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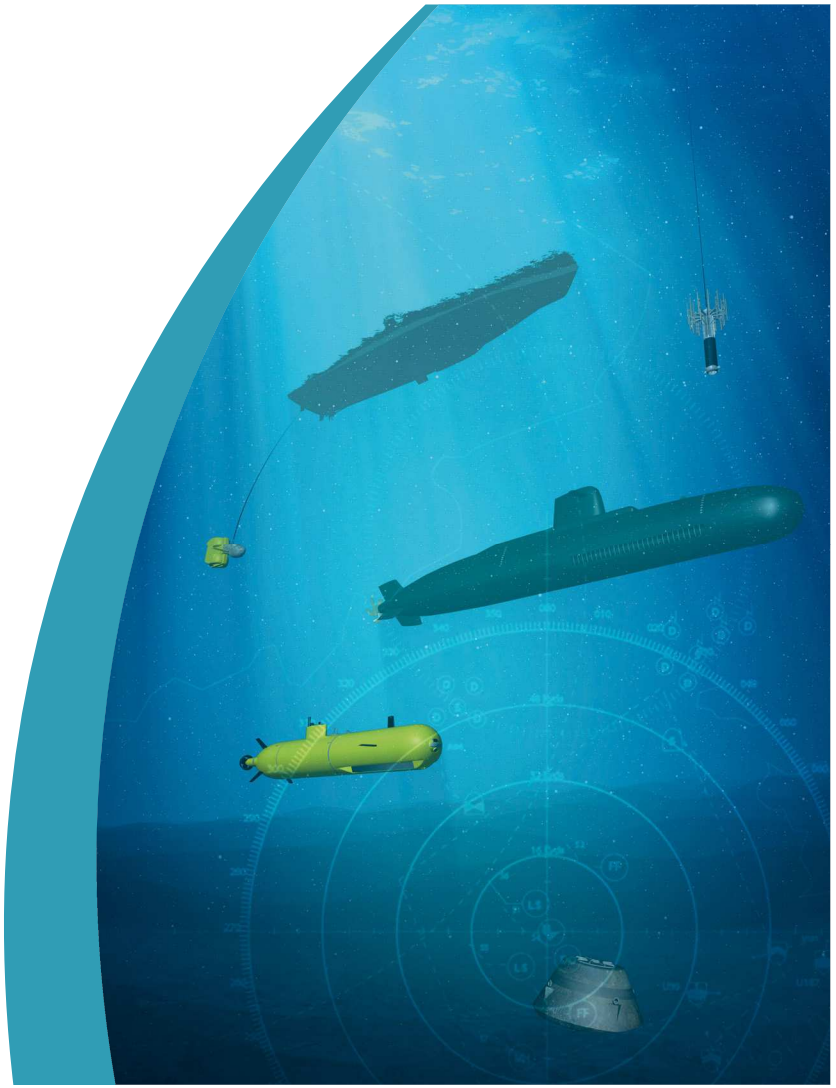
EDTAS AMM
29th November 2017 - Melbourne

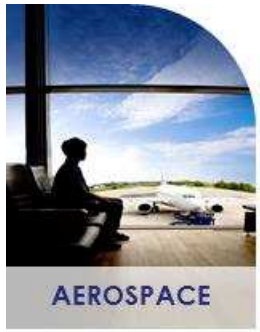
Key challenges in Underwater Acoustics and Mechanical Technologies

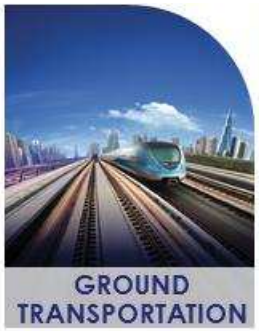
Daniel ANDREIS
Thales Underwater Systems SAS
Meta Competence Centre Sonar Hardware Products

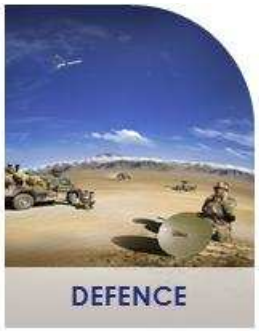


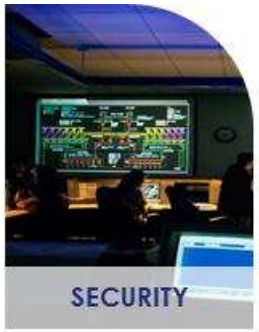
Thales Group Activities

DUAL MARKETS Military & Civil









TRUSTED PARTNER FOR A SAFER WORLD

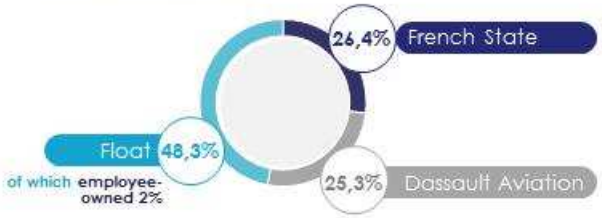
Employees
64,000

Revenues in 2016
14,9 billion euros

Global presence
56 countries

Self-funded R&D* 2016
731 million euros

Shareholders
(at 31 December 2014)



A balanced revenue structure

* Does not include therefore R&D undertaken with external funding.

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Defence Missions Systems

DMS

Supports the armed forces in gaining and sustaining decision-making and operational superiority in all theatres

DMS has a large presence in Australia as the Maritime Business Unit based at Garden Island & Rydalmere Sydney and a significant software team in Western Australia.

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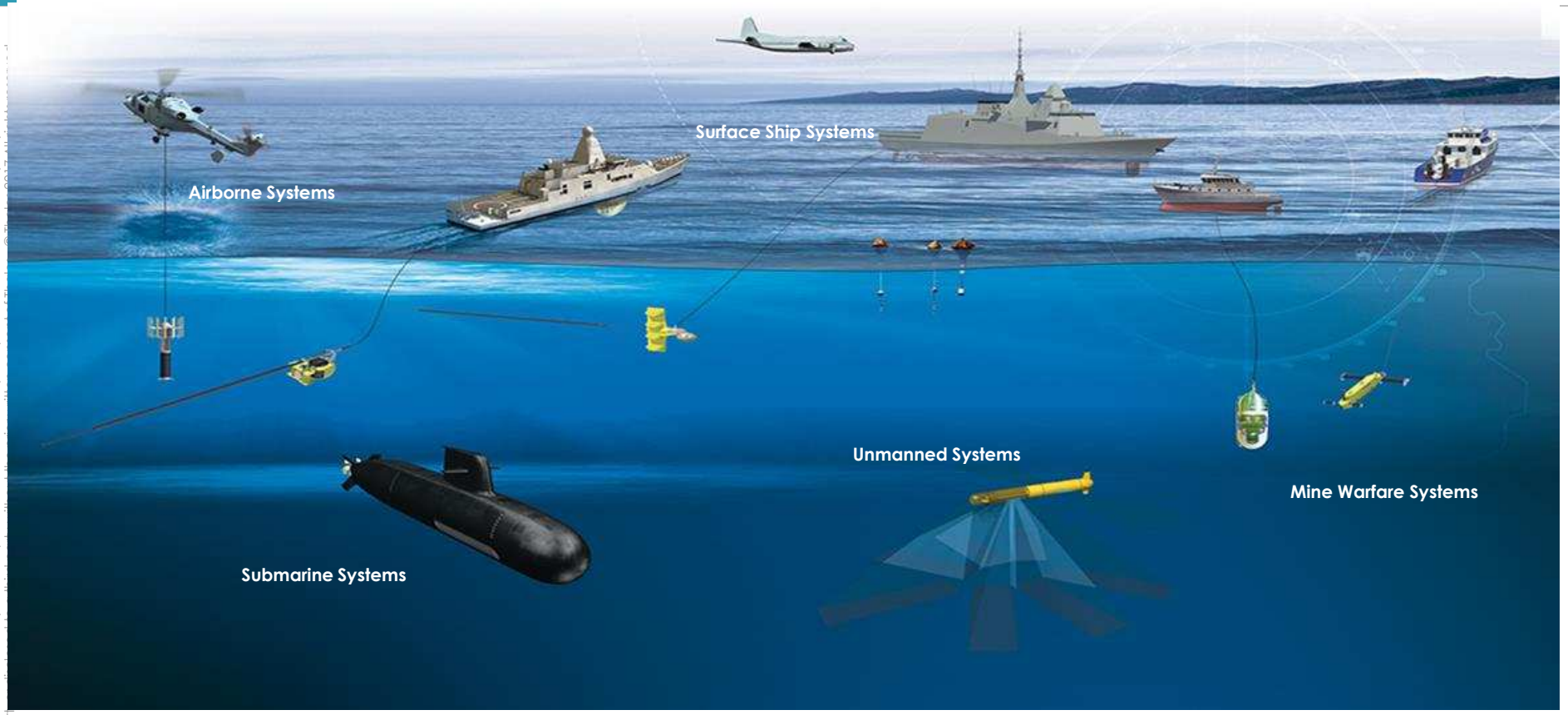
Underwater Systems



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Underwater Systems international base

Australia is a core part of the global UWS business and develops and exports piezo electric ceramics and transducers into some of the worlds largest sonar programs

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KEY CHALLENGES FOR UNDERWATER ACOUSTICS & MECHANICS

Breakthroughs in performances

High sensitivity sensors
High efficiency active transducers

Very large arrays
Wide frequency & spatial coverage

Target Stealth:
Advanced acoustic cladding materials

Minimize SONAR system footprint

Miniature sensors & embedded electronics
Compact & robust mechanical systems

Low power electronics, for data acquisition and processing
Embedded energy storage capabilities
Optimized thermal management architecture & materials

Economical footprint:
Simplification of hardware design with reduced number of parts, new manufacturing & assembly techniques for cost reduction

Transition to Drones

Environmental footprint:
low consumption of power and resources

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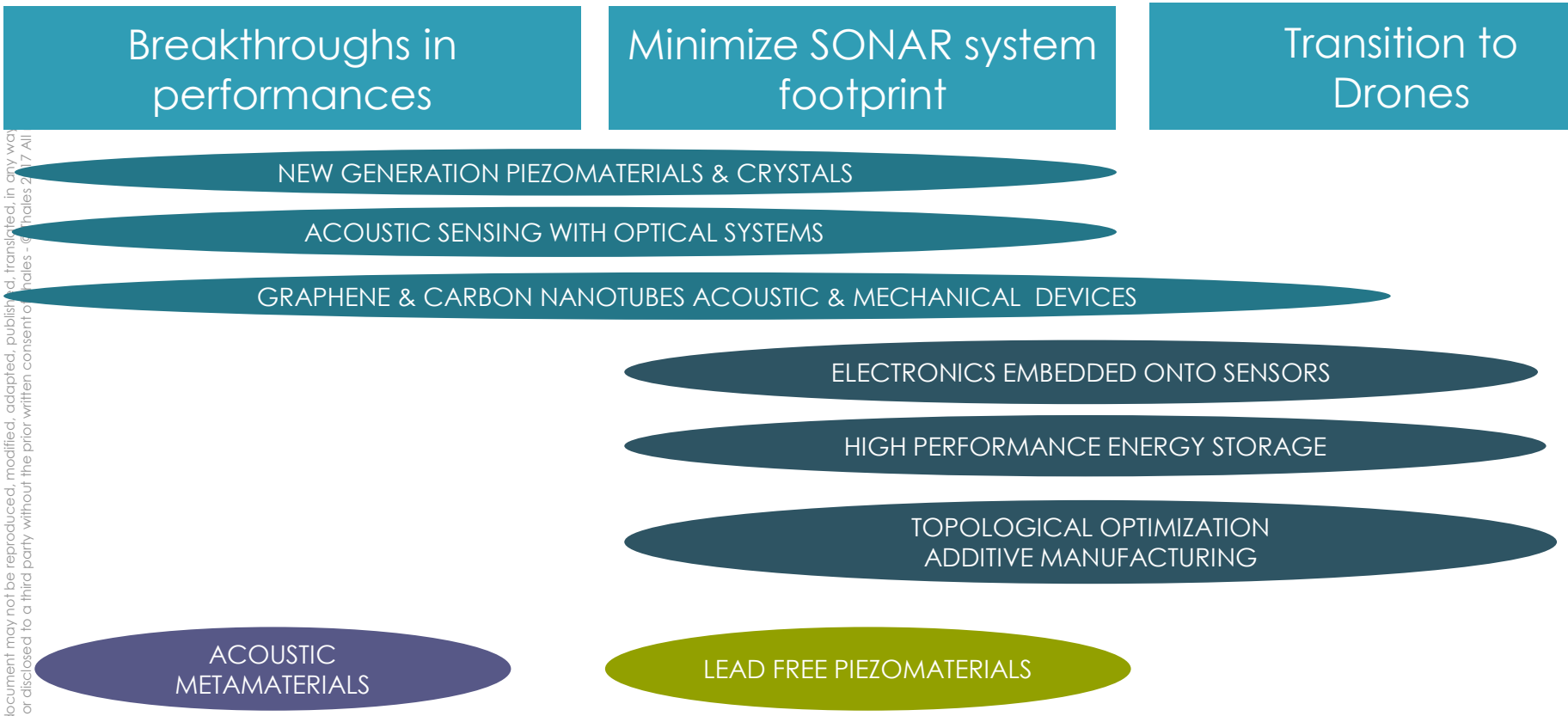
EXAMPLES OF KEY TECHNOLOGIES TO MEET THE CHALLENGES



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Advanced Piezo materials: SINGLE CRYSTAL TECHNOLOGY

Crystal solid solution with giant piezoelectric effects

- Pb(Zn1/3Nb2/3)O3-xPbTiO3 [PZN-xPT] Binary
- Pb(Mg1/3Nb2/3)O3 -xPbTiO3 [PMN-xPT] Binary
- Pb(In1/2Nb1/2)O3- xPb(Mg1/3Nb2/3)O3 - yPbTiO3 [PIN-xPMN-yPT] Ternary
- Pb(Mg1/3Nb2/3)O3 –xPbZrO3-y yPbTiO3 [PMN-xPZ-yPT] Ternary

New properties thanks to crystalline structure

- different piezoelectric properties with crystal cuts and polarization orientation
- new piezoelectric vibration modes versus ceramic (for example mode d36)

Breakthrough in sensors & transducers performances compared to conventional ceramics

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Advanced Piezo materials: SINGLE CRYSTAL TECHNOLOGY

Application to Passive sensors : +10 to +20 dB increase of Figure-Of-Merit compared to conventional ceramics

$$F.O.M = Sh^2C \approx \left(\frac{\sigma}{P}\right)^2 V \frac{d^2}{K^T}$$

Choice of crystal formulation and cut to maximize sensitivity

Hydrophone Mechanical Amplification Factor

Application to Active Transducers :

	High Power PZT Ceramic	Single Crystal Binary	Single Crystal Ternary	Single crystal transducer
Coupling coefficient k_{33} %	<70 %	~80-90%	~80-90%	◆ *Ultra-wide bandwidth*
Compliance s^E_{33} 10^{-12} m^2/N	~15	53-80	46-50	◆ *Compactness*
FOM (*) active transducer $d_{33}^2/{}_g s_{33}^E$ 10^{-}	4	20-40	25-30	◆ High TVR

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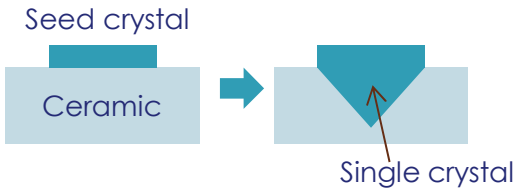
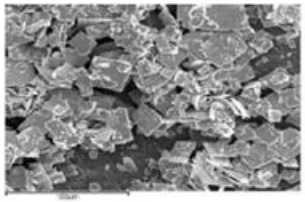
Advanced Piezo materials: SINGLE CRYSTAL TECHNOLOGY

Key research & development areas :

Crystal growth process

Modified Bridgman / SSCG: Solid State Conversion Growth / Textured ceramics -tape casting





Formulation

- PMN-PT, PMN-PIN-PT, PMN-PZ-PT
- Lead free crystals
- Doping

Challenges : material maximum size, homogeneity, manufacturing cost

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Advanced Piezo materials: SINGLE CRYSTAL TECHNOLOGY

Key research & development areas :

- Crystal stability versus stress

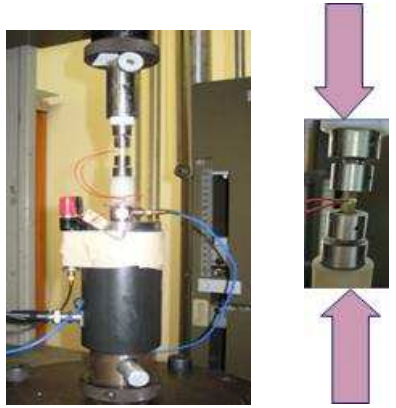
  Need for high power capability for SONAR transmit arrays
  - High electrical field, high temperature

  Need to operate at depth
  - High mechanical stress

- Optimisation of crystal formulation to avoid phase transitions

  Doping

  Non-linear behaviour requires specific acoustic design process & tools :
  - Specific characterization test benches
  - Specific multi-physics acoustic modelling tools



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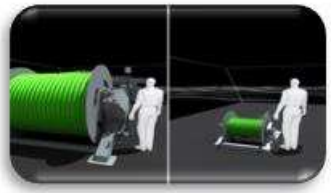
Advanced Piezo materials – Potential applications

Compact and Very-wide band Projectors

- Target : > 3 octaves, for modern sonar codes and agility
  - Bio-mimicking, Techno-mimicking, Underwater Communications
- In a small volume : Compact Dipping Sonar, Drones
- While keeping high source level and long pulses capabilities

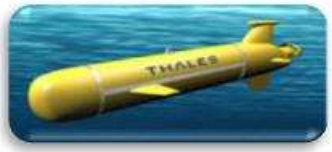
Miniaturization of passive sensors

- Small diameter linear arrays
  - can be Directive (Vector Sensors : Hydrophone + accelerometers)



Very-wide band HF arrays for future imaging systems

- Compact acoustic payloads for underwater drones
- Enabler for advanced processing : difficult targets e.g. buried mines



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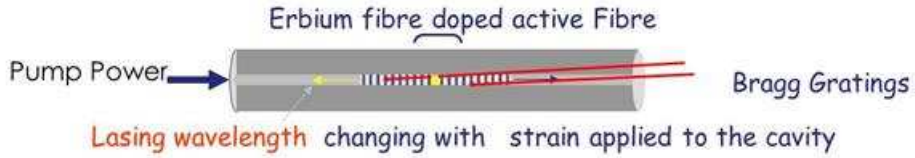
Acoustic Sensing with Optical Systems

Breakthrough technology based on Fibre-laser



A revolution in acoustic array design

- No more immersed electronics : Small-size arrays, high reliability
- Very long arrays, very long interrogation distance

A technology enabler for new high performance products

- Maritime Surveillance : Rapidly deployable, Wide Area Surveillance
- Linear Towed arrays : **Thin and very long towed arrays** :
  - Compact towed array sonar for submarines and surface ships

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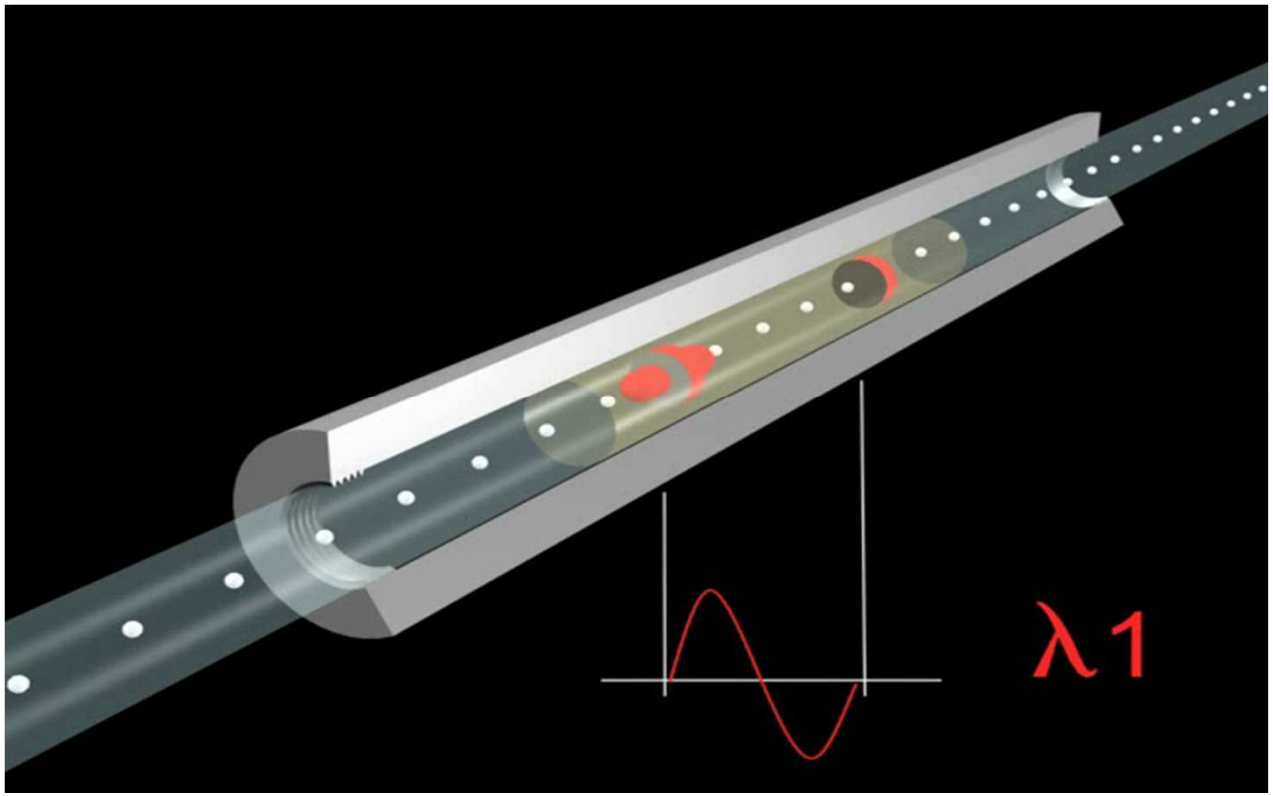
PRINCIPLES OF FIBRE LASER HYDROPHONE

Acoustic signal sensing by optical fibre components

Distributed Feedback Fibre Laser **frequency modulation by acoustic signal**



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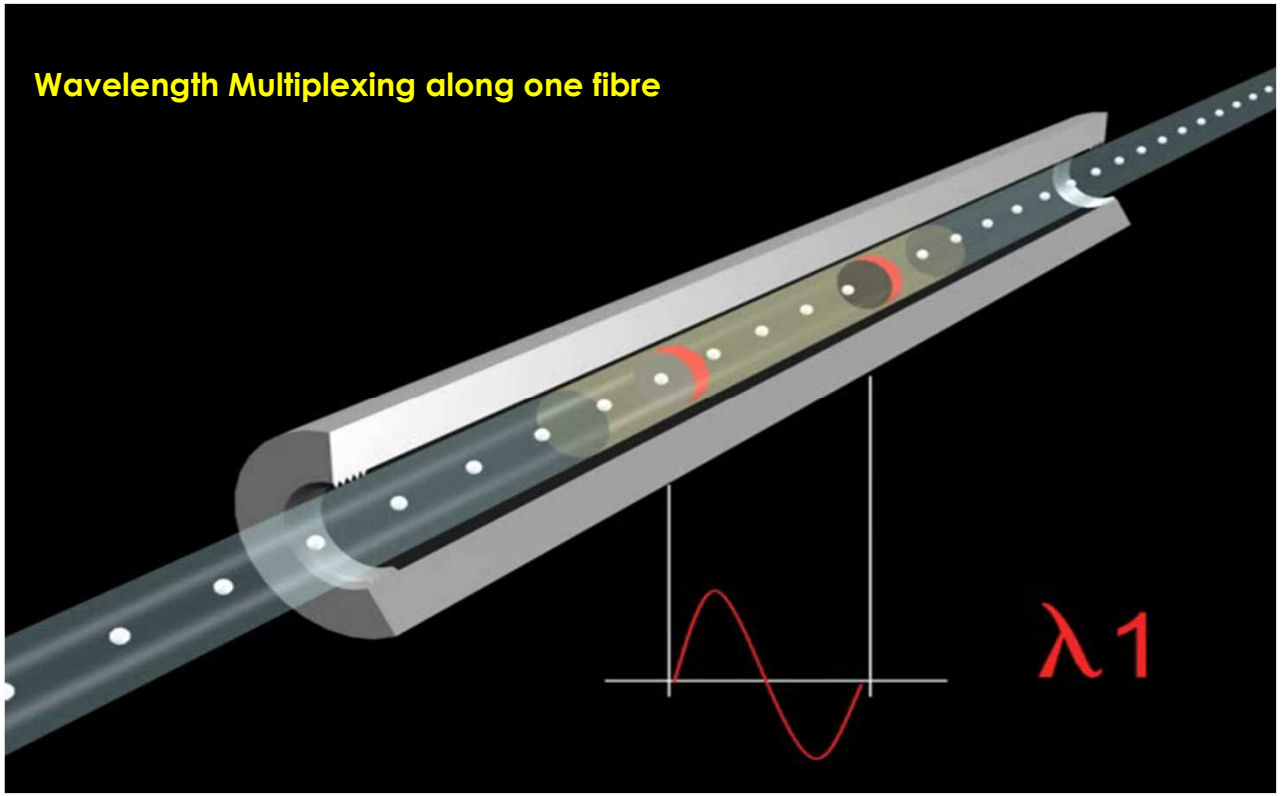
PRINCIPLES OF FIBRE LASER HYDROPHONE

Acoustic signal sensing by optical fibre components

Sensor multiplexing along one fibre



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Graphene & CNT Acoustic and Mechanical Devices

High piezo-resistivity

- Hydrophones

High thermal conductivity

- Thermal interface materials
  - Vertically aligned carbon nanotubes

- Acoustic sound sources : Thermo-acoustic sound generators
  - Based on foams

High strength : High Young's modulus and fracture strength

- Carbon Nanotube based ropes, e.g. for acoustic towed arrays

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Advanced Energy Storage Technologies

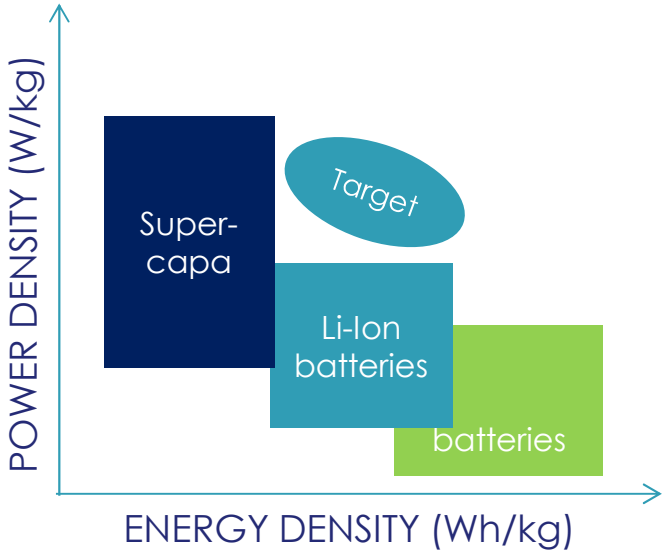
Need for compact energy storage solution for active SONAR transmission

Specific SONAR requirements :

- very high power density for pulse transmission
- resistance to high temperature, safety

Benefits of Graphene & CNTs electrodes :

- Carbon nanotubes / graphene nanoplatelets
- High specific surface area, electrical conductivity
- Conformability



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Acoustic Meta-Materials

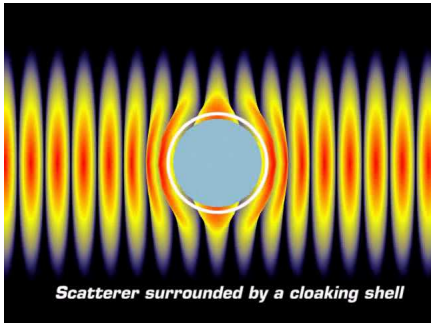
Meta-Material : artificial material structured at sub-wavelength size

- periodic set of inclusions into a matrix
- example : Bubble Meta Screens

Basic pattern : phononic crystal

- Band-gaps effects :
  - frequency domain where waves propagation is impossible
  - due to diffraction of waves by inclusions and subsequent destructive interferences
- odd properties in pass-bands :
  - negative refraction index
  - waves focalisation
  - super-absorption

Ultimate use-case : acoustic invisibility cloaking….



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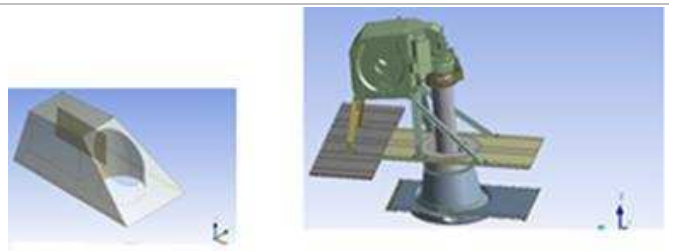
Additive Manufacturing

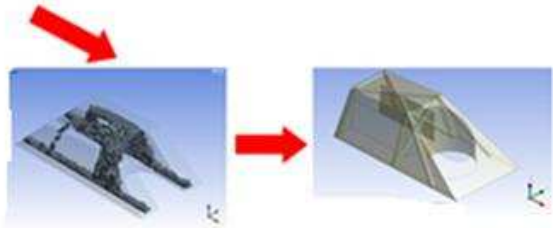
TOPOLOGICAL OPTIMIZATION TOOLS

- Reduction of Size and Weight
- Reduction of number of parts



FUNCTIONAL OPTIMIZATION AND COST REDUCTIONS

- e.g. Thermal Management



METAL and ALLOYS

PIEZOELECTRIC MATERIALS DEVICES ?, e.g. 1.3 Composite

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Additive Manufacturing

Thales 3D factory in Casablanca, Morocco

Industrial competence centre dedicated to additive manufacturing of metal parts

- whole value chain of 3D printed parts

  - from concept design and detailed specifications to new product industrialisation, powder chemistry, additive manufacturing, inspection, testing and treatment

- both prototypes and volume production
- factory opened in September 2017
- parts of up to 25 cm x 25 cm x 30 cm
- larger part sizes planned for the future

- Additive Layer Manufacturing
- High-intensity laser

- Aluminium and Titanium

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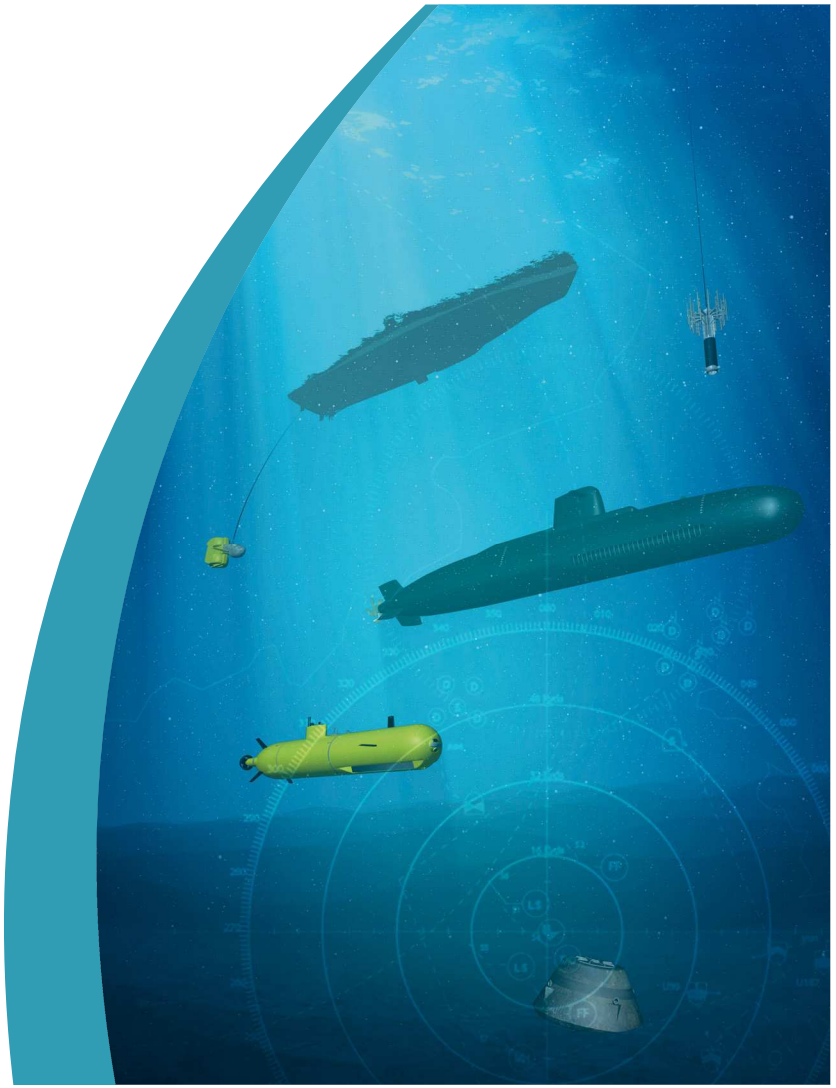
THANKS FOR YOUR ATTENTION



www.thalesgroup.com