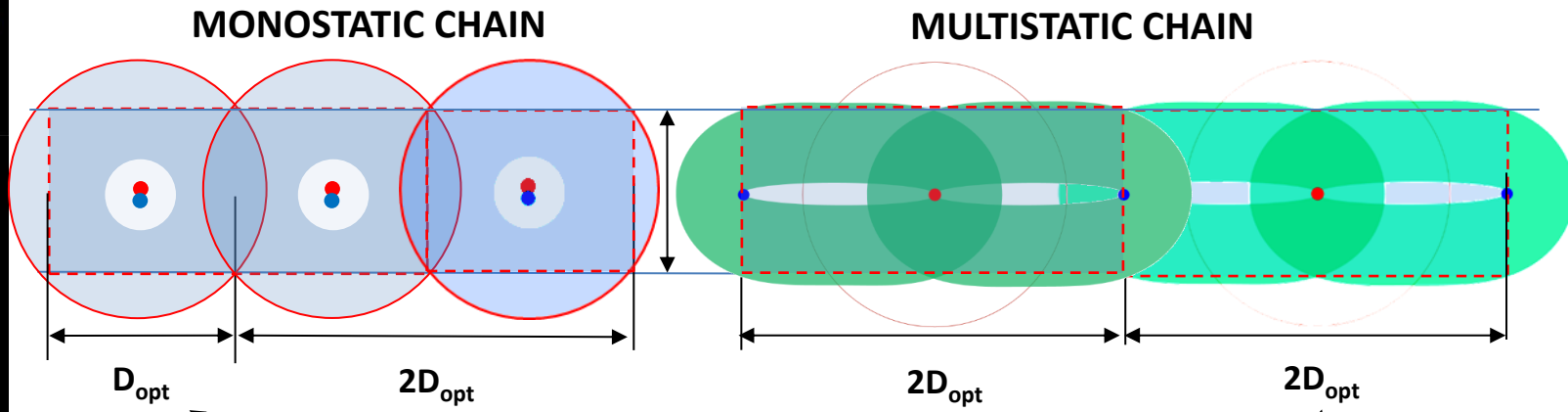

Extending the barrier length :

Adding 1TX+1RX here on left of first pattern
→ **barrier length extension = D_{opt}**

2) Adding 1TX+1RX here on right of 1st pattern
→ **barrier length extension = $2D_{opt}$**

Extending barrier length requires twice less material in multistatism than monostatism

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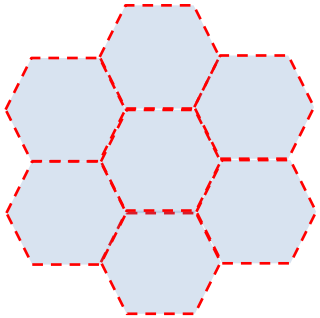
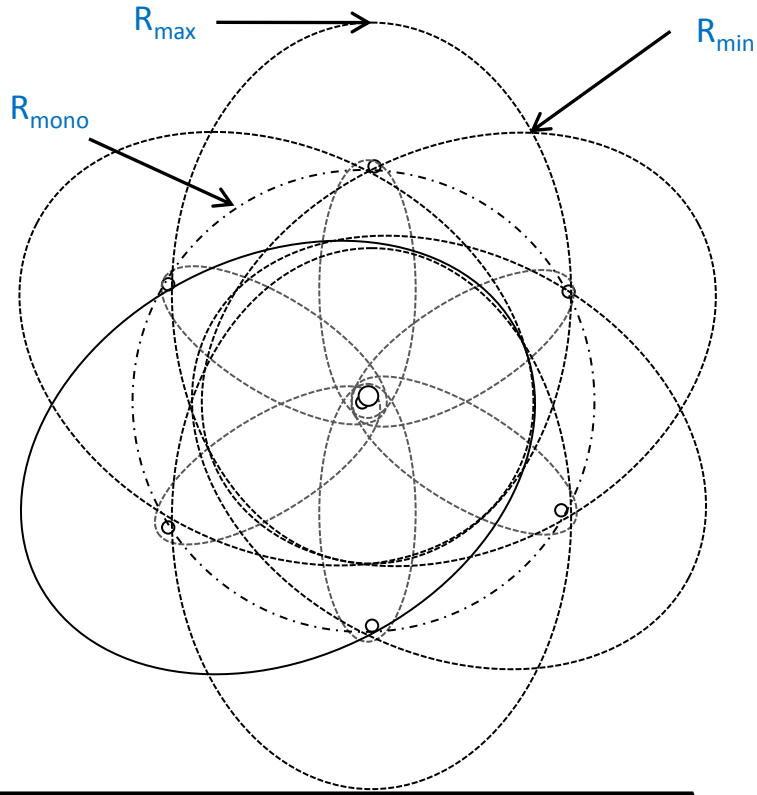
Multistatic 1TX/6RX pattern for flexible surface covering

Solution = 6 RX on R_{mono} circle centered on Tx

- full detection is achieved inside the area
- without blanking zones
- Rmax=$(1+\sqrt{5})/2 * R_{mono}$ = Gold number
- 2 RX detections ➔ 2 Doppler ≠ projections

Hexagone is perfect for **paving:**





This pattern is well suited for large surface covering and easy partial adaptation
Additional advantage : 2 Doppler projections and blanking zones cross-covering

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Multiple threats and large zone protection example

Objective: Fixed Asset protection example for different UW threats

Approach: Place multistatic specific patterns to secure a given reaction time for different TS/speed threats before reaching HVU Asset

Location : Oil & Gaz Terminal at Fos sur Mer

Simulation Hypotheses : worst yearly bathycelerimetry, Sea State 6 noise, bottom slope considered for each pattern

Sonar material : TX and RX Thales modules fixed on the sea bottom (TX location at yellow points, RX location at black points)

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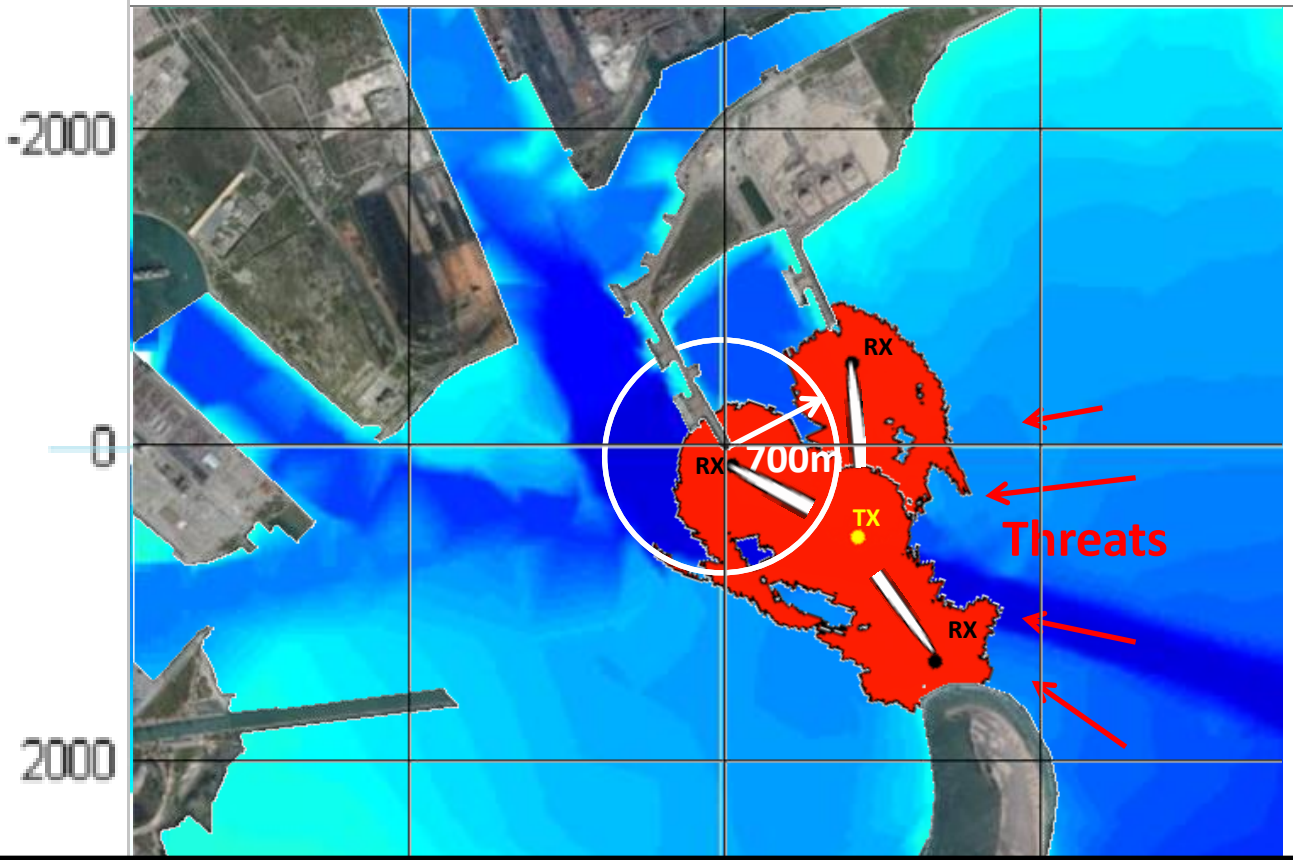
Barrier for closing port entrance and continuous detection slow speed/low TS targets such as Closed Circuit divers



Slow speed Threats with Target Strength
TS = -25 dB

-25dB CC diver

-15dB Diver with propulsion vehicles or medium speed SDV

-5dB Diver with fast SDV / Drone / Midget

Worst bathy case
Negative gradient

700m protection thickness achieved with 1TX/3RX + closing FOS entrance

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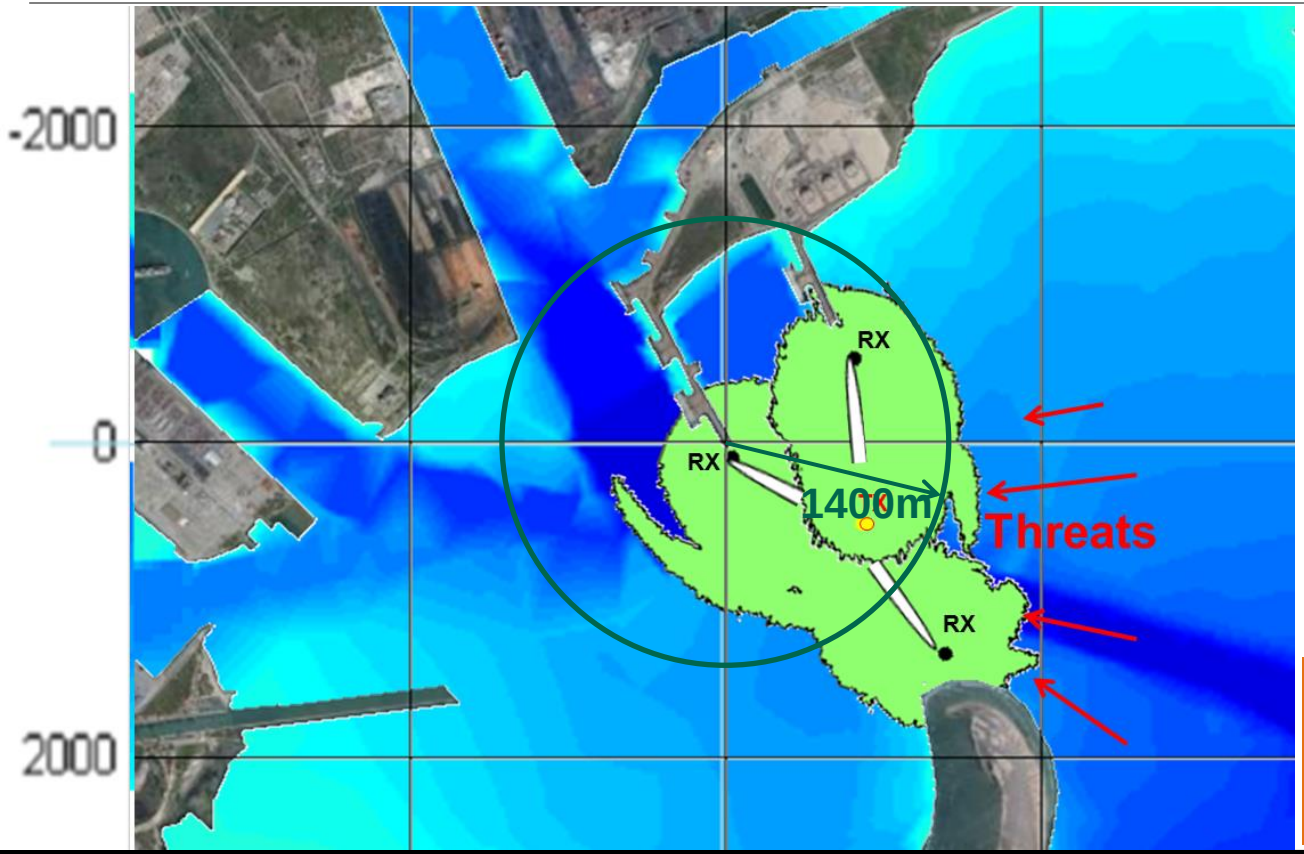
Barrier for closing port entrance and continuous detection medium speed/ medium TS targets (aided divers, small drones …)



Medium speed Threats with Target Strength
TS = -15 dB

-25dB CC diver

-15dB Diver with propulsion vehicles or medium speed SDV

-5dB Diver with fast SDV / Drone / Midget

Worst bathy case
Negative gradient

1TX/3RX for TS=-15dB, 1400m is twice more : enough if target < 3 knots

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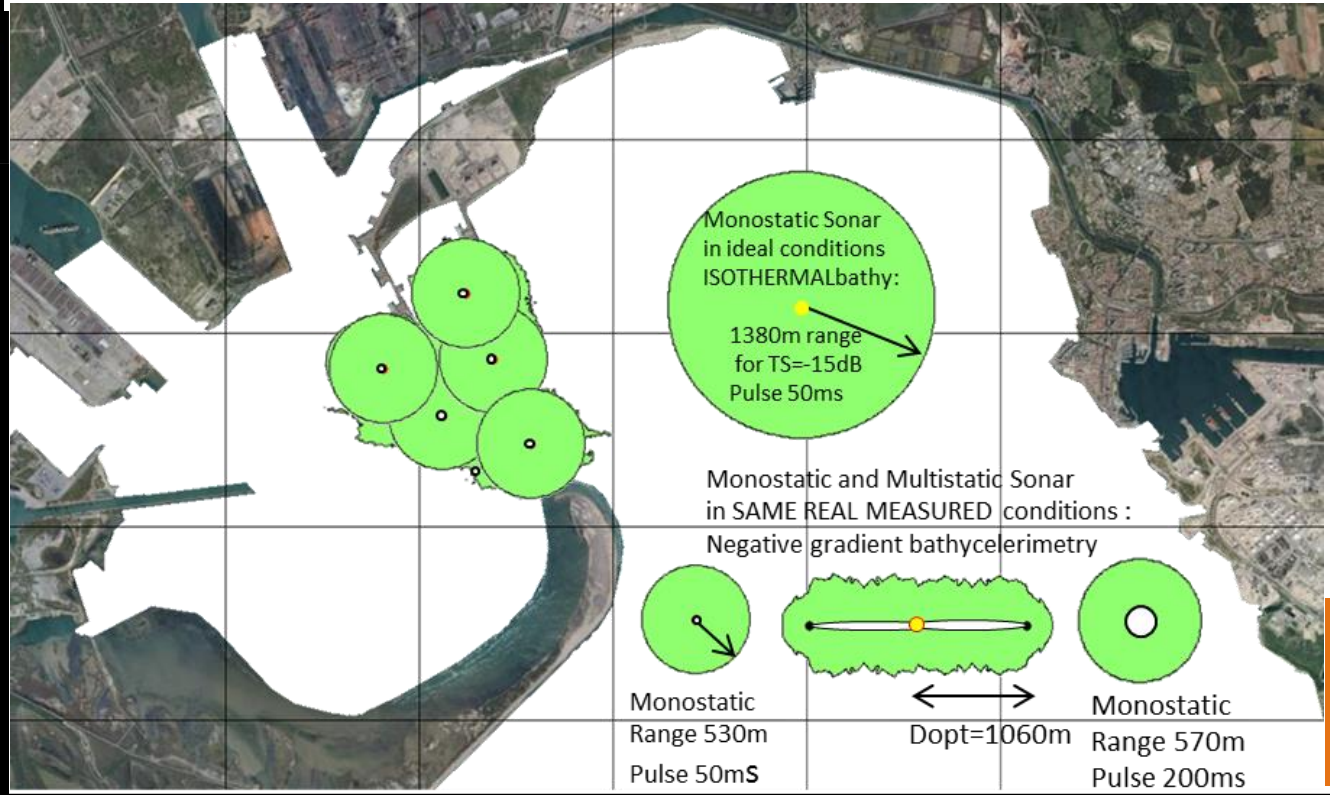
Comparison of close protection for -15dB threats with multistatic versus monostatic solution in worst real bathycelerimetry case



Medium speed Threats with Target Strength
TS = -15 dB

-15dB

Divers with propulsion aids or medium speed SDV

Worst bathy case
Negative gradient

Worst bathy detection range divides ideal case by more than 2: 530/1380
Worst case protection need: Multistatic 1TX/3RX vs. Monostatic 5TX/5RX

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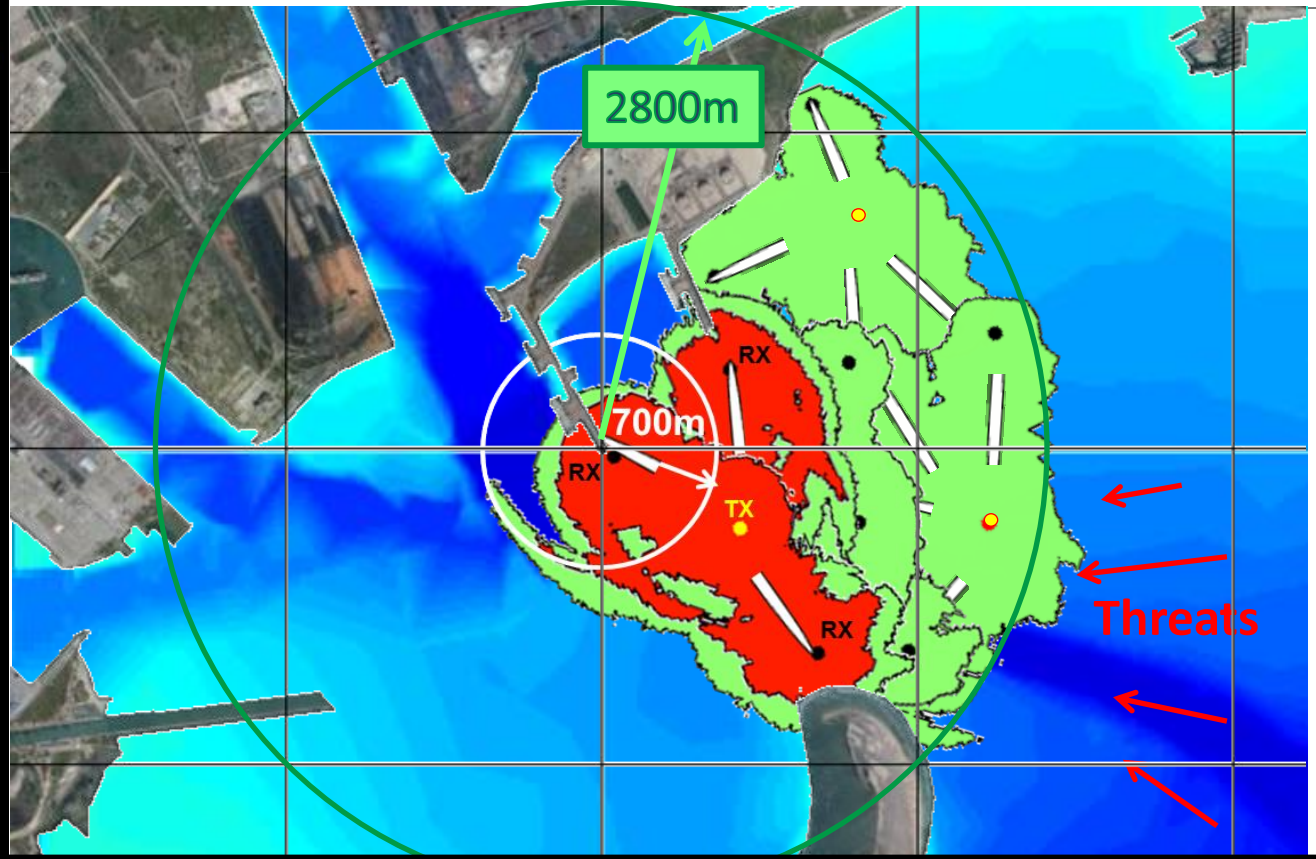
Barrier for closing port entrance and continuous detection for target faster speed (SDV, drones, …)



Medium speed Threats with Target Strength
TS = -15 dB

-15dB

Divers with propulsion aids or medium speed SDV

Worst bathy case
Negative gradient

Improved protection with 2TX+6RX → 2800m primo-detection = 15' @ 6kts

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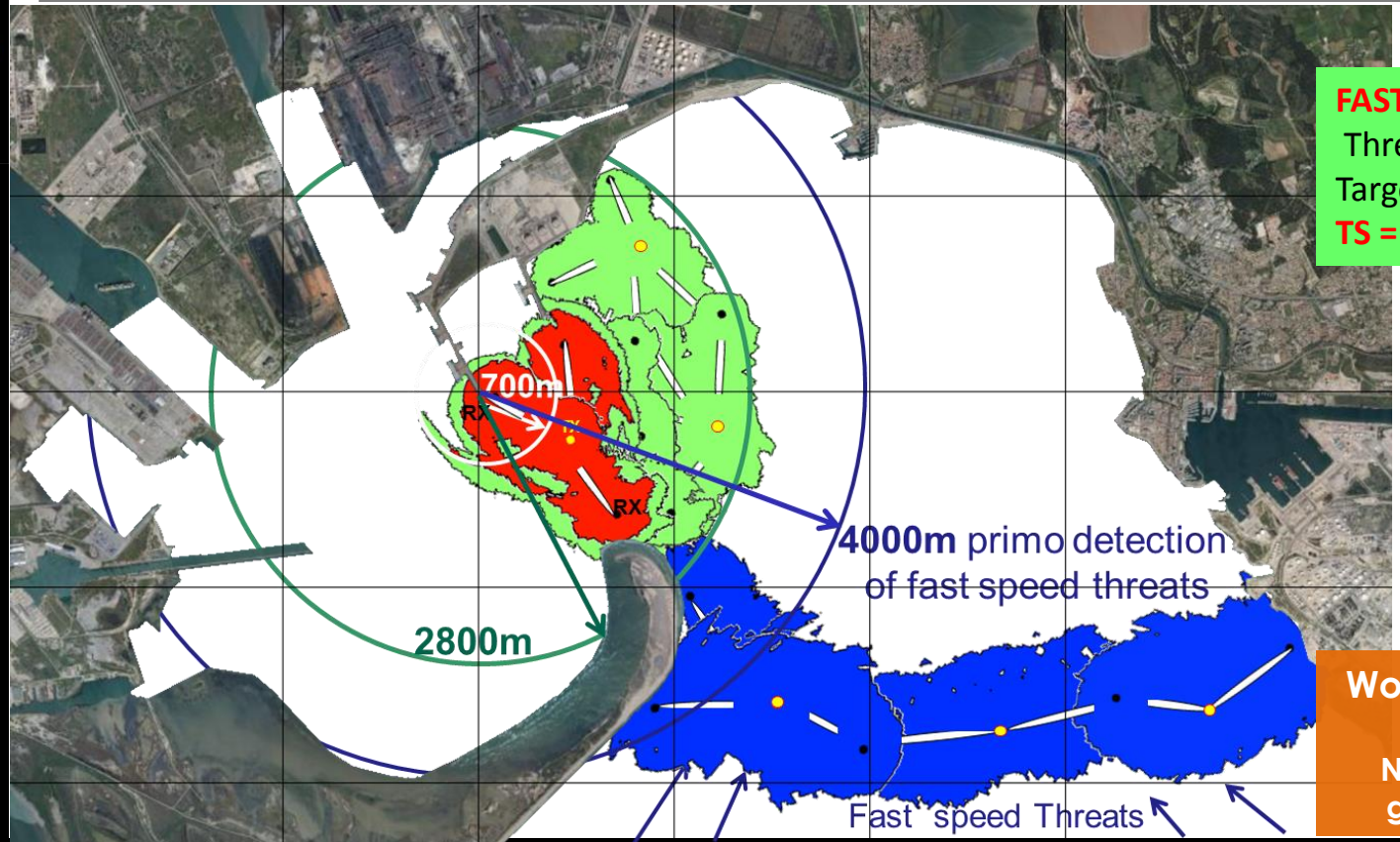
Flexible and closing successive areas with barrier or surface patterns for protection of various speed/index threats



700m on 1.5kt divers, 2800m 6kts SDV, to 4000m 8knots big SDV/drones

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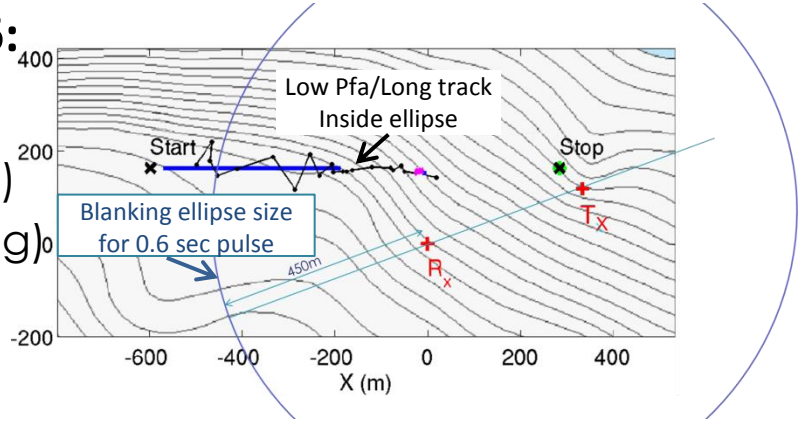
SEA TRIALS LESSONS LEARNT and PROVING Key Advances

Prototype development (sectorial reduced power TX)

and testing at sea in 2015 and 2016:

- in coastal harsh conditions

- Bathycelerimetry (< 0 gradient)
- Sea bottom (downward-sloping)



- against a variety of threats,

- have demonstrated

- Detection during transmission (RX as TX) ➔ Long codes
- Doppler Detection with High Resolution ➔ NL limited
- Low PFa / Long range achieved at sea with mature algorithms

➔ Multistatic solution key advantages confirmed

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CONCLUSION / FUTURE

- **Multistatic patterns** optimise a **barrier and surface detection flexible shape** with **much less TX+RX numbers** than monostatism
- Pattern **choice for barrier chain or surface objective is shown**
- **Receivers can be shared** with collaborative patterns arrangement
- Blanking zones are small with **RX as TX processing, and can nearly disappear using specific patterns or arrangements**
- A real example secures **15 minutes primo-detection** for a **large range of threats speeds & index**

➔ **Multistatic is the multithreat & large protection solution of choice, with minimal TX/RX material**