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THE UK ACOUSTICS NETWORK

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EPSRC
Engineering and Physical Sciences
Research Council

# UK Acoustics Network
# Special Interest Group Underwater Acoustics
# UK US Underwater Acoustics Conference
# 4-5 December 2018, St Anne's College, Oxford

## 4 December 2018

| | | |
|---|---|---|
| **From 0900** | | **Arrival, coffee available** |
| | | **Introduction (Day 1)** |
| 0925 | Duncan Williams | **Welcome** |
| 0930 | Willem Hackmann | **SPECIAL TALK**<br>A History of Sonar |
| 1000 | Marcia Isakson | **US INVITED TALK**<br>Recent Developments and Future Issues in Underwater Acoustics |
| | | **Session 1 (Chair, Duncan Williams)** |
| 1030 | John Colosi | **US INVITED TALK**<br>A Scintillating Problem: Sound Propagation Through the Stochastic Ocean |
| 1100 | Philippe Blondel | Mapping and Living in Marine Habitats: Sonars, Seismics and Ambient Sounds |
| 1120 | Usama Kadri | 3D Tsunami Navigation via Nonlinear Triad Resonance with Acoustic-Gravity Waves |
| 1140 | Alan Hunter | Imaging Ocean Waves with Sound Waves and Light Waves |
| **1200** | | **Poster Session / Lunch** |
| | Erik Neefjes | Thermo-Visco Acoustics in Narrow Channels |
| | Ben Thomas | Time Delay Estimation for Repeat Pass Synthetic Aperture Sonar Micro Navigation |
| | Mohammed Alghazi | Deep Water Drifting by Acoustic-Gravity Waves Generated by Submarine Earthquakes |
| | | **Session 2 (Chair, Robert Headrick)** |
| 1330 | John Smith | **UK INVITED TALK**<br>Underwater Applications of Structural Acoustics |
| 1400 | Aaron Gunderson | Numerical Green's Function Determination Technique for the Far Field Acoustic Scattering Evaluation |
| 1420 | Dick Hazelwood | Seabed Vibrational Waves Create Localised Evanescent Water Waves |
| 1440 | Angus Best | Spatial Acoustic Properties: Rocks, Sediments, Hydrates and Gas |
| **1500** | | **Break** |
| | | **Session 3 (Chair, Richard Craster)** |
| 1530 | David Knobles | **US INVITED TALK**<br>Seabed Physics in the New England Mudpatch (Presented by Mohsen Badiey) |
| 1600 | Brian Hefner | Identifying Environmental Factors in Mid-Frequency Reverberation Using a Bottom Mounted System |
| 1620 | Steven Lloyd | Wave Monitoring Using a UAS Flight Controller for Hydrophone Retraction and Extension |
| 1640 | Pierre Cauchy | Use of Ocean Gliders for Passive Acoustic Monitoring |
| 1700 | Richard Craster | **UK ACOUSTICS NETWORK TALK**<br>About the UK Acoustics Network / Discussion |
| **1730** | | **Close (Day 1)** |
| **From 1900** | | **Pre-Dinner Drinks Reception and Conference Dinner** |

Institute of Acoustics

ASA ACOUSTICAL SOCIETY OF AMERICA

# UK Acoustics Network
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# 4-5 December 2018, St Anne's College, Oxford

## 5 December 2018

| | | |
|---|---|---|
| **From 0900** | | **Arrival, coffee available** |
| | | **Introduction (Day 2)** |
| 0945 | John Colosi | **Welcome** |
| 0950 | Philippe Blondel | **A B WOOD MEDAL**<br>2018 Presentation to Nathan Merchant |
| 1000 | Nathan Merchant | **UK INVITED TALK (A B WOOD MEDAL LECTURE)**<br>Underwater Noise Monitoring and Modelling in the UK and North East Atlantic |
| | | **Session 4 (Chair, John Colosi)** |
| 1030 | Chris Harrison | **UK INVITED TALK**<br>Doppler Passive Fathometry |
| 1100 | DJ Tang | Variability of Mid-Frequency Sound Propagation and Detection |
| 1120 | Daniel Babatunde | Unmanned Aerial Vehicles as a Platform for Autonomous PAM of the Harbour Porpoise |
| 1140 | Richard Craster | Metasurfaces Underwater and on Elastic Surfaces |
| **1200** | | **Poster Session / Lunch** |
| | Bernabe Gomez | Inverse Solution for Acoustic Radiation from a Slender Fault |
| | Byron Williams | Acoustic-Gravity Wave Propagation from a Slender Fault |
| | Usama Kadri | Effect of Sea Bottom Elasticity on Gravity / Acoustic Waves from Submarine Earthquakes |
| | | **Session 5 (Chair, Stephen Robinson)** |
| 1330 | Robert Headrick | **US INVITED TALK**<br>Recent At Sea Propagation Studies |
| 1400 | Charles Holland | Seabed Reflection Measurements, Modelling and Inferences |
| 1420 | Alan Hunter | Growing Piezocomposite Underwater Transducers by Freeze Casting |
| 1440 | Sarah Marley | Spatial and Temporal Variation in the Acoustic Habitat of Bottlenose Dolphins |
| **1500** | | **Break** |
| | | **Session 6 (Chair, Nick Chotiros)** |
| 1530 | Peter Tyack | **UK INVITED TALK**<br>How Anthropogenic Changes in Ocean Soundscapes Affect Marine Life |
| 1600 | Mohsen Badiey | Recent Studies of Physics of Acoustic Waveguide Over Continental Shelf Break |
| 1620 | Robert Blackwell | Detecting and Removing Aliased Seabed Echoes in Fisheries Acoustic Data |
| 1640 | Nikhil Banda | Advances in the Active Detection of Cetacea with Opportunistic Seismic Sources |
| 1700 | *Nick Chotiros* | **UK ACOUSTICS NETWORK TALK**<br>Developing International Partners of ONR Global and funding opportunities / Discussion |
| **1730** | | **Close (Day 2)** |
| **From 1730** | | **Depart** |

# Day 1 – Introduction

**SPECIAL TALK**

**A History of Sonar: Asdic to Sonar and the Cross-over to the Science of Underwater Acoustics**

*Dr Willem Hackmann, Linacre College Oxford*

These two acronyms encapsulate the origins of sonar research which began in the First World War to curb the U-boat menace. Of course interest in the sea as a medium goes back much further, but arguably the modern scientific starting point is the determination of the velocity of underwater sound by Colladon and Sturm in 1826. The Royal Navy acknowledged in 1873 the importance of science when it founded the Royal Navy College at Greenwich, but it were the accelerated technologies of warfare in the 20th century such as the submarine that led to radical methods both organizational and technical to combat this new form of warfare. The distinction between pure and applied science became increasingly difficult to make. This brief introduction illustrates the historical interrelatedness of naval mission-oriented research in sonar and oceanography resulting in spin-offs such as A.B. Woods's Textbook of Sound (1930), the Admiralty echo sounder and its post-war impact on the fishing industry, the discovery of long-range deep-sound channels, operational research and mathematical modelling and signal processing. For historians it is hard to determine to what extent naval involvement may have distorted research priorities in the past, but on the other hand, it is undeniable that this has been of great benefit to the discipline of Underwater Acoustics. This lecture is based on full access to naval documents and interviews with scientists involved in this work in Britain and the USA for my book Seek and Strike (HMSO, 1984).

Dr Willem Hackmann is Emeritus Fellow of Linacre College, Oxford, and Emeritus Reader in the History of Science. Dr Hackmann was commissioned to write Seek and Strike: Sonar, Anti-Submarine Warfare and the Royal Navy 1914-54 (HMSO, 1984). For the first two years of his history of sonar project he was attached to the Science Museum in Oxford, and by the time he completed it 6 years later he was Assistant Curator at the Museum of the History of Science Museum, University of Oxford. He remained in Oxford until his retirement.

**US INVITED TALK**

**Recent Developments and Future Issues in Underwater Acoustics**

*Dr Marcia Isakson, ARL University of Texas at Austin*

The field of underwater acoustics has changed significantly since Colladan and Sturm first measured the speed of sound in Lake Geneva. With the advent of computer technology, computational acoustics was born allowing for predictive models of acoustic propagation and scattering in complex environments. This field is currently burgeoning as evidenced by the creation of a new Technical Specialty Group at the Acoustical Society of America dedicated to cross-disciplined research in computational acoustics. These methods can now predict three-dimensional acoustics propagation and reverberation in complex areas using finite elements and spectral elements. In this overview talk, new developments will be traced by highlighting the work of five researchers: finite element modeling by Dr. Aaron Gunderson from the Applied Research Laboratory at the University of Texas at Austin, spectral element modeling by Dr. Paul Cristini from the Laboratorie de Mecanique et d'Acoustique, Aix-Marseille University, Arctic acoustics by Dr. Megan Ballard of the the Applied Research Laboratory at the University of Texas at Austin, sensor technology from Dr. Andone Lavery from Woods Hole Oceanographic Institute, and underwater soundscapes by Dr. Jennifer Miksis-Olds of School of Marine Science and Ocean Engineering, The University of New Hampshire. The future of underwater acoustics remains as unbounded today as it did the day the Colladan and Sturm crouched in their boats measuring Lake Geneva. Due to fundamental laws of physics, acoustics will always be the primary tool for communication, remote sensing and environmental assessment in our rivers and oceans. We should develop our capabilities to monitor the health of the earth by quantifying underwater carbon capture, assessing coral reef health, and keeping track of the changing Arctic by continuing work on modeling and understanding acoustic propagation and scattering in complicated and complex environments.

Dr Marcia Isakson earned a PhD from The University of Texas in 2002, having been stationed with the US Army at Fort Hood between 1994 and 1997, following her MA in Physics in 1994. Since 2001, Dr Isakson has been involved in research in underwater acoustics at the Applied Research Laboratories at the University of Texas at Austin. Dr Isakson is currently serving as the past-president of the Acoustical Society of America where she has also served on the executive council and chaired several committees. Dr Isakson has been designated as a Distinguished Lecturer of the IEEE Oceanic Engineering Society since 2010.

# Day 1 – Session 1

**US INVITED TALK**

**A Scintillating Problem: Sound Propagation Through the Stochastic Ocean**

*Prof John Colosi, Naval Postgraduate School*

Not long after the 1944 discovery of the ocean sound channel by Ewing and Worzel it became quite evident that this was a fluctuating channel giving rise to frequent transmission fade outs and rapid phase jumps that complicate practical applications. In a 1950 National Research Council report Eckart and Carhart state, that if sound is transmitted through the sea, ``… *the intensity of the signal received from one second to the next will not be constant; it fluctuates often by a factor of 10. Indeed the presence of fluctuations is perhaps the most constant characteristic of sound in the sea*''. This talk will review the present state of our understanding of the nearly 70 year old subject of sound propagation though the stochastic ocean, where key contributions have come from (1) developments in physical oceanography such as the Garrett-Munk internal wave spectrum and spicy sound speed structure, (2) technological advances in source and receiver capability, (3) advances in computing and data processing power, and (4) developments in theoretical physics such as Feynman path integrals, transport theory, and dynamical systems theory. New challenges exist aplenty including gaining an understanding of arctic and high latitudes, the mixed layer and upper ocean, and monitoring various aspects of climate change. For progress, significant contributions from all four of the aforementioned fields will be required.

Prof John Colosi received his BA degree in Physics from the University of California, San Diego in 1988, and a PhD in Physics from the University of California, Santa Cruz in 1993. Presently he is a Professor of Oceanography at the Naval Postgraduate School (NPS) in Monterey California, and an adjunct Professor in Ocean Sciences at the University of California Santa Cruz. Prof Colosi was the recipient of the 2001 A B Wood Medal, and the 2011 Medwin Prize in Acoustical Oceanography. He is a Fellow of the Acoustical Society of America, and has twice been a Scripps Institution of Oceanography Cecil H. and Ida M. Green Scholar. His scientific interests are in wave propagation through random media, acoustical remote sensing, and internal waves and tides.

**Mapping and Living in Marine Habitats: Sonars, Seismics and Ambient Sounds**

*Dr Philippe Blondel, University of Bath*

Thorough mapping of the marine environments has started close to 70 years ago, and it makes use of increasingly sophisticated instruments mostly relying on acoustics. These instruments either create their own sounds and listen to their echoes, or rely exclusively on sounds produced naturally or by a variety of physical processes. We are using these tools to harvest resources like fish and hydrocarbons, to monitor the increases in commercial and recreational shipping, their sustainability and their impacts, and to de-risk the development of marine renewable energies. This creates challenges for data storage, long-term data access, reliable standardisation and interpretation, and for comparison between regions and between times. These challenges, and the different ways forward, will be illustrated with examples from Arctic waters to temperate coastal environments. The quantitative results afforded by acoustic measurements can then be meaningfully used to solve controversies, or add a useful evidence base to on-going activities and debates.

**3D Tsunami Navigation via Nonlinear Triad Resonance with Acoustic-Gravity Waves**

*Dr Usama Kadri, Cardiff University*

It is well established now that resonant triads is possible within the family of surface-gravity and acoustic–gravity waves [e.g. Kadri & Akylas, *J. Fluid Mech.* 2016]. Such interaction allows energy exchange between these virtually decoupled waves. The interaction of two surface gravity waves of similar periods but opposite directions give rise to an acoustic–gravity wave of similar, but much larger, time and length scales, respectively — in a mechanism similar to that proposed by Longuet-Higgins. On the other hand the interaction of a single surface-gravity and two acoustic–gravity waves, in an inviscid compressible ideal ocean comprises triad members that have a comparable length scale, whilst the two acoustic–gravity waves have much larger time scales. Under these settings, the wavelength of the gravity mode is assumed longer than a regular surface gravity wave, resembling a tsunami, but short enough that the dispersion relation is yet observed. Kadri [*9th South China Sea Tsunami Workshop* 2017] argued that with proper finely tuned interaction conditions the original amplitude of a tsunami envelope can drop significantly (by almost 30%) redistributing its energy over a larger space creating secondary envelopes that are positioned behind, i.e. their arrival to the shoreline is delayed; a fractal of all of which if achieved in practice may save many lives and properties. However, the analysis is based on a 2D theory. Here, we present an extended 3D theory for the amplitude evolution equations for two gravity waves interacting with an acoustic mode to prepare the ground for a basic proof-of-concept experiments for this energy exchange mechanism.

**Imaging Ocean Waves with Sound Waves and Light Waves**

*Dr Alan Hunter,  University of Bath*

Coastal communities are being exposed to ever greater risk of coastal erosion and flooding as a result of sea level rise and larger storm waves. Improved understanding of breaking waves will enhance our ability to predict and defend against these risks. To this end, researchers at the University of Bath have been using advanced sensing systems to measure and monitor coastal erosion caused by wave interactions with the beach.  In 2017, a prototype scale experiment was conducted in the GWK wave flume (Hannover, Germany) with a cross-section of 5x7 m and over 300 m in length. A combination of underwater sonar and above-water lidar systems were used to estimate the cross-sections of waves as they broke onto the shore.

# Day 1 – Posters

**Thermo-Visco Acoustics in Narrow Channels (Poster)**

*Erik Neefjes, University of Manchester*

Recent work in acoustic metasurfaces has shown their potential in absorbing sound almost perfectly in narrow frequency ranges by coupling resonant effects to visco-thermal damping within their microstructure. As it is expected, correctly understanding acoustic attenuation mechanisms in narrow, viscous-fluid-filled channels is of fundamental importance for such applications. A theoretical framework is presented that demonstrates the controlling mechanisms of thermo-viscous acoustic propagation in arbitrary Newtonian fluids, focusing on the differences in attenuation among air and water. For rigid-walled channels, whose widths are of the order of Stokes' boundary layer thickness, attenuation in air at 10 kHz can be over 200 dB/m; in water it is less than 37 dB/m. However, for water, the rigid wall assumption is invalid due to the importance of fluid-structure-interaction effects. In fact, these effects can increase attenuation dramatically, to over 77 dB/m for a steel-walled channel, with a reduction in phase-speed approaching 70%.

**Time Delay Estimation for Repeat Pass Synthetic Aperture Sonar Micro-Navigation (Poster)**

*Ben Thomas, University of Bath*

Accurate time delay estimation is a vital stage of the redundant phase centre (RPC) micro-navigation algorithm for Synthetic Aperture Sonar. It computes the path traversed by the array to within the sub-wavelength precision required to support the coherent processing. This algorithm has been generalised to produce registered navigation estimates for multiple tracks in the slant-range plane and extended to estimate inter-pass heave and sway while simultaneously generating a coarse bathymetry estimate for interferometric SAS. Due to the nature of the short-time correlation-based time delay estimation method, the time delay estimates can be corrupted by phase wrapping, causing errors corresponding to integer numbers of time periods at the centre frequency. This results in minor image defocusing and errors in the resulting navigation estimate in the single-pass case. In Thomas, Hunter & Dugelay [2018] this resulted in corruption of the navigation and bathymetry estimates. In this work we examine methods for detecting and correcting these errors, based on the RANSAC algorithm as suggested in Ziliang [*Eur. Conf. Synth. Aperture Radar* 2018].

**Deep Water Drifting by Acoustic-Gravity Waves Generated by Submarine Earthquake (Poster)**

*Mohammed Alghazi, Cardiff University*

The assumption that the ocean is not compressible has been assumed in many researches on deep ocean currents which is reasonable in some applications. Where an incompressible ocean with constant depth $h$ for every frequency $\omega$ for wave number $k$ it only has one progressive wave which is the gravity wave. However, Taking compressibility into consideration there will be $m$ progressive wave modes for every frequency $\omega$ for horizontal wave numbers $k_n$ where n = 0,1, ..., $m$ and $k_0$ is almost equal to the gravity wave in the incompressible case. These waves are called Acoustic-Gravity Waves (AGW) and they are progressive type of waves generated among others by interaction between wind and wave, submarine earthquake and other sources with amplitudes governed by the restoring force of gravity. Similarly to other well known water drifting mechanisms, AGWs may play an important role in creating currents in the ocean and transporting water that are important for the healthiness of the oceans. Although this mechanism has been demonstrated qualitatively, it is still not known how much water is being transported compared to other mechanisms. To this end, we study the distribution of the generation of AGWs by submarine earthquakes and estimate the amount of energy transferred. It is found that AGWs play a prominent role in transporting water at various locations in the ocean.

# Day 1 – Session 2

**UK INVITED TALK**

**Underwater Applications of Structural Acoustics**

*Prof John Smith, Defence Science & Technology Laboratory*

Over the last 40 years the use of singular perturbation theory together with simple analytical models has vastly improved our understanding of fluid-structure interactions. Most of this work has been based on fluid loading expansions that neglect the role of symmetric waves. Here we look at how these interactions can be included into the scheme and a more complete picture obtained.

Prof John Smith is a Senior Principal Scientist at the Defence Science & Technology Laboratory and a Visiting Professor at Exeter University with interests in physical acoustics and underwater acoustics. Prof Smith is a Fellow of the Institute of Acoustics and received the A B Wood Medal in 2012.

**Numerical Green's Function Determination Technique for Far Field Acoustic Scattering Evaluation**

*Dr Aaron Gunderson, ARL University of Texas at Austin*

Finite element models provide highly accurate solutions for acoustic scattering from objects resting on or buried within seafloor, but models are limited in spatial dimensions due to processing time constraints and computational capabilities. Far field scattering results may be acquired in postprocessing through the use of the Helmholtz-Kirchhoff (H-K) integral. The H-K integrand contains the Green's function of the environment, which may be known or calculated analytically for simple environments. With increasing environmental complexity, analytic forms of Green's functions become harder to approximate and/or take longer to determine. A numerical method is presented which uses the same finite element model to solve numerically for the Green's function, and which requires only solving for the field received from the source or receiver location at each point on the H-K integral contour. The method is generalisable to any arbitrary target and environment. Results are shown for various elastic objects in free field and on smooth and rough seafloor interfaces, and are demonstrated to give good agreement with published experimental and model results. Near field finite element models are created with a target and its immediate local environment surrounded by perfectly matched layers (PMLs) to simulate an infinite environment. Models are solved time-harmonically through a fully scattered field formulation, which has been shown to avoid numerical artifacts associated with inclusion of an infinite interface positioned adjacent to PMLs.

**Seabed Vibrational Waves Create Localised Water Waves**

*Dr Dick Hazelwood, R&V Hazelwood Associates*

Measurements and studies of seabed vibration over the past 8 years have yielded an improved understanding of the highly dispersive nature of seismic interface waves across a real sedimentary seabed. Increasing interest in their environmental importance has occurred as it becomes clearer how the water motion is amplified by the low acoustic impedance near the seabed interface. Finite element analysis (FEA) has been used to study the propagation of seismic interface waves to allow these effects to be evaluated. A new infinite half space model extends those described by Rayleigh and Scholte, by using a linearly graded solid structure. A region of little dispersion (an "Airy phase") occurs with a primarily infrasonic content, wherein the propagation of peak intensity is good, with little or no expansion of the drive impulse with time and distance. This retains a cylindrical spreading structure of peak intensity, ignoring absorption. Driven by a Ricker wavelet (the Mexican Hat form) a compact wavelet propagates without the usual expansion in time, seen as additional oscillations with increased zero crossings. However this compact form morphs from a single hump to a single dip and back. The morphing rate is controlled by the gradient of the solid shear wave speed with depth. For this selected simple form, the "Morphing Mexican Hat" (MMH), we find a simple ratio between the maximum horizontal particle velocity and the acoustic pressure. This takes the form of an impedance, similar to that seen in plane pressure waves, but lower by a factor, typically around 12, given by the slow group velocity of the MMH form. This means that the water particle velocities near the seabed are higher than might be expected, but that there is predictive power available from pressure measurements.

**Spatial Acoustic Properties: Rocks, Sediments, Hydrates and Gas**

*Dr Angus Best, National Oceanography Centre*

There is a still a need to understand the fundamental laws that govern sound wave propagation in geological materials beneath the seafloor, in sediments and rocks. Sound wave interaction with the seafloor is central to many applications, from naval defence to geotechnical surveys to mineral exploration. Over the last 15 years, research at the NOC Geophysics Laboratory has focussed on topics including hydrocarbon reservoir characterisation, geological CO2 storage, seafloor hydrates and deep sea minerals. Laboratory experimental studies using newly developed instrumentation have delivered new insights not achievable from in situ studies alone. Examples include elastic wave velocity anisotropy in fractured reservoir rocks, including effects of pore fluid viscosity on shear wave splitting; velocity and attenuation in partially gas saturated rocks and sediments including new theory, and the effect of methane hydrate content and morphology on velocity and attenuation in sediments. Foremost among these advances is a more precise description of frequency-dependent effects, from seismic (< 200 Hz), through sonic (1 – 10 kHz) to ultrasonic (> 400 kHz) ranges, captured in theoretical models. The results to date demonstrate the complexity of sound wave interaction with the seafloor, a largely unexplored and heterogeneous environment, and yet general physical principals seem to hold true for quite disparate materials. For example, local viscous flow is a dominant attenuation mechanism over broad frequency ranges, clearly related to the texture of rocks and sediments.

# Day 1 – Session 3

**US INVITED TALK**

**Seabed Physics in the New England Mudpatch**

*Dr David Knobles, Knobles Scientific and Analysis*

Presented by *Dr Mohsen Badiey, University of Delaware*

In shallow water ocean environments information content in acoustic remote sensing for the sound speed and attenuation in the seabed can possess large uncertainties due in part to the presence of multiple sediment layers possessing horizontal variability over a large band of spatial wavenumbers. Further, models that predict the dispersion relationship between the real and imaginary parts of the sound speed for the multiple sediment layers are generally effective models whose parameters are generally inferred from both acoustic and physical measurements. Such issues are currently being addressed for acoustic field measurements made in the New England Mudpatch where the ONR Seabed Characterization Experiment was performed in March-April 2017. Bayesian-Maximum Entropy statistical inference, the Buckingham viscous grain-shearing model, and stochastic propagation models that consider the non-deterministic 2-D roughness between a fine-grained and a sand sediment layer are utilised in the analysis of the acoustic field data. Some of the data examined include the received acoustic field generated by multiple deployments of MK-64 SUS and the Combustive Sound Source (CSS). Further, the acoustic analyses are supported with *a priori* information derived from a subbottom profiling survey and a piston core survey of the seabed performed by the UT Institute of Geophysics and the United States Geological Survey, respectively.

Dr David Knobles received his PhD in nuclear theory in 1989 from the University of Texas at Austin. From 1989 through 1992 he did a post-doctoral fellowship in nuclear physics at the University of Texas at Austin. He was a research scientist at The Applied Research Laboratories, The University of Texas at Austin from 1980-1985 and 1992-2016. Currently he is owner of Knobles Scientific and Analysis (KSA) and is a Fellow of the Acoustical Society of America. His research interests include theoretical physics, remote sensing, cosmology, and bioacoustics. He is currently serving as co-chief scientist for the ONR Seabed Characterization Experiment.

**Identifying Environmental Factors in Mid-Frequency Reverberation Using a Bottom-Mounted System**

*Dr Brian Hefner, University of Washington*

Accurate environmental acoustic models are essential for sonar performance prediction in spatially and temporally changing environments. In order to develop and assess these models, one needs to both collect data over the time scales of interest and remove the uncertainties and bias associated with sensor motion from the data. To accomplish this, we have developed a benthic lander capable of making directional, mid-frequency reverberation measurements over a month-long deployment. The utility of the Autonomous Reverberation Measurement System (ARMS) was made clear by the 2013 Target and Reverberation Experiment (TREX13) during which a bottom-mounted horizontal line array and omnidirectional source collected data over the course of a month. While having a fixed system on the seafloor made it possible to study how the spatial variability of the seabed and the diurnal changes in biological clutter affected the reverberation, the need to cable those systems to the ship made it impossible to collect data during high sea states. By operating autonomously and utilising a directional source and receiver, a small research vessel can deploy the system to safely collect data during any sea state. In addition to discussing the design, utility, and operation of the ARMS, this talk will also focus on how this system is being applied to address research questions in mid-frequency acoustics. For example, the ARMS was deployed off Geoje Island in South Korea in the spring of 2017. The seafloor at the experiment site was punctuated with rock outcroppings that produced large acoustic returns. With the source, receiver, and scatterer fixed on the seafloor, it was possible to focus on the temporal variability of signal excess for these targets.

**Wave Monitoring Using a UAS Flight Controller for Hydrophone Retraction and Extension to Reduce the Effects of Flow Noise**

*Steven Lloyd, Loughborough University*

Unmanned Aerial Systems (UAS) have seen a substantial increase in their use for sensor deployment, from physical sample collection of water and blow hole mucus, to population counts and photogrammetry from cameras. The research to be presented involves a new method of hydrophone deployment, via the use of a UAS. Previous work has shown this method to be feasible, although battery life is a concern, and limits its use. Landing and deploying a hydrophone, using waterproof UAS such as the HexH2O, Splashdrone and QuadH20, increases the deployment time. Surface deployment results in large amounts of noise being induced onto the hydrophone from subsonic frequencies, due to movement of the deployed UAS on the surface pulling the hydrophone up and down vertically. Traditional methods of surface heave reduction are too heavy for a UAS to carry; therefore a new method of surface heave reduction is being developed by the authors involving the use of onboard accelerometers already used by the UAS inside the Flight Controller to control a motor for the extension and retraction of an attached hydrophone. The Pixhawk 2.0 flight controller was used for testing on a FANUC robotic arm, which moved the Pixhawk through predefined circles of varying sizes and planes at a number of different velocities. This motion may not mimic the full complexity of ocean waves, although it will suffice for this stage of research. The acceleration after each test was extracted, filtered and integrated, to obtain the displacement. Results show that the Pixhawk used can track the FANUC arm accurately, even at speed. This new technique could be used to make deployments cheaper, and easier to retrieve, as it removes the need to retrieve hydrophones and equipment from the seabed. The results, future development and a more detailed methodology will be presented, along with a full list of benefits such a system could bring to passive acoustic monitors.

**Use of Ocean Gliders for Passive Acoustic Monitoring**

*Pierre Cauchy, University of East Anglia*

Ocean gliders are long range and low-cost autonomous platforms, able to silently collect multidisciplinary oceanic data profiles at high spatiotemporal resolution. They are highly suitable for Passive Acoustic Monitoring (PAM) of the oceanic environment. We have been deploying Passive Acoustic Monitoring (PAM) gliders for 6 years, developing new ways of observing the oceanic environment from ambient noise analysis. We adapted the Weather Observation Through Ambient Noise (WOTAN), demonstrating the ability to estimate surface wind speed from the underwater ambient noise recorded from a glider. We observed several high wind speed events (> 15 m/s). We propose a two-regime linear relationship between the wind speed at 10 m and the sound pressure level, which validates a previous linear model for light winds (below 12 m/s) and extends its validity range to strong winds of up to 21.5 m/s. This novel method for measuring surface wind speed will improve the quantification of critically important air-sea fluxes, providing in-situ measurements in remote locations or adverse weather conditions. We broaden the observation spectrum of the ocean gliders, demonstrating how such recordings of the underwater soundscape can be used to monitor the marine life. We were able to detect sperm whales and map their distribution along glider tracks in the NW Mediterranean Sea. This ability could provide observations that will increase the coverage of the usual survey methods and reduce their bias (e.g. seasonal, fair-weather). We gathered evidence that, in many different environments, the analysis of soundscape recorded by gliders enables a wide range of non-invasive observations of the sea surface conditions, the marine life and the anthropogenic contribution to the marine noise. The various applications to physical oceanography, biology, ecology and regulations will enhance interactions between the scientific communities and allow comprehensive monitoring of areas of interest (e.g. marine protected areas).

# Day 2 – Introduction

**A B WOOD MEDAL**

The A B Wood medal and attendant prize is awarded in alternate years to acousticians based in the UK / Europe (even years) and in the US / Canada (odd years). It is aimed at younger researchers, those who are aged under 40, whose work is associated with the sea. Following his graduation from Manchester University in 1912, Albert Beaumont Wood became one of the first two research scientists at the Admiralty to work on antisubmarine defence. He designed the first directional hydrophone and was well known for the many contributions he made to the science of underwater acoustics and for the help he gave to younger colleagues. The A B Wood Medal was instituted after Albert's death by his many friends on both sides of the Atlantic and was administered by the Institute of Physics until the formation of the Institute of Acoustics.

Previous winners of the A B Wood Medal include Jan Dettmer (US), Yan Pailhas (Europe), Brian Heffner (US), John Smith (UK), John Colosi (US), and Chris Harrison (UK).

The 2018 A B Wood Medal will be presented by Dr Philippe Blondel, University of Bath.

**UK INVITED TALK – A B WOOD MEDAL LECTURE**

**Underwater Noise Monitoring and Modelling in the UK and North East Atlantic (A B Wood Medal Lecture)**

*Dr Nathan Merchant, Centre for Environmental Fishers and Aquaculture Science*

This presentation will offer a brief overview of the author's career to date, before focusing on current areas of research. Passive acoustic monitoring and monitoring of noise-generating activities is underway in UK waters and the wider northeast Atlantic to inform the development of management measures to address underwater noise pollution. This includes work to try to characterise trends in underwater noise levels, to produce modelled maps of noise from shipping, and to monitor levels of impulsive noise activity and its potential impacts on marine life. An overview of this work will be presented, from the perspective of the author's role as a scientific advisor to Defra and as co-convenor of the OSPAR technical group on underwater noise.

*Dr Nathan Merchant leads the Noise and Bioacoustics team at the Centre for Environment, Fisheries, and Aquaculture Science (Cefas), and has a PhD in underwater acoustics from the University of Bath. He is a scientific advisor on underwater noise to the UK Department for Environment, Food & Rural Affairs (Defra) and oversees scientific advice on underwater noise to regulatory bodies in England and Wales. He co-chairs the OSPAR Intersessional Correspondence Group on Noise, which provides scientific coordination for the North-East Atlantic, and is a member of the European Technical Group on Noise, which advises on the implementation of Descriptor 11 of the EU Marine Strategy Framework Directive (MSFD).*

# Day 2 – Session 4

**UK INVITED TALK**

## Doppler Passive Fathometry

*Dr Chris Harrison, CMRE*

Passive fathometry is a technique whereby broad band ambient ocean noise received on an array of hydrophones is averaged and cross-correlated to produce a sub-bottom profile [Siderius, Harrison, & Porter, *J. Acoust. Soc. Am.* 2006]. Here this technique is extended to determine the vertical velocity of the array, and compensate for it, without any prior knowledge, i.e. Doppler Passive Fathometry. For Fourier transform lengths beyond a certain limit, the differing Doppler between the direct and bottom reflected paths spoils the correlation match, however it is shown by using some experimental data, where the array was known to suffer from arbitrary but near periodic motion, that compensation is possible, enabling continuing time integration. In the process, the vertical velocity becomes known. Velocity, with peak value ~ ±1 m/s, is plotted against time and shown to be 90° out of phase with depth, as expected for periodic motion. Since stationary targets have already been detected by noise correlation [Harrison, *J. Acoust. Soc. Am.* 2008] it is implied that the range of moving targets can also be determined

Dr Chris Harrison received his MA in Natural Sciences from Clare College, Cambridge in 1968. In 1972 he completed his PhD at the Scott Polar Research Institute, Cambridge and spent two summer seasons in the Antarctic depth sounding ice with an airborne radar. He started work in acoustics at Admiralty Research Laboratory, Teddington, and spent two years, from 1976 to 1978, as Exchange Scientist at Naval Research Lab, Washington DC. From 1978 to 1999 he worked as an acoustics consultant, mainly under contract to the UK MOD and DERA, in a software company that is now a part of British Aerospace. From 1999 to his retirement in 2011 he worked in La Spezia, Italy at the NATO Undersea Research Centre (aka. SACLANTCEN, aka. NURC, aka. CMRE). His interests include propagation, reverberation, noise, and sonar performance models, and most recently he has been involved in cross-correlating noise from a vertical array to retrieve the Greens function or impulse response of the seabed.

## Variability of Mid-Frequency Sound Propagation and Detection

*Dr DJ Tang, University of Washington*

A review will be presented of shallow water experimental research at APL-UW on mid-frequency (1-10 kHz) sound detection during the past 20 years. It will cover both passive measurements, where noise notch is exploited for improved detection, and active transmissions, where focus is on transmission and reverberation under different ocean conditions. Sample results from four experiments will be given, include ASIAEX (2001) in the East China Sea, Shallow Water 06 (2006) off the New Jersey coast, TREX13 (2013) in the Gulf of Mexico, and KOREX-17 (2017) on the east coast of S. Korea. We will demonstrate the impact on mid-frequency sound propagation by internal waves, rough sea surfaces, tide, and other environmental factors. Looking forward, simulations of sound propagation will be presented using recently collected 3D sound speed field data taken by a towed CTD chain. The results suggest that to mitigate variability the next logical step is to conduct contemporaneous acoustic and oceanographic measurements.

## Unmanned Aerial Vehicles as a Platform for Autonomous PAM of the Harbour Porpoise

*Daniel Babatunde, Loughborough University*

The maturity and ubiquity of research-based UAV (Unmanned Aerial Vehicle) robotic platforms over the past few years has provided an opportunity for the development of smart and autonomous aerial monitoring systems. The work described is being carried out in association with Natural England. There is a requirement to monitor marine mammal populations, particularly harbour porpoises, in a series of new candidate special areas of conservation.

The project has the aim of providing unmanned, autonomous visual and passive underwater acoustic monitoring of cetacean species using unmanned aerial vehicle systems. The systems under development are intended to operate in conjunction with more conventional monitoring methods (boat or aircraft based) to provide the ability to maintain adaptive monitoring in the vicinity of a specified location in a way previously inaccessible to existing methodologies. As well as photographic and video monitoring, it is intended that the vehicles will be able to land on and take off from the sea surface to capture underwater acoustic data from the animals under investigation. This has the objective of supplementing existing long-term monitoring methods such as the deployment of porpoise detectors (CPODs) and extending the current capabilities of boat-based acoustic monitoring methods through "reactive" tracking. The selected platform utilises off-the-shelf hardware and open source software. We present current progress towards the development of continuous unmanned UAV flight operations using the Robot Operating System. While standard UAV's will allow preliminary results to be obtained and analysed, several unique capabilities will be required, including unattended operation, automated recharging/battery changing, and water-based landing and take-off.

**Metasurfaces Underwater and on Elastic Surfaces**

*Prof Richard Craster, Imperial College London*

This talk will give an overview of the potential of ideas emerging in metamaterials to impact upon the design of underwater devices or surfaces. The aim of a metasurface is to create broadband, sub-wavelength, devices or interfaces to guide or cloak sound. Examples drawn from elastic surface waves will be presented together with preliminary results for underwater surfaces.

# Day 2 – Posters

**Inverse Solution for Acoustic Radiation from Slender Fault (Poster)**

*Bernabe Gomez, Cardiff University*

Submarine earthquakes generate acoustic waves and also are potential sources for triggering tsunamis. The mentioned sound waves carry important information about the generating source and can leave measurable signals in the far field, which can be recorded by distant hydrophones. It is proposed the use of the mentioned waves pressure signal, in order to retrieve both geometrical and dynamical earthquake properties, which is simplified as a slender rectangle that uplifts from the bottom of the sea with a certain speed. Sensitivity analysis has been carried out, to suggest minimum hydrophone specifications, in order to obtain a good accuracy retrieving the fault characteristics. Based in previous studies an inverse approach for pressure signals is applied. Acoustic waves propagate in the ocean at speeds close to 1500 m/s, which overcomes by far the speed of tsunamis, that are conditioned by gravity and water depth (For water depths of 4 km, which is the average depth of Pacific Ocean, tsunamis can travel up to 200 m/s), this fact, allows the use of acoustic waves recordings as potential tools for tsunami detection. Acoustic waves propagation are described by the three dimensional wave equation with the addition of slight compressibility of the water. The acoustic signal for the first mode radiated from the earthquakes sound is reproduced in a certain location and analysed. In a first step the location and eruption time are obtained with analytical solutions by time arrival differences, secondly the rest of parameters such as geometry, disturbance duration and uplift speed are retrieved by analytical and numerical methods. The algorithm is applied with low computational efforts, in order to achieve an almost real time assessment of the signal.

**Acoustic-Gravity Wave Propagation from a Slender Fault (Poster)**

*Byron Williams, Cardiff University*

Researchers have been studying compression-type waves, known as acoustic–gravity waves, that radiate during a submarine eruption racing ahead of the tsunami wave front. Thus, they can act as tsunami precursors. Various mathematical models have been developed that include oscillating infinite strips, infinite stripes with a finite rise time, circular cross-sections and rectangular cross-sections, to name a few. The more physical 3D models require extensive computation. An alternative approach was recently proposed by Mei & Kadri [*J. Fluid Mech.* 2018], who suggested utilising the asymptotic technique of multiple scales with a slender fault model of the rupture. This allows near real-time analysis. However, attention was only focused on the acoustic modes where gravity was completely ignored. In the current work we show that including gravity not only provides a more accurate solution that can be essential when employing the inverse approach to retrieve the eruption main properties, but also provides a solution for the tsunami envelope. Thus, tsunami calculation time is optimised which enhances the sought early tsunami warning system.

**Effect of Sea-bottom Elasticity on Gravity / Acoustic Waves from Submarine Earthquakes (Poster)**

*Dr Usama Kadri, Cardiff University*

The vertical displacement of faults generate a tsunami alongside a family of propagating compression-type waves known as acoustic–gravity waves that are believed to travel near the speed of sound in water, i.e. 1500 m/s. It is well established now that acoustic–gravity waves can be used for early tsunami detection warning. Several authors have studied the propagation of acoustic–gravity waves under various conditions, e.g. Abdolali, Kadri, Parsons Kirby, [*J. Fluid Mech.* 2017], which includes a list of related references. More recently, Mei & Kadri, [*J. Fluid Mech.* 2018], presented an inverse technique for near-real time calculations of a slender fault properties using pressure-time series recordings. The proposed technique along with the vast majority of current models concern employing the phase velocity of acoustic–gravity waves that radiate during the impact, and mainly consider their propagation in the water layer. However, considering the elasticity of the sea-bottom the propagating acoustic–gravity waves can penetrate through the elastic medium. Here, we carry out a detailed study on the evolution of the propagating acoustic–gravity as they penetrate through the elastic medium. Such penetration modifies the propagation speed and thus the arrival time of signals at a given hydrophone station, which might be crucial when applying the inverse approach on real hydrophone data.

# Day 2 – Session 5

**US INVITED TALK**

## Recent At-Sea Propagation Studies

*Dr Robert Headrick, Office Naval Research*

The ONR sponsors scientific investigations of ocean and seabed acoustic propagation, attenuation, and scattering throughout the world. This presentation will primarily cover preliminary findings from two recent large scale investigations. The Canada Basin Acoustic Propagation Experiment (CANAPÉ) that was conducted in the Beaufort Sea through a 2015 pilot effort and a one year main deployment from 2016 to 2017 and the Seabed Characterization Experiment conducted South of Martha's Vineyard in a mixed mud and sand region on the East Coast Continental Shelf of North America.

Dr Robert Headrick served in the US Navy as a Submarine Officer from 1983 to 1997. Following completion of his PhD in Oceanographic Engineering from the MIT / WHOI Joint Programme, he transferred to the Oceanography Officer community, serving there until 2006, retiring out of the ONR, but retained to the present as a civil servant working in the Ocean Battlespace Sensing Department in the Ocean Acoustics Team.

## Seabed Reflection Measurements, Modelling and Inferences

*Dr Charles Holland, ARL Pennsylvania State University*

Sediment geoacoustic properties generally control reflection and scattering from the seabed and thus significantly affect acoustic propagation and reverberation. While important progress has been made over the last 5 decades in understanding the depth and frequency dependence of geoacoustic properties, many significant knowledge gaps remain. One way to address these gaps is via measurement of the seabed reflection coefficient. The reflection coefficient contains features in angle space that are highly informative, e.g., the critical angle and the angle of intromission, but the most informative region of the data space is the frequency-angle resonances due to Bragg interference. In particular, the interference patterns contain detailed information on the frequency and depth dependence of sound speed and attenuation and the depth dependence of density. In this paper, we discuss advantages and limitations of reflection measurements for resolving detailed sediment geoacoustic structure, including dispersion. Measurements from 0.1-10 kHz, data processing, modeling, and geoacoustic inferences are briefly reviewed with examples from various sedimentary environments in the Mediterranean, Atlantic, and Gulf of Mexico. We also discuss promising future research areas including two-dimensional (depth and range) quantitative geoacoustic mapping, estimation of small-scale, less than O(1) m geoacoustic structure and potential measurements to validate sediment acoustic models.

## Growing Piezocomposite Underwater Transducers by Freeze Casting

*Dr Alan Hunter, University of Bath*

Piezocomposite materials are used in many underwater transducers due to their desirable acoustic performance.

The conventional method for creating 1-3 piezocomposite is to "slice-and-dice" a monolithic piezoelectric material using a precision saw. This is expensive and wasteful. We have used a new technique, known as freeze-casting, to grow natural 1-3 piezocomposite material by freezing a solution of piezoelectric powder, polymer, and water, followed by freeze-drying and sintering. Underwater transducers made from these freeze-cast piezocomposites have been built and tested. This new approach is much cheaper and more versatile than the conventional method.

**Spatial and Temporal Variation in the Acoustic Habitat of Bottlenose Dolphins**

*Dr Sarah Marley, University of Portsmouth*

As human activities continue to expand across the marine environment, anthropogenic ocean noise is also rapidly increasing. This is of concern to acoustically-specialised species, particularly those displaying a high degree of habitat overlap with anthropogenic activities, such as bottlenose dolphins (*Tursiops sp*.). There is a need to describe the soundscape of coastal dolphin habitats and examine how prominent anthropogenic noise sources may impact these animals. The Swan River in Western Australia flows through the state capital of Perth, containing over 2 million people, and consequently experiences a range of anthropogenic activities. However, the river is also extensively used by a resident community of Indo-Pacific bottlenose dolphins (*T. aduncus*). Autonomous underwater acoustic recorders were used to collect data throughout the Swan River, which were analysed via weekly spectrograms, power spectrum density percentile plots, octave-band levels, broadband noise levels, and generalised estimating equations. Land-based theodolite tracking at two sites provided information on vessel traffic and dolphin behaviour, which were assessed using generalised additive models and Markov chains. Acoustic datasets collected from 2005 to 2015 indicated that the Swan River was comprised of multiple acoustic habitats, each with its own characteristic soundscape and temporal patterns in underwater noise. The 'noisiest' site from an anthropogenic perspective and in relation to dolphin communications was the Fremantle Inner Harbour (mean broadband noise level: 106 dB re 1 µPa rms [10 Hz – 11 kHz]). Theodolite tracking at this site found that dolphins remained present during periods of high vessel traffic. However, behavioural observations indicated significant alterations to dolphin movement speeds and activity states at high vessel densities. Furthermore, whistle characteristics varied in conditions of high broadband noise. This work suggests that dolphins maintain occupancy at key foraging sites within the Swan River despite the presence of vessels, but alter their behaviour in periods of high vessel traffic.

# Day 2 – Session 6

**UK INVITED TALK**

**How Anthropogenic Changes in Ocean Soundscapes Affect Marine Life**

*Prof Peter Tyack, St Andrews University*

Sound propagates so well in the ocean that it is the most effective way to probe the marine environment and communicate over long distances. This makes sound critical for marine life and for seagoing humans. Most fish and invertebrates sense sound-induced particle movement; some fish and all mammals detect changes in sound pressure. Many marine animals produce sound, from the long-range, low-frequency calls of baleen whales and spawning fish to the intense high-frequency impulses of snapping shrimp and echolocation clicks of toothed whales. Acoustic cues are essential for larvae to settle in appropriate environments, for the mating systems of many fish and mammals, for predator-prey relationships, and for social species to maintain cohesion. Elevated noise can disrupt these functions and can stress marine animals, increasing metabolic rate and mortality while slowing growth and reproduction. Behavioural reactions to anthropogenic noise can often best be thought of as defensive reactions to potential threats. Strandings of beaked whales during naval sonar exercises show that these reactions can sometimes be lethal. Playback experiments demonstrate that sonar and other sounds cause beaked whales to cease echolocating during deep foraging dives. While sonar can kill some individual whales, chronic elevation of noise in combination with other stressors probably poses a greater risk to marine life. Sound is an essential ocean variable for predicting and managing these effects.

Prof Peter Tyack is Professor of Marine Mammal Biology at the University of St Andrews and studies acoustic communication and social behaviour in marine mammals. He graduated *summa cum laude* in Biology from Harvard College and his PhD is in Animal Behaviour from Rockefeller University. He has developed new methods to sample behaviour continuously from marine mammals and has used these to study communication and echolocation as well as responses to anthropogenic sounds using dose escalation experiments. Prof Tyack has served on the Ocean Studies Board of the US National Academy of Sciences and 4 US National Research Council Committees on the effects of sound on marine mammals

**Recent Studies of Physics of Acoustic Waveguide Over Continental Shelf Break**

*Dr Mohsen Badiey, University of Delaware*

Shallow water ocean acoustics has been a topic of significant current interest in underwater acoustics community over the last two decades. During this period, several advancements in technology have resulted in systems for data collection and observation. But the most important aspect that have resulted from these measurements and analysis is a better understanding of the waveguide and the uncertainties in the physical parameterization of the waveguide. In this presentation, we discuss the broadband acoustic wave propagation in different waveguides and discuss the uncertainty that different components such as the sea surface, water column sound speed profile, and the sea bottom (both bathymetry and seafloor properties) can induce in a statistical analysis of such data. Several experimental studies along with challenges to measure physical input parameters will be discussed.

**Detecting and Removing Aliased Seabed Echoes in Fisheries Acoustic Data**

*Robert Blackwell, British Antarctic Survey*

Echo sounders are routinely used to estimate animal abundance and distribution in marine ecosystems. Ships of opportunity (e.g. fishing vessels) and marine autonomous vehicles are now being used in addition to research vessels to increase spatial and temporal sampling, leading to increased acoustic data volumes. Traditional, manual scrutinisation of fisheries acoustic echograms is becoming impractical for large data volumes and unsupervised algorithms are needed for automated processing. Noise and corruption can reduce the accuracy of biological estimates and must be excluded from analyses. Algorithms already exist to detect many forms of unwanted signal automatically, but aliased seabed echoes (also known as “false bottoms” or “shadow bottoms”), caused by seabed reverberation from preceding pings coinciding with echoes from the current ping, are usually removed by hand. Using data from acoustic surveys near South Georgia, we compare statistical and machine learning approaches to aliased seabed detection, and show that a deep convolutional neural network has the best performance (96% accuracy, 89% reliability). However, modern machine learning techniques can be hard to interpret, complex to implement and are limited by their training regime. We therefore use our results to inform the design of a simple, easily explainable algorithm that has comparable performance (accuracy 96%, reliability 77%). The new method is easy to implement and enables fully automatic, unsupervised detection and removal of aliased seabed using single frequency, split-beam echo sounder data, without the need for bathymetry. This work is a step forward in the automation of echo sounder data processing and enables new ocean observing systems which report ecosystem metrics from ships and marine autonomous vehicles in near real-time.

**Advances in the Active Detection of Cetacea with Opportunistic Seismic Sources**

*Dr Nikhil Banda, Seiche Ltd*

There is a strong requirement to augment the current detection capabilities of marine mammals exposed to underwater anthropogenic noise sources. Increased regulatory requirements, concerns over existing mammal population, and the impact of different noise sources on their health and well-being are regularly addressed in current studies. Passive Acoustic Monitoring (PAM) and Thermal Imaging (TI) techniques are the established practices that are currently employed by the Marine Mammal Observers (MMOs) to detect and identify the presence of marine mammals near an active noise source (such as the airguns or a piling operation). To potentially provide additional information to the MMOs when animals are either non-vocalising or are diving, active acoustic detection is being strongly considered. In such a case, acoustic energy from opportunistic sources (e.g. seismic airguns) can be employed. The challenges for a successful detection using active noise sources include analysing the multi-frequency and multi-scattered data, knowledge of acoustic scattering strength of marine mammals, and the ability to isolate & identify the appropriate acoustic reflections from different parts of the animals. Research work is currently underway to address these issues, including controlled experiments in a tank to detect a 3D printed scaled marine mammal target, development of an inversion algorithm to identify the scattered acoustic signals, and comparison of experimental results with the results of the inversion algorithm. These results, when combined, will provide the first proof-of-concept demonstrating the capabilities of the active acoustic detection methodology. In this talk, preliminary results from the experiments and inversion algorithm will be presented and the challenges faced will be reported. The success of these scaled tests is expected to lead onto full-scale and live testing in the ocean, with known noise sources. This will eventually lead onto commercialisation for potential use either by the regulators or the MMOs.

# Attendance List

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|---|---|
| **ABBAS,** Irfan | Sheffield University |
| **ALGHAZI,** Mohammed | Cardiff University |
| **ANTILL,** Rachel | APEM |
| **BABATOUDE,** Daniel | Loughborough University |
| **BADIEY,** Mohsen | University of Delaware |
| **BANDA,** Nikhil | Seiche Ltd |
| **BENYON,** Luke | Atlas Elektronik UK |
| **BEST,** Angus | National Oceanography Centre |
| **BILAL,** Muhammed | Harbin Engineering University |
| **BLACKWELL,** Rob | British Antarctic Survey |
| **BLONDEL,** Philippe | University of Bath |
| **BRIND,** Richard | Atlas Elektronik UK |
| **BROOKER,** Alex | Clarke Saunders Associates |
| **BROWN,** Alex | Hartley Anderson Ltd |
| **BYFORD,** Delphine | Ministry of Defence |
| **CARTER,** Amber | APEM |
| **CAUCHY,** Pierre | University of East Anglia |
| **CHING,** Phil | Spirare Sound |
| **CHOTIROS,** Nick | ONR Global |
| **COLOSI,** John | Naval Postgraduate School |
| **CRASTER,** Richard | Imperial College London |
| **CRAWFORD,** Nick | National Physical Laboratory |
| **CURTIS,** Alan | Thales UK |
| **DEEKS,** Julian | DSTL |
| **DOBBINS,** Peter | IOA |
| **DOWIE,** Mark | Bruel & Kjaer |
| **DRYDEN,** Stuart | Stuart Dryden Oxford |
| **EDWARDS,** Maxwell | DSTL |
| **FARCAS,** Adrian | Cefas |
| **FORRESTER,** Michael | QinetiQ |
| **FRASER,** Michael | ERM |
| **FRINAULT,** Betina | University of Oxford |
| **GOFFIN,** Shannon | DSTL |
| **GOMEZ,** Bernabe | Cardiff University |
| **GUNDERSON,** Aaron | ARL University of Texas at Austin |
| **HACKMANN,** Willem | Linacre College Oxford |
| **HAIG,** Kenneth | QinetiQ |
| **HARRISON,** Chris | CMRE |
| **HAZELWOOD,** Dick | R&V Hazelwood Associates |
| **HEADRICK,** Robert | ONR |

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|---|---|
| **HEFNER,** Brian | University of Washington |
| **HERBERT,** Andrew | Defence Equipment and Support |
| **HIGGIE,** Katherine | UK Hydrographic Office |
| **HIGHAM,** Chris | Wheko |
| **HILL,** Toby | QinetiQ |
| **HILL,** Myles | QinetiQ |
| **HODDER,** Ben | QinetiQ |
| **HOLDEN,** Andrew | DSTL |
| **HOLLAND,** Charles | ARL Pennsylvania State University |
| **HOOK,** Kristian | ISVR University of Southampton |
| **HOUSE,** Charlie | ISVR University of Southampton |
| **HUNTER,** Alan | University of Bath |
| **IENT,** Simon | Xodus Group |
| **ISAKSON,** Marcia | ARL University of Texas at Austin |
| **JAMIESON,** Alice | Marine Management Organisation |
| **KADRI,** Usama | Cardiff University |
| **KAZER,** Sally | GoBe Consultants |
| **LLOYD,** Steven | Loughborough University |
| **MARLEY,** Sarah | University of Portsmouth |
| **MARTIN,** Michael | QinetiQ |
| **MAYOR,** Terry | Weatherford |
| **MERCHANT,** Nathan | Cefas |
| **MILES,** David | Atlas Elektronik UK |
| **MOYS,** Eleanor | DSTL |
| **NEEFJES,** Erik | University of Manchester |
| **OSMENT,** Megan | Atlas Elektronik UK |
| **RIDDOCH,** Nick | NRG Marine Consultants |
| **ROBINSON,** Stephen | National Physical Laboratory |
| **SMITH,** John | DSTL |
| **SMITH,** Jennifer | Xodus Group |
| **SPIVACK,** Mark | University of Cambridge |
| **STEPHENSON,** Simon | RPS Group |
| **SWANBORN,** Denise | Oxford University |
| **TANG,** Dajun | University of Washington |
| **THOMAS,** Ben | University of Bath |
| **TOOGOOD,** Emma | Marine Management Organisation |
| **TYACK,** Peter | St Andrews University |
| **VAN GEEL,** Nienke | Scottish Association for Marine Science |
| **WARD,** Jake | National Physical Laboratory |
| **WILLIAMS,** Duncan | DSTL |
| **WILLIAMS,** Byron | Cardiff University |