Meeting report

Michael Ainslie.

Validation of sonar performance assessment tools: A workshop held in memory of David E Weston

In April 2010, a group of 29 delegates from Europe, North America and Australasia gathered in Gillespie Centre at Clare College, Cambridge to honour the memory of David E Weston. But who was David Weston and why were these people prepared to travel such a long way to get here?

Simply put, David made a unique contribution to our understanding of underwater acoustics and to our ability to model sonar performance. He spent most of his career at government research laboratories in the UK, with extended stays in the USA, resulting in fruitful international collaborations with fellow scientists like Chris Tindle from New Zealand, one of the invited speakers at the workshop. In retirement, David worked as a consultant for the defence industry, passing on his valuable knowledge to others, and it was during this phase of his career that he worked most closely with Chris Harrison, the keynote speaker of the April symposium.

David's hallmark was his ability to identify and explain trends in apparently random behaviour, enabling him to separate out effects in his measurements of wind, fish, season, tides and waves. He is perhaps best known for his discovery and promulgation of the extraordinary effect that fish can sometimes have on the absorption and scattering of underwater sound. This aspect of David's work lives on through the research of Orest Diachok, the third invited speaker.

Through his written publications, David remains an inspiring teacher and will continue to do so long after his death. He was president of the Institute and a recipient of its prestigious Rayleigh Silver Medal as well as of the Helmholtz-Rayleigh Interdisciplinary Silver Medal of the Acoustical Society of America.

The opening address was given by Michael Ainslie of TNO, who reminded the audience of Weston's achievements and unique ability to shed light on the most difficult of problems and (to use one of his own favourite phrases) to 'see the wood despite all the trees'.

David's career was devoted to improving our understanding of sonar performance in a time when computer power was limited. Today we take computers and computer models for granted to support decision making both in the long term (sonar design, strategic planning) and short term (sonar deployment, tactical planning), but on what to do we justify our faith in these models? The symposium on the validation of sonar performance assessment tools, or Weston memorial workshop, was designed to address this question by defining some well specified sonar scenarios. Participants were invited to run a sonar performance model of their choice on one or more of these problems with a view to comparing their outputs for the same set of inputs.

Two generic sonar problems were specified. The first (known to participants as problem A1) was a bio-sonar problem inspired by the work of Whitlow Au and co-workers, involving a killer whale hunting its prey of Pacific salmon. The second (problem A2) involved a low-frequency active sonar (LFAS), with source centre frequency between 250Hz and 3.5kHz and a 65 element horizontal receiving array. Problem A2 was based on 'Problem T' of the Second Reverberation Modelling Workshop held at ARL Texas in May 2008 [ftp://ftp.ccs.nrl.navy.mil/pub/ram/RevModWkshp_II/].

Proceedings of the Weston memorial workshop are available on CD from the Institute of Acoustics (email linda.canty@ioa.org.uk). Work on A1 and A2 continues at research establishments around the world (for example, at BWB/FWG in Germany, the Defence Research and Development Canada (DRDC), NATO Undersea Research Centre (NURC) in Italy, Penn State University in the US, and the Netherlands Organisation for Applied Scientific Research (TNO)). New participants interested in either test case are encouraged to contact the workshop organisers. The test problems are available from ftp://bobbie.fel.tno.nl : contact the organisers for login details. An opportunity for researchers to compare notes again will arise on 20-24

continued on page 14

Meeting report - *continued from page 13*

June 2011, at Underwater acoustic measurements: Technologies and results (UAM 2011), to be held on the island of Kos, Greece.

The meeting was a truly international one, with invited speakers travelling from Italy, USA and New Zealand. Workshop problem solutions were submitted by participants from Canada, USA, Germany, Italy and the Netherlands.

Opening address by Michael Ainslie

Ladies and gentlemen, welcome first of all to this marvellous venue. Thank you for coming, especially those who have travelled from other continents. I thank also the Institute of Acoustics for giving me the honour and unique opportunity to commemorate the work of David Weston, who can safely be described as the mainstay of research on underwater acoustics in the United Kingdom during the second half of the 20th century. Thanks also to my fellow organisers Linda Canty, Peter Dobbins and Barry Uscinski and to the members of the Scientific Committee.

David was a prolific writer. His work spanned five decades, during which he wrote 67 papers with 24 co-authors in 11 different journals. But David's true attributes cannot be measured in numbers. His nature was to strive always for the most elegant and insightful solutions to even the most complicated problems, inspiring his fellow researchers, many of whom are in the audience today, by his example. I am confident that this will be illustrated amply by the three invited talks given by Chris Harrison, from NURC, Chris Tindle, from the University of Auckland and Orest Diachok, from Johns Hopkins University, as well as by the contributed papers scheduled for tomorrow morning.

An additional purpose of this meeting is to find ways of testing our sonar performance models. Thanks to all those who have taken the trouble to solve the test problems specified in advance of the workshop. I am especially looking forward to the discussion periods this afternoon and on Friday morning, which Kevin Macan-Lind, Chief Executive of the Institute of Acoustics, has kindly agreed to chair.

The meeting closes with an awards ceremony, including the A B Wood Medal Lecture by Mario Zampolli, with whom it has been a pleasure to work since he joined TNO from NURC a year ago. This is followed by the IOA Best Diploma Student Award for Neil McBride, and by a special Weston Award, the winner of which will be announced just before lunchtime on Friday. The nature of the prize will be announced at the same time.

The mathematicians amongst you will know of the Hungarian mathematician Paul Erdős, whose name is immortalised by the so-called 'Erdős number', which measures the proximity of his fellow researchers to Erdős's own work in a very simple way: Erdős himself has an Erdős number of 0, by definition. His immediate co-authors have an Erdős number of 1, their co-authors have an Erdős number of 2, and so on.

Defining the 'Weston number' in the same way, I have calculated this number for a few prominent scientists. For example, Lord Rutherford's Weston number is 2, and Einstein's is 6. To help you calculate your own Weston number, I give you a list of his 24 co-authors. If your name is on this list, you have a Weston number of 1. If not, but you recognise one of the names as your co-author, then your Weston number is 2. What is your Weston number? With this light-hearted question I hand over to Kevin Macan-Lind, who has some administrative announcements to make before the keynote speech.

Technical sessions

Wednesday 7 April

Chris Harrison gave the invited keynote address and set the conference scene with a presentation entitled 'Seeing the wood for the trees'. He emphasised that while SONAR performance is assessed using the SONAR equation, it is important to be aware of the underlying physics and that the various terms in the equation are not independent. He noted that David Weston was renowned for taking an overview of problems without getting lost in the detail. David's flux methods and waveguide invariants have led to practical and useful results in propagation, signal processing and sonar performance. Kevin LePage (NURC) summarised results from two reverberation modelling workshops sponsored by ONR and the establishment of benchmark reverberation problems. There has been some good agreement of results from different models but there are still some issues in some treatments of reverberation which impact on sonar performance modelling. Mario Zampolli (TNO) outlined the way the scenarios for the LFAS test problems (scenario A2) for the symposium were developed. They are intended to represent low frequency active sonar with source frequencies from 250Hz to 3.5kHz in shallow coastal waters. The test cases are progressively more complicated as they consider range dependence, summer sound speed profiles, surface roughness, bottom layering and the presence of solitary waves. He showed preliminary comparisons between predictions from different participants using the models ALMOST (TNO), INSIGHT (BAE SYSTEMS) and MOCASSIN (FWG).

Solutions to the A2 test problems were presented after lunch by Dale Ellis (DRDC), Pieter Schippers (TNO), Charles Holland (Penn State University), Kevin LePage (NURC) and Jan Ehrlich (BWB). Dale Ellis presented normal mode and ray theory predictions of reverberation and echo level for problem A2.1 (a shallow water Pekeris waveguide), including comparisons with a flux model. Pieter Schippers presented solutions of reverberation and echo level, noise level and signal to background ratio for all A2 test problems using the ALMOST sonar performance model. Charles Holland presented energy flux predictions for A2.1, including comparisons with a normal mode model.

Kevin LePage spoke about the development of a sonar simulator to deliver element level time series in order to test control and navigation algorithms for an AUV and demonstrated the results from the simulator's propagation, echo and reverberation engine applied to the A2 scenario. Jan Ehrlich described the assumptions of the Mocassin and MSM models and discussed the capabilities of Mocassin relative to the requirements of the A2 scenario. He described the results of applying it to the scenario. It was noted in discussion that it includes mode diffusion and this was recommended for other modellers to consider.

Thursday 8 April

Chris Tindle described the concept of beam displacement, and the pioneering work in collaboration with David Weston that led to the development of low frequency ray propagation models. He described how the same ideas lead to a ray theory of wavefronts and illustrated the application of these to surface reflection and scattering problems.

Charles Holland described the effects of lateral variation and uncertainty in seabed properties, showing how by using Weston's energy flux methods that the field can be simply described in terms of the geometric mean of the reflection coefficient and the arithmetic mean of cycle distance.

Daniel Rouseff (APL UW, Seattle) described the insights afforded by Weston's early work on Moiré fringes, sound focusing and beaming and their relevance to Chuprov's waveguide invariant. He described more recent work showing how these ideas, developed originally for passive sonar can be extended to active sonar, working at a higher acoustic frequency.

Jean-Pierre Sessarego (LMA CNRS, Marseille) described tank measurements at hundreds of kilohertz of scattering from a shell near the air-water boundary. The measurements were compared with a theory that generally compared very favourably. The theory is sufficiently general that it can handle arbitrary boundary conditions (eg seabed). In the context of the conference, the measurement capability strongly suggested conducting such tank measurements as one way of validating the sonar models. The tank is sufficiently large to do waveguide problems.

Alex Tolstoy (A Tolstoy Scientific Inc) examined some of the difficulties in matched-field geoacoustic inversion including significant uniqueness problems. Alex showed a method to reduce uniqueness problems by an exhaustive search method in a multi-stage process using short-range low frequency data first and then moving up in frequency and range. A main conclusion was that the geoacoustic inversion problem is far from solved and a recommendation was made that a focused workshop would help the community go forward.

The honour of presenting the first talk of the afternoon again fell to Dale Ellis, who presented results for short-time reverberation associated with multiple surface-bottom, known as 'fathometer' reflections, for Problem XI

of the first ONR reverberation modelling workshop for frequencies between 250Hz and 3.5kHz.

D J Tang (APL UW, Seattle) described a novel mechanism by which clutter can be introduced in shallow water reverberation: Steep ray paths are generated by a non-Gaussian sediment ripple field, reflected from the sea surface, and then backscattered at the next seabed interaction. The backscattering strength is enhanced due to the steep paths, creating clutter in the reverberation.

Chris Strode (NURC, La Spezia) compared results from the multi static tactical planning aid (MSTPA) model with predictions using the CASS model. In addition to signal to noise ratio, the MSTPA model considers metrics such as 'mean time to track' and localisation error. He also described optimisation problems involving evasion (best path through sonar field) and detection (maximise area coverage).

Four more papers followed after the tea break. Yong Zhang (DSTO, Australia) described various degradations to processing gain such as scalloping loss and correlation loss, including methods to calculate these for situations involving rough surface scattering, target motion, multipaths and finite target size. Xavier Cristol (Thales Underwater Systems, France) described degradations to sonar processing resulting from the sea surface and compared calculations using the AMOS, Saxton-Baker and Weston-Ching empirical models, showing that available measurements could be explained by a combination of bubble attenuation and rough surface scattering. Kevin Heaney (OASIS Inc, USA) described research on optimising sonar deployment by maximising the total detection area for multiple receivers. He presented optimisation results for the Phillipine Sea tomography experiment PhilSea 2009. Alan Fenwick (University of Aberdeen, UK) described the problems associated with modelling of trans-ocean sound propagation over thousands of kilometres using ray theory, for which an irregular ray pattern leads to exponential growth in the number of ray paths. He described an alternative method to solve this problem, derived from the parabolic equation, analogous to the Hamiltonian of classical mechanics, and showed how the alternative method could be tested.

The drinks reception and conference dinner took place in the evening of Thursday 8 April.

Friday 9 April

Orest Diachok took the audience down memory lane with a history of David Weston's contributions to bio-acoustical oceanography, starting with his pioneering experiments with long range active sonar in the 1960s that were '45 years ahead of their time'. Anomalous propagation measurements made during these experiments were attributed by David to the absorption of sound by large schools of fish. The idea that sound might be strongly affected in this way was considered speculative at the time, but has been vindicated by synchronous biological and acoustical measurements.

Michael Ainslie presented the details of scenario A1, involving a killer whale hunting its prey. The orca sonar pulse has a very large bandwidth, extending in frequency from 20kHz to 80kHz, and one of the purposes of this test was to improve understanding of the effect of this large bandwidth on sonar performance. Jan Ehrlich described his results for problem A1 using the MSM sonar performance model, including the effect on array gain of an anisotropic noise field. It was noted that anisotropy of the ambient noise field results in a correction of between 5 and 26 dB to the array gain, depending on the distance to the fish (through the changing steer direction).

The meeting closed with an awards ceremony. Mario Zampolli received the A B Wood medal from IOA president John Hinton OBE for his contributions to the understanding of scattering from elastic objects in acoustic waveguides and of long range sound propagation in the sea, and this was followed by the IOA Best Diploma Student Award to Dr Neil McBride, also presented by John Hinton. Finally, a one-off Weston 'Wood for trees' award (sponsored by Springer-Praxis) was awarded to Jan Erhlich for his comprehensive discussion of sonar issues, clear presentation of interesting and thought-provoking results and his novel simulations of a biological sonar. The prize, a copy of *Principles of Sonar Performance Modeling* (Springer-Praxis, 2010), was presented by Philippe Blondel, series editor for Springer-Praxis.

Acknowledgements

The author was motivated above all by a desire to see David Weston's achievements commemorated in a fitting manner. He thanks the Institute of Acoustics for making this possible and regrets that David's widow Joyce was unable to attend owing to a recent knee operation. He also thanks TNO for support, his co-organisers Linda Canty, Barry Uscinski and Peter Dobbins, and the scientific committee made up of Chris Harrison, Charles Holland, Dale Ellis, Gary Heald, Mario Zampolli and Tim Clarke. Finally he thanks Lt Cdr Bjørn Kerstens of the Royal Netherlands Navy for posing the question 'Which sonar performance model should I use for evaluating LFAS performance?' which led to the idea of holding a validation workshop.

David E Weston (16 November 1929 - 19 January 2001)

David's obituary was published in Acoustics Bulletin in September/October 2001 (volume 26 no.5). The workshop was held in his memory, so the appreciation from 2001 is reproduced here.

David E Weston, former President of the Institute of Acoustics, 1970 recipient of the *Rayleigh Silver Medal* and 1998 recipient of the Acoustical Society of America's *Helmholtz-Rayleigh Interdisciplinary Silver Medal in Acoustical Oceanography and Underwater Acoustics*, died of heart failure at his home on 19 January 2001. He was a Fellow of the Institute of Physics, Fellow of the Institute of Acoustics, and Fellow of the Acoustical Society of America.

David obtained his BSc in physics at Imperial College in 1950. This was followed by an MSc in 1952, also at Imperial College and supervised by R W B Stephens, on the propagation of sound waves in tubes. He joined the Admiralty Research Laboratory (Teddington) in 1951 and dedicated the next 50 years to the study of ocean acoustics and sonar. In this time he made ground-breaking contributions to many different aspects of underwater sound, from generation mechanisms to the detection process, through propagation, scattering, absorption and ambient noise. As a young scientist

continued on page 16

Meeting report - *continued from page 15*

he worked with A B Wood on the attenuation of sound propagating through mud, both at sea nd in a model scale tank.

He also developed his own brand of propagation theory based on conservation of flux and invariance of basic ray properties, that enabled him to predict fundamental characteristics of the field without needing to trace individual rays. That flux theory, and the associated 'Weston invariants' now form the scientific basis fro the computer models ASTRAL and INSTANT.

In the 1960s, influenced by his postgraduate work on tubes, David developed an interest in the scattering and absorption of sound by fish bladders. He conducted a series of shallow water experiments with D Revie and others at Perranporth in the Bristol Channel, designed to quantify these effects. The data collected at the time were unique and today are still regarded as among the best available.

In addition to this pioneering experimental work he personally laid the foundations for the currently accepted theory of scattering and absorption of sound by fish.

David spent two sabbatical periods in the USA, the first of which in 1964-65 was spent at the Hudson Laboratories (Columbia University). His second visit, to the Applied Research Laboratory (University of Texas) in 1979, resulted in a successful collaboration with C T Tindle, investigating the theoretical relationships between ray properties such as cycle distance and reflection loss, and modal eigenvalues and decay rates.

Apart from the two American visits, David worked at Admiralty laboratories continuously from 1951 until his retirement in 1989 as Individual Merit Deputy Chief Scientific Officer, from what by then had become the Admiralty Research Establishment in Portland (Dorset). After his retirement, David worked as a consultant to BAeSEMA Ltd (later BAE Systems) in New Malden, Surrey, and his advice continued to be sought by scientists throughout the world resulting in many invited lectures and visits to research laboratories.

In fact David never fully retired. He continued to publish at a prolific rate, contributing further to a final total of 67 publications in learned journals, two encyclopaedia entries and countless conference papers and unpublished reports. Even on the day he died, there were some carefully annotated papers on his desk concerning a long-standing interest of his: anomalous propagation measurements, attributed to the presence of high fish population densities in the Yellow Sea.

David's early work was rewarded in 1970 by the British Acoustical Society (a forerunner of the IOA) in the form of the *Rayleigh Silver Medal*, and in the same year he received the prestigious DSc degree from the University of London. His scientific excellence across multiple disciplines was recognised by the Acoustical Society of America by awarding him its *Helmholtz-Rayleigh Medal* in 1998.

David's scientific work was complemented by a long and selfless involvement with the affairs of the Institute of Acoustics: he was a council member from 1974 to 1986 and chaired both the Underwater Acoustics group (1977-79) and the Publications committee (1980-82) prior to his term as President (1982-84).

It is fitting that his last publication was a history of underwater acoustics in the IOA [D E Weston (1999) *Underwater acoustics during the life of the Institute*, Acoustics Bulletin vol 24 no3, pp17-20]. David also served on the Acoustics group committee of the Institute of Physics.

David had strong convictions that he would articulate passionately, but always with an open mind and the greatest respect for a differing opinion. This rare combination of integrity and humility was rounded by a cheeky sense of humour, characterised by his reaction to a frustrated comment by his colleague Dr Chris Harrison.

Having for the umpteenth time derived what he had thought to be a new result, only to discover that it had been published many years ago by a certain D E Weston, with tongue in cheek Chris suggested a new universal theorem: 'No matter how novel your theorem is, D Weston has already thought of it'. After a few moments' consideration David retorted 'Your theorem is clearly false, because you thought of it before me'.

David enjoyed life to the full, and never more so than when walking with friends in the Lake District or playing bridge. He loved all kinds of music and spent much of his spare time helping to organise the Weymouth Music Festival. Sorely missed by family, friends and colleagues, he is survived by his widow Joyce, daughter Anna and son Peter.

Active sonar performance modelling, validation and simulation

Organisers: Michael Ainslie, Dale Ellis and Charles Holland

There is a growing interest to develop and validate echo and reverberation models for sonar performance prediction and simulation. Compromises between fidelity, accuracy, robustness and speed are typical trade-offs made in various modelling approaches. This session encompasses echo and reverberation modelling as well as measurements intended to support validation of active sonar performance models. Frequencies of interest include, but are not limited to, those chosen for the recent US ONR reverberation modelling and UK IOA sonar performance assessment workshops, including both man-made and bio-sonar.

Fourth UAM Conference, Underwater Acoustic Measurements: Technologies and Results, 20-24 June 2011, Kos, Greece

Organisers: John Papadakis and Leif Bjørnø.

http://www.uam-conferences.org/index.php/topics/structured-sessions

Citation for A B Wood Medal for Dr Mario Zampolli

Mario Zampolli is currently a Senior Scientist in the Sonar Department at the Netherlands Organisation for Applied Scientific Research (TNO). His research on finite element methods has contributed significantly to our understanding of the scattering of sound from elastic objects.

Mario started his research as a mathematics student at the University of Bologna (Italy), with a thesis on optimal control applied to aerodynamics. A collaboration with the Aerospace Engineering Department of the University of Rome La Sapienza led him to Boston University, where, as a part of his PhD studies in mechanical engineering, he conducted research on the vibrations of a membrane inside the cavity of a microelectromechanical system (MEMS) chip, and on the effect of viscosity on diffraction from sharp edges. Through this work, he became involved in the translation and study of Sommerfeld's Mathematical Theory of Diffraction, leading to the first complete English translation, now published as a book, of Sommerfeld's seminal text.

Mario then moved to the NATO Undersea Research Centre (NURC) in Italy. Here he developed a finite element model for scattering from axisymmetric submerged elastic targets, with internal structural detail, for frequencies at which the wavelength is on the order of the size of the object, or smaller. In this regime, the echo is rich in structural resonances, which can be used for classification purposes. This work, including experimental validation, has resulted in five journal publications. The target scattering model developed by Mario at NURC is currently employed at national laboratories, universities and industry around the world, for applications as diverse as mine-countermeasures, anti-submarine warfare and medical ultrasound. The same finite element method has also been applied to two-way interaction of sound with the seabed in long range sound propagation problems at low frequencies, for benchmarking range-dependent elastic parabolic equation models. These results are published in two further journal papers.

At TNO, Mario quickly adapted to his new surroundings and colleagues, and is already making his mark with his innovative approach to research on low frequency active sonar, multipath filtering for the detection of buried objects, minesweeping and harbour security.

Not just a gifted acoustician, Dr. Zampolli is also a natural communicator, as illustrated by his contributions to the organisation of, and enthusiastic participation in numerous international conferences, and recognised by invited seminars at American, British and Italian universities.

The Institute of Acoustics is proud to award the 2010 A B Wood Medal to Dr Mario Zampolli for his contributions to the understanding of scattering from elastic objects in acoustic waveguides and of long range sound propagation in the sea.