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In Memory of David E Weston

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Edited by Michael A Ainslie

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Editorial: Validation of Sonar Performance Assessment Tools

Michael A Ainslie

A workshop held in memory of David E Weston.

In April 2010, a select group of 29 delegates from Europe, North America and Australasia gathered in Clare College's Gillespie Centre 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.

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.

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 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) is 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) involves a low frequency active sonar (LFAS), with source centre frequency between 250 Hz and 3.5 kHz and a 65 element horizontal receiving array. Problem A2 is based on 'Problem T' of the second Reverberation Modeling 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 (77A St Peter's Street, St. Albans, Hertfordshire, AL1 3BN, United Kingdom; email: ioa@ioa.org.uk). Work on A1 and A2 continues at research establishments around the world (for example, at the Bundeswehr Technical Centre for Ships and Naval Weapons (BWB/FWG) in Germany, the Defence Research and Development Canada (DRDC), NATO Undersea Research Centre (NURC) in Italy, Pennsylvania State University in the US, and the Netherlands Organisation for Applied Scientific Research (TNO).

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.

WEDNESDAY 7 APRIL

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 intractable of problems and for "Seeing the wood for the trees", which fittingly is the title of Chris Harrison's invited keynote address [Harrison 2010]. Chris emphasised that while sonar performance is assessed using the sonar equation, it is important to be aware of the underlying physics and of the inter-dependence between the various terms in that equation. Examples of David Weston's renowned ability to solve problems without getting lost in the detail are his flux methods and waveguide invariants, which have led to practical and useful results in propagation, signal processing and sonar performance. Kevin LePage (NURC) [Perkins et.al. 2010] summarised results from two reverberation modelling workshops sponsored by ONR, the goal of which has been the establishment of benchmark reverberation problems. While difficulties still remain, there has been some good agreement of results from different reverberation models. Mario Zampolli (TNO) [Zampolli et al. 2010] outlined the way the scenarios for the LFAS test problems (Scenario A2) for the symposium were developed. These scenarios, which are based on selected test cases from the ONR workshops, are intended to represent low frequency active sonar 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, INSIGHT and MOCASSIN.

Solutions to the A2 test problems were presented after lunch by Dale Ellis (DRDC), Pieter Schippers (TNO), Charles Holland (Pennsylvania 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.I (a shallow water Pekeris waveguide), including comparisons with a flux model [Ellis 2010a]. 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 [Schippers 2010]. Charles Holland presented energy flux predictions for A2.I, including comparisons with a normal mode model [Holland 2010a]. Kevin LePage described a sonar simulator designed to deliver element level time series in order to test control and navigation algorithms for an autononomous underwater vehicle. He demonstrated the results from the simulator's propagation, echo and reverberation engine applied to the A2 scenario [LePage 2010]. Jan Ehrlich described the assumptions of the MOCASSIN and MSM models and described the results of applying MOCASSIN to Scenario A2 [Ehrlich 2010a].

THURSDAY 8 APRIL

On Thursday, 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 [Tindle 2010].

Charles Holland described the effects of lateral variation and uncertainty in seabed properties, showing how by using Weston's energy flux methods the field can be simply described in terms of the geometric mean of the reflection coefficient and the arithmetic mean of cycle distance [Holland 2010b]. 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 [Rouseff & Zurk 2010].

Jean-Pierre Sessarego (LMA CNRS, Marseille) described laboratory scale measurements of scattering from a shell near the air-water boundary at acoustic frequencies of hundreds of kilohertz. The measurements were compared with a theory that generally compared very favourably. The theory is sufficiently general that it can handle arbitrary boundary conditions (e.g., seabed). The tank is sufficiently large to do waveguide problems, offering the possibility to validate sonar performance models [Sessarego et al. 2010]. Alex Tolstoy (A Tolstoy Scientific Inc) examined some of the difficulties in matched-field geoacoustic inversion including uniqueness problems. Alex showed a method to mitigate these 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. [Tolstoy 2010].

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 Modeling Workshop for frequencies between 250 Hz and 3.5 kHz [Ellis 2010b]. 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 [Tang 2010]. 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) [Strode 2010].

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 [Zhang & Miyamoto 2010]. 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 [Fattaccioli & Cristol 2010]. 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 [Heaney & Campbell 2010]. 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.

FRIDAY 9 APRIL

On Friday morning, the start of the third and final day, 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 [Diachok 2010].

Michael Ainslie presented the details of Scenario A1, involving a killer whale hunting its prey [Ainslie & Zampolli 2010]. The orca sonar pulse has a large bandwidth, extending in frequency from 20 kHz to 80 kHz, 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 [Ehrlich 2010b]. 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" [Zampolli 2010], 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, judged by the three invited speakers and 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.

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The present 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 due to a recent knee operation. He also thanks his co-organisers: Linda Canty, Barry Uscinski[1] and Peter Dobbins, and the Scientific Committee: Chris Harrison, Charles Holland, Dale Ellis, Gary Heald, Mario Zampolli and Tim Clarke. He thanks Chris Tindle, Alan Fenwick and Charles Holland for providing summaries of the sessions that each of them chaired. Finally, credit goes to Lt Cdr Bjørn Kerstens of the Royal Netherlands Navy for posing the question "Which sonar performance model should I use for evaluating LFAS performance?" that led to the idea of holding a validation workshop and for his continuing support before and after that workshop. A version of this editorial appeared in the December 2010 edition of the Acoustics Bulletin [Ainslie 2010].

1 Barry was killed in a tragic accident while flying his model Spitfire in October 2010. His impish smile will be sadly missed.

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Contents

19. **Passive sonar performance engine (SPE)**
KD Heaney, OASIS Inc., Fairfax, Virginia, USA
RL Campbell, OASIS Inc., Fairfax, Virginia, USA

20. **Bio-alpha, transmission loss and modeling of biological scattering**
Orest Diachok, Johns Hopkins University, Applied Physics Laboratory, Laurel MD, 20723-6099 USA, E-mail: Orest.Diachok@jhuapl.edu

21. **Sonar scenario A1: killer whale vs chinook salmon**
MA Ainslie, TNO, Delft, Netherlands; and ISVR, University of Southampton, UK.
M Zampolli, TNO, The Hague, Netherlands.

22. **Calculations for scenario A1 with the MSM code**
J Ehrlich, Bundeswehr Technical Centre for Ships and Naval Weapons, Maritime Technology and Research, Research Branch for Underwater Acoustics and Marine Geophysics (FWG) Berliner Straße 115, 24340 Eckernförde, Germany

23. **Elastic scattering from submerged objects near boundaries – modeling, experiments and thoughts on the way ahead**
M Zampolli, TNO Defence Security and Safety, The Hague (Netherlands)email: mario.zampolli@tno.nl