Acoustics 2019

Moving forward with Acoustics

Program and Book of Abstracts

Cape Schanck, Victoria, 10-13 November 2019

Australian Acoustical Society

Contents

ACOUSTICS 2020

Next year's conference will be held in Wellington, New Zealand.
It will be a joint conference of the Acoustical Society of New Zealand and the Australian Acoustical Society

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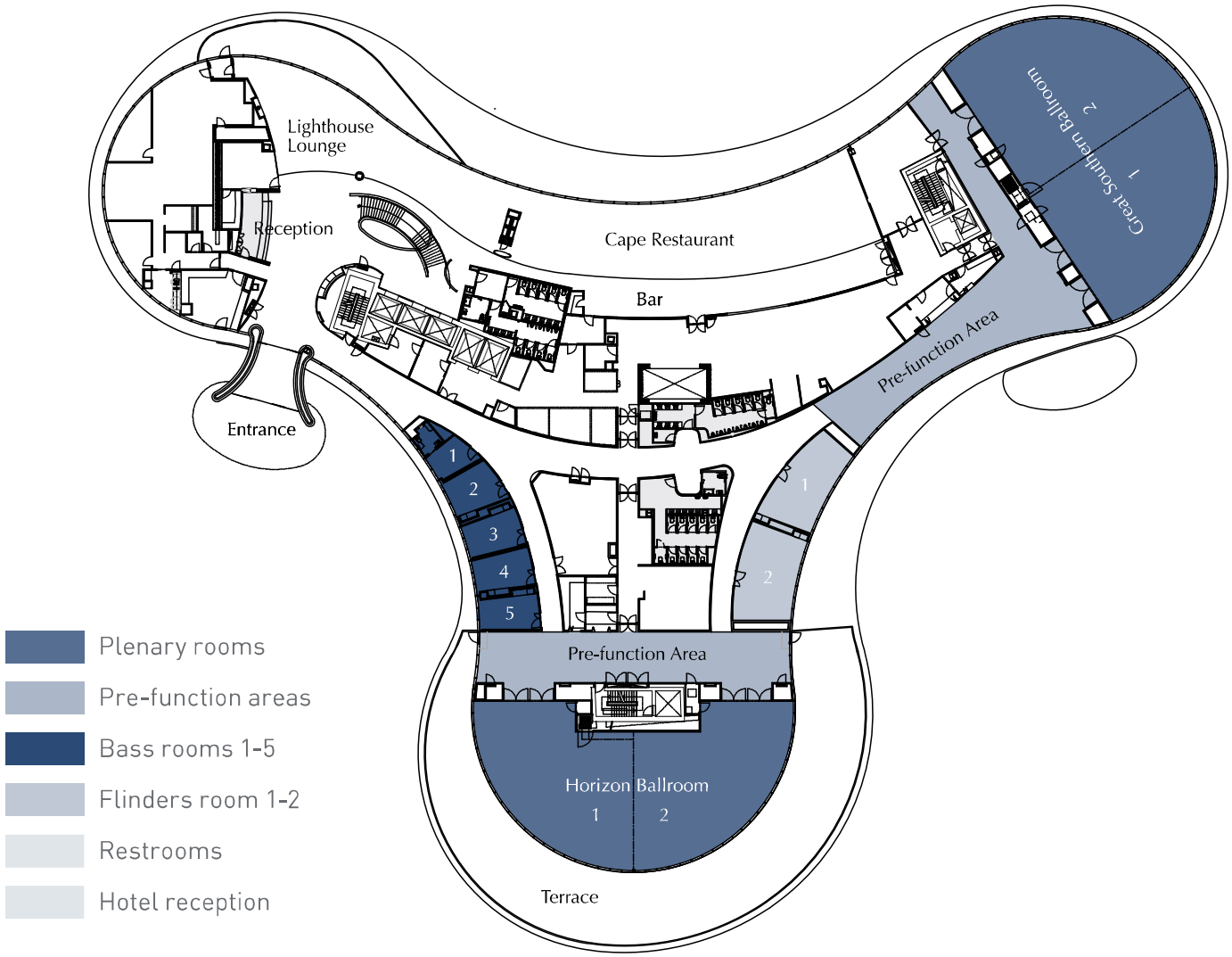
VENUE MAP



More information on the facilities available at the venue can be found at:
https://www.racv.com.au/travel-leisure/racv-resorts/our-destinations/cape-schanck-resort/facilities.html

Information on the local area is available at
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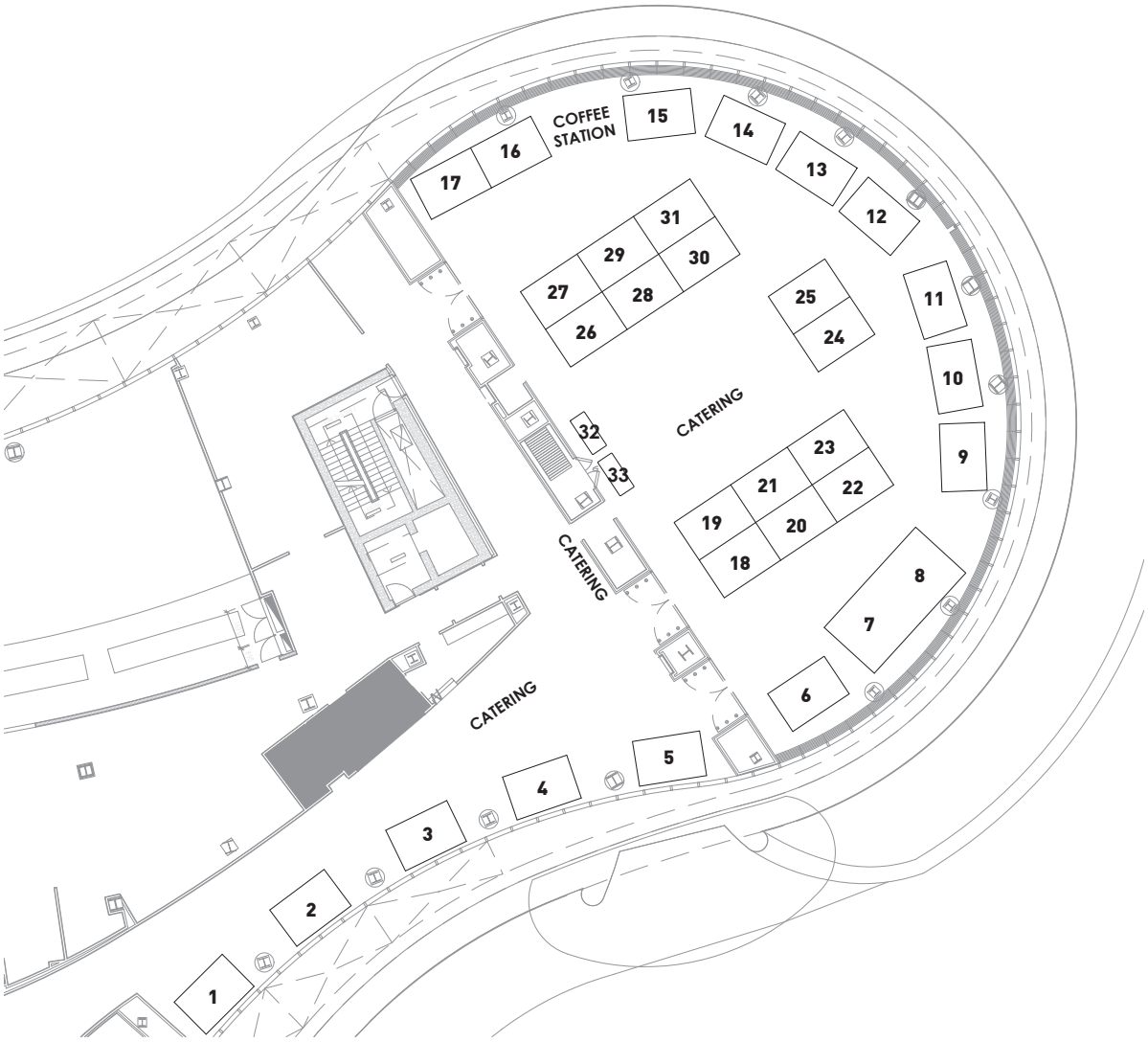
Please note that the resort is a non-smoking resort. Smoking is only permitted in the designated smoking area which is essentially close to the open air car park. Smoking in the rooms or in the balconies of the rooms will result in a $250 AUD Smoking Fine.

EXHIBITORS

Exhibitors are located in the Great Southern Ballroom



Company Name	Booth
EMS Bruel & Kjaer	1
SAVtek	2
Enviroflex	3
Marshall Day Acoustics	4
Ecotech	5
HW Technologies	6
Vibration Solutions	7 & 8
CSR Martini	9
Magnetite	10
Asona	11
Bruel &Kjaer Australia	12
Embelton	13
Acoustics Testing Service, University of Auckland	14
IAC Acoustics (Australia)	15
Mason – Mercer	16 & 17

Company Name	Booth
Instyle	18
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Acu Vib Electronics	21
Acoustic Research Labs (ARL)	22
Pliteq	23
Ortech	24 & 25
Soundblock	26
Dynamic Composite Technologies (DCT)	27
Autex	28
Regupol	29
ETMC	30
Polyvox Sound Masking	31
Abey - Acoustics	32
Howden	33

ACKNOWLEDGEMENTS

Acoustics 2019 would like to acknowledge the following, without whom this conference would not be possible.

Venue

RACV Cape Schanck Resort

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PROGRAM SUMMARY

		Stream 1 (Horizon Ballroom 1)	Stream 2 (Horizon Ballroom 2)	Stream 3 (Flinders room 2)
		SUNDAY 10 NOVEMBER		
18:30	20:30	Registration and welcome cocktail function		
		MONDAY 11 NOVEMBER		
8:00	9:00	Registration		
9:00	9:10	Conference opening		
9:10	10:00	**Plenary: Dr Irene van Kamp**		
10:00	10:30	*Morning tea*		
10:30	11:00	**Keynote: Mr Nick Wimbush**		
11:00	11:20	*D1-AM2-S1*	*D1-AM2-S2*	
11:20	11:40	Policy, Regulation &	Underwater Acoustics 1	
11:40	12:00	Standards		
12:00	12:20			
12:20	12:40			
12:40	13:30	*Lunch*		
13:30	14:00		**Keynote: Dr Stephen Moore**	
14:00	14:20	*D1-PM1-S1*	*D1-PM1-S2*	
14:20	14:40	Environmental noise	Underwater Acoustics 2	
14:40	15:00			
15:00	15:20			
15:20	15:40			
15:40	16:20	*Afternoon tea*		
16:20	16:40	*D1-PM2-S1*	*D1-PM2-S2*	
16:40	17:00	Transportation noise 1	Underwater Acoustics 3	
17:00	17:20	Road traffic noise		
17:20	17:40			
19:00	23:00	**Conference dinner (Horizon Ballroom)**		

PROGRAM SUMMARY

		Stream 1 (Horizon Ballroom 1)	Stream 2 (Horizon Ballroom 2)	Stream 3 (Flinders room 2)
TUESDAY 12 NOVEMBER				
8:00	9:00	Registration		
9:10	10:00	**Plenary: Professor Jian Kang**		
10:00	10:30	*Morning tea*		
10:30	11:00		**Keynote: Adj. Prof. John Davy**	
11:00	11:20	*D2-AM2-S1*	*D2-AM2-S2*	*D2-AM2-S3*
11:20	11:40	Transportation noise 2	Building acoustics	Underwater Acoustics 4
11:40	12:00	Aircraft noise	& vibration	
12:00	12:20			
12:20	12:40			
12:40	13:30	*Lunch*		
13:30	14:00	**Kenote: Dr Kym Burgemeister**		
14:00	14:20	*D2-PM1-S1*	*D2-PM1-S2*	*D2-PM1-S3*
14:20	14:40	Transportation noise 3	Room acoustics 1	Signal processing
14:40	15:00	Railway noise & vibration	Design & methods	
15:00	15:20			
15:20	16:00	*Afternoon tea*		
16:00	16:20	*D2-PM2-S1*	*D2-PM2-S2*	
16:20	16:40	Wind turbine noise	Room acoustics 2 - Materials	
16:40	17:40	**AGM (Horizon Ballroom 1)**		
18:00	21:30	**Twilight 9-hole golf tournament** (additional cost, subject to interest)		

PROGRAM SUMMARY

		Stream 1 (Horizon Ballroom 1)	Stream 2 (Horizon Ballroom 2)	Stream 3 (Flinders room 2)
WEDNESDAY 13 NOVEMBER				
8:00	9:00	Registration		
9:00	9:20	*D3-AM1-S1*	*D3-AM1-S2*	
9:20	9:40	Cognition &	Noise and vibration control 1	
9:40	10:00	indoor environment		
10:00	10:20			
10:20	11:00	*Morning tea*		
11:00	11:20	*D3-AM2-S1*	*D3-AM2-S2*	
11:20	11:40	Aeroacoustics	Noise and vibration control 2	
11:40	12:00			
12:00	12:40	**Closing ceremony**		
12:40	14:00	**Farewell lunch**		
14:30		Bus to Melbourne departs		

SESSION SCHEDULE

		Stream 1 (Horizon Ballroom 1)		Stream 2 (Horizon Ballroom 2)	
		MONDAY 11 NOVEMBER			
9:00	9:10		**Conference opening**		
9:10	10:00	96	**Irene van Kamp - Update of WHO evidence reviews and their implications for policy and research**		
10:30	11:00	94	**Nick Wimbush - Noise in planning and environmental impact assessment in Australia**		
11:00	11:20	17	Colin Tickell - AS 1055: 2018 revision	25	Haiyan Ni - Sediment characterization from acoustic echo-sounding using an artificial neural networks
11:20	11:40	34	Jeffrey Parnell - The relevance of the 2018 WHO noise guidelines to Australasian road traffic noise objectives.	35	Alex Zinoviev - Interchangeability of two existing formulations of sound propagation in isothermal surface ducts
11:40	12:00	64	Ben Hinze – Road traffic noise impacts and property turn-over	36	Alec Duncan - Acoustic propagation in realistic 3D nonlinear internal waves
12:00	12:20	10	Ross Palmer - Noise from amplified entertainment venues	6	Adrian Jones - Estimates of coherent leakage of sound from ocean surface ducts for first and higher order modes
12:20	12:40	85	Robert Fitzell - Expected ambient noise levels in different land-use-areas	22	Qiannan Hou - Long-range average reverberation intensity attenuation characteristics in shallow water
13:30	14:00			**72**	**Stephen Moore - Acoustic signature control on maritime platforms**
14:00	14:20	86	Robert Fitzell - Noise impact and its magnitude	29	James Lau - Investigation of temporal coherence and related issues during the littoral continuous active sonar 2016 trial
14:20	14:40	61	Norm Broner - Noise in a big city - is Jerusalem different?	93	Damien Killeen - Acoustic velocity signatures of airguns - preliminary results
14:40	15:00	49	Mark Latimore - Remotely piloted aircraft systems (RPAS) noise in an urban environment	53	Li Chen - An improved correlation of bubble size distribution with the measured acoustic spectrum for a turbulent bubble plume
15:00	15:20	63	Mahbub Sheikh - Indiscernible noise – a review of acoustic criteria for impulsive noise event in presence of background noise	98	Nicholas Padfield - Exploring the classification of acoustic transients with machine learning
15:20	15:40	31	Tim Procter - The use of probabilistic noise modelling in the design of open cut mines		
16:20	16:40	57	John Wassermann - Investigation of uniform and non-uniform traffic distribution on road traffic noise prediction for multi-lane roadways	48	Alec Duncan (for Christine Erbe) - Signature whistles of indo-pacific bottlenose dolphins (tursiops aduncus) in the Fremantle inner harbour, Western Australia
16:40	17:00	79	Jeffrey Peng - Comparison of equivalent continuous noise levels and day-evening-night composite noise indicators for assessment of road traffic noise	26	Brian S Miller - A passive acoustic survey for marine mammals conducted during the 2019 Antarctic voyage on euphausiids and nutrient recycling in cetacean hotspots (ENRICH)
17:00	17:20	44	James Mcintosh - Long term acoustic performance of different asphalt configurations	82	Douglas Cato - Surface generated underwater noise in open and enclosed waters
17:20	17:40	47	Michael Chung - Ronda CPX trailer measurements in Queensland	56	Zhang, Zhi Yong - Icebergs and storms in the southern ocean as sources of low frequency noise along Australian southern coasts
19:00	23:00		**Conference dinner (Horizon Ballroom)**		

SESSION SCHEDULE

		Stream 1 (Horizon Ballroom 1)		Stream 2 (Horizon Ballroom 2)		Stream 3 (Flinders room 2)	
		TUESDAY 12 NOVEMBER					
9:10	10:00	11	**Jian Kang - Urban sound planning – a soundscape approach**				
10:30	11:00			**4**	**John Laurence Davy - Structural connections and the sound insulation of cavity walls and double glazing**		
11:00	11:20	65	Ben Hinze - Comparison of flight tracking against ANEF contours	16	Peter Pirozek - The effects of mass-air-mass resonance on the R_w+C_{tr} performance of wall systems.	102	Xia Pan - Investigation of underwater hull radiation due to machine noise
11:20	11:40	42	Clyton Moyo - Assessing the environmental impacts of aircraft noise	97	Andrew Hall - Mass-air-mass resonance cavity suppression using Helmholtz resonators	5	Li Peng - Low-frequency underwater acoustics sensitivity calibration in a chamber
11:40	12:00	41	Belinda Fenner - Competing considerations for aircraft noise monitor placements	101	Luca Dall'Acqua D'Industria - Acoustics behaviour of CLT structure: transmission loss, impact noise insulation and flanking transmission evaluations	39	Alec Duncan - The sounds of electric ferries
12:00	12:20	20	Ryan McKay - Experimental investigation of contra-rotating multi-rotor UAV propeller noise	27	Hasitha Nayanajith Polwaththe Gallage - Effectiveness of the rubber ball compared to the tapping machine as the impact source to measure the impact sound insulation properties		
12:20	12:40	71	Richard Howell - Benchmarking a quasi-steady method for predicting propeller unsteady loads	9	Douglas G. Valerio – A practical approach to building isolation		
13:30	14:00	70	**Kym Burgemeister - Acoustic design for the Melbourne Metro Tunnel project**				
14:00	14:20	68	Philip Setton - The effect of track decay rate on in-carriage noise for resilient track fixings.	33	Yuxiao Chen - Ray-tracing computer-aided-design tools in auditoria design – past and future	21	Binh Nguyen - 2D tomographic imaging of active sonar echoes using a non-uniform FFT technique.
14:20	14:40	78	Peter Karantonis - Ground-borne noise & vibration propagation measurements and prediction validations from a railway tunnel project	43	Shuai Lu - Improving shape design of auditoriums with real-time feedback based on parametric modeling, simulation and machine learning	30	Chaoying Bao - Use of robust Capon beamformer for extracting audio signals
14:40	15:00	8	Luke Zoontjens - Curving noise from the Western Australian freight rail network: wayside monitoring and mechanism analysis	76	Matthew Ottley - Lateral reflections in the Sydney town hall; preservation of room acoustics in a historically significant venue	32	Boaz Suranyi - Cepstral coefficient feature extraction for active sonar classification
15:00	15:20	62	Hayden Puckeridge - Comparison of rail noise modelling with CadnaA and SoundPlan	73	Lily Harkom - Using acoustic cameras with 3D modelling to visualise room reflections	40	Gareth Capon - Use of a deep convolutional neural network and beamforming for localisation and diagnosis of industry noise sources
16:00	16:20	66	Kristy Lee Hansen - Comparison between annoyance due to traffic noise and wind farm noise in a non-focused listening test	75	Christian Nocke - 20 years of micro-perforated (transparent) sound absorbers		
16:20	16:40	80	Duc Phuc Nguyen - Wind farm infrasound detectability and its effects on the perception of wind farm noise amplitude modulation	12	Daniel Castro - Walk-through auralisation framework for virtual reality environments powered by game engine architectures, part II		
16:40	17:40		**AGM (Horizon Ballroom 1)**				

SESSION SCHEDULE

		Stream 1 (Horizon Ballroom 1)		Stream 2 (Horizon Ballroom 2)	
WEDNESDAY 13 NOVEMBER					
9:00	9:20	69	Amanda Robinson - Co-teaching in (refurbished) flexible learning spaces: promoting quality acoustics for learning and collaboration.	3	Marshall V. Hall - Analytical models of acoustic scattering by an infinite air-filled steel cylindrical shell in water under plane-wave excitation
9:20	9:40	87	Marion Burgess - Learned helplessness: effect on future performance from noise and negative past performance.	14	Jesse Coombs - The effect of hemispherical surface on noise suppression of a supersonic jet
9:40	10:00	95	André L'Espérance - Improving speech privacy and acoustic comfort in offices	52	Steven De Candia - Modelling the vibroacoustic behaviour of expansion chamber silencers for fluid-filled pipe systems
10:00	10:20	37	Colin Tickell - Restaurant acoustic comfort assessment methods	51	Darryl McMahon - Transmission, reflection and energy exchanges for waves in finite one-dimensional PT-symmetric periodic structures
10:20	11:00		*Morning tea*		
11:00	11:20	13	Jesse Coombs - The influence of flexible tabs on high speed jet noise	50	Michael Hayne - Static insertion loss, transmission loss and noise reduction testing of an acoustic louvre
11:20	11:40	60	Graeme Lane - Embedded large eddy simulation method for predicting flow-induced noise	77	Tim Beresford - Lightweight noise barriers: the real-world effects of panel surface mass and absorption on acoustic performance
11:40	12:00	74	Li Chen - Prediction of small-scale rotor noise using a low-fidelity-model-based framework	23	Henry Chan - Case studies of innovative window and balcony design for traffic noise mitigation
12:00	12:40		**Closing ceremony (Horizon Ballroom 1)**		
12:40	14:00		**Farewell lunch**		

PROCEEDINGS

Monday 11 November

Morning

Horizon Ballroom

Plenary - DR IRENE VAN KAMP

Chair: Andrew Mitchell

Horizon Ballroom 1

Keynote - MR NICK WIMBUSH

Chair: James McIntosh

D1-AM2-S1: Policy, regulations & standards

Chair: Lex Brown

Horizon Ballroom 2

D1-AM2-S2: Underwater acoustics 1

Chair: Stephen Moore

Afternoon

Horizon Ballroom 2

Keynote - DR STEPHEN MOORE

Chair: Norm Broner

Horizon Ballroom 1

D1-PM1-S1: Environmental noise

Chair: Marc Buret

Horizon Ballroom 2

D1-PM1-S2: Underwater acoustics 2

Chair: Douglas Cato

Evening

Horizon Ballroom 1

D1-PM2-S1: Transportation noise 1 - Road traffic noise

Chair: Felice Wong

Horizon Ballroom 2

D1-PM2-S2: Underwater acoustics 3

Chair: Adrian Jones

Conference Dinner – Horizon Ballroom – 19:00-23:00

Tuesday 12 November

Morning

Horizon Ballroom

Plenary - PROFESSOR JIAN KANG

Chair: Lex Brown

09:10 Urban sound planning – a soundscape approach

Kang, Jian *27*

Horizon Ballroom 2

Keynote: ADJUNCT PROFESSOR JOHN DAVY

Chair: Andrew Mitchell

10:30 Structural connections and the sound insulation of cavity walls and double glazing

Davy, John Laurence *27*

Horizon Ballroom 1

D2-AM2-S1: Transportation noise 2 - Aircraft noise

Chair: Jeff Parnell

11:00 Citywide noise mapping for ANEF Contours

Hinze, Benjamin; Tsakiris, Janos; Zhao, Jessica; Tang, Wei *27*

11:20 Assessing the environmental impacts of aircraft noise

Moyo, Clyton; Latimore, Mark; Fenner, Belinda; Zissermann, Paul *28*

11:40 Competing considerations for aircraft noise monitor placements

Fenner, Belinda; Latimore, Mark; Moyo, Clyton; Zissermann, Paul *28*

12:00 Experimental investigation of contra-rotating multi-rotor UAV propeller noise

McKay, Ryan; Kingan, Michael; Go, Robin *28*

12:20 Benchmarking a quasi-steady method for predicting propeller unsteady loads

Howell, Richard; Dylejko, Paul; Croaker, Paul; Skvortsov, Alex *28*

Horizon Ballroom 2

D2-AM2-S2: Building acoustics & vibration

Chair: Andrew Mitchell

11:00 The effects of mass-air-mass resonance on the Rw + Ctr performance of wall systems

Pirozek, Peter *29*

11:20 Mass-air-mass resonance cavity suppression using Helmholtz resonators

Hall, Andrew; Dodd, George; Schmid, Gian *29*

11:40 Acoustics behaviour of CLT structure: transmission loss, impact noise insulation and flanking transmission evaluations

Loriggiola, Fabrio; Dall'Acqua d'Industria, Luca (presenter); Granzotto, Nicola; Di Bella, Antonino *29*

12:00 Effectiveness of the rubber ball compared to the tapping machine as the impact source to measure the impact sound insulation properties

Polwaththe Gallage, Hasitha Nayanajith; Palmer, Ross; Eric, Huang; Roger, Hawkins *29*

12:20 A practical approach to building isolation

Valerio, Douglas G. *30*

Flinders room 2

D2-AM2-S3: Underwater acoustics 4

Chair: Alec Duncan

11:00 Investigation of underwater hull radiation due to machine noise

Pan, Xia; Wilkes, Daniel; Forrest, James *30*

11:20 Low-frequency underwater acoustics sensitivity calibration in a chamber

Li Peng,; Yin Yilong, ... *30*

11:40 The sounds of electric ferries

Parsons, Miles James; Parsons, Sylvia Karin; Duncan, Alec (presenter); Erbe, Christine *30*

Afternoon

Horizon Ballroom 1

Keynote - DR KYM BURGEMEISTER

Chair: James McIntosh

13:30 Acoustic design for the Melbourne Metro Tunnel project
Burgemeister, Kym; Digerness, Joseph; Fong, Ken-Yi; Setton, Philip; Thompson, Derek *30*

D2-PM1-S1: Transportation noise 3 - Railway noise & vibration

Chair: James McIntosh

14:00 The effect of Track Decay Rate on in-carriage noise for resilient track fixings
Setton, Philip; Burgemeister, Kym; Digerness, Joseph; Fong, Ken-Yi; Wedd, Nick *31*

14:20 Ground-borne noise & vibration propagation measurements and prediction validations from a railway tunnel project
Karantonis, Peter; Weber, Conrad; Hayden, Puckeridge *31*

14:40 Curving noise from the Western Australian freight rail network: wayside monitoring and mechanism analysis
Li, Binghui; Zoontjens, Luke (presenter) *31*

15:00 Comparison of rail noise modelling with CadnaA and SoundPLAN
Puckeridge, Hayden; Braunstein, Timothy; Conrad, Weber *31*

Horizon Ballroom 2

D2-PM1-S2: Room acoustics 1 - Design & methods

Chair: Daniel Castro

14:00 Ray-tracing computer-aided-design tools in auditoria design – past and future
Chen, Yuxiao; Fearnside, Peter *32*

14:20 Improving shape design of auditoriums with real-time feedback based on parametric modelling, simulation and machine learning
Wang, Chunxiao; Lu, Shuai (presenter) *32*

14:40 Lateral reflections in the Sydney Town Hall; preservation of room acoustics in a historically significant venue
Ottley, Matthew *32*

15:00 Using acoustic cameras with 3D modelling to visualise room reflections
Harkom, Lily; Thompson, Derek *32*

Flinders room 2

D2-PM1-S3: Signal processing

Chair: Richard Howell

14:00 2D tomographic imaging of active sonar echoes using a non-uniform FFT technique
Nguyen, Binh; Tran, Hai-Tan; Wood, Shane *33*

14:20 Use of robust Capon beamformer for extracting audio signal
Bao, Chaoying; Jia, Ling; Pan, Jie *33*

14:40 Cepstral coefficient feature extraction for active sonar classification
Suranyi, Boaz; Nguyen, Binh *33*

15:00 Use of a deep convolutional neural network and beamforming for localisation and diagnosis of industry noise sources
Capon, Gareth; Chen, Hao; Bao, Chaoying; Sun, Hongmei; Matthews, David; Pan, Jie *33*

Evening

Horizon Ballroom 1

D2-PM2-S1: Wind turbine noise

Chair: Norm Broner

16:00 Comparison between perceptual responses to traffic noise and wind farm noise in a non-focused listening test
Hansen, Kristy; Nguyen, Phuc; Lechat, Bastien; Zajamsek, Branko; Alamir, Mahmoud; Micic, Gorica; Catcheside, Peter *34*

16:20 Wind farm infrasound detectability and its effects on the perception of wind farm noise amplitude modulation
Nguyen, Duc Phuc; Hansen, Kristy; Zajamsek, Branko ; Micic, Gorica ; Catcheside, Peter *34*

Horizon Ballroom 2

D2-PM2-S2: Room acoustics 2 - Materials

Chair: Rohan Barnes

16:00 20 years of micro-perforated (transparent) sound absorbers
Nocke, Christian *34*

16:20 Walk-through auralization framework for virtual reality environments powered by game engine architectures, Part II
Castro, Daniel; Verstappen, André; Platt, Samuel *34*

AGM – Horizon Ballroom 1 – 16:40 -17:40

Wednesday 13 November

Horizon Ballroom 1

D3-AM1-S1: Cognition & indoor environment

Chair: Marc Buret

09:00 Co-teaching in (refurbished) flexible learning spaces: Promoting quality acoustics for learning and collaboration
Robinson, Amanda; Bellert, Anne *35*

09:20 Learned helplessness: effect on future performance from noise and negative past performance.
Burgess, Marion; Molesworth, Brett R C *35*

09:40 Improving speech privacy and acoustic comfort in offices
L'Espérance, André; Boudreau, Alex; Boudreault, Louis-Alexis; Gariépy, François; Mackenzie, Roderick *35*

10:00 Restaurant acoustic comfort assessment methods
Tickell, Colin; Collings, Stephen *35*

D3-AM1-S2: Aeroacoustics

Chair: Paul Dylejko

11:00 The Influence of flexible tabs on high speed jet noise
Coombs, Jesse; Schembri, Tyler; Zander, Anthony *36*

11:20 Embedded large eddy simulation method for predicting flow-induced noise
Lane, Graeme; Croaker, Paul; Ding, Yan *37*

11:40 Prediction of small-scale rotor noise using a low-fidelity-model-based framework
Chen, Li; Batty, Trevor; Giacobello, Matteo; Wajaja, Ronny *37*

Horizon Ballroom 2

D3-AM2-S1: Noise and vibration control 1

Chair: Rohan Barnes

09:00 Analytical models of acoustic scattering by an infinite air-filled steel cylindrical shell in water under plane-wave excitation
Hall, Marshall V *35*

09:20 The effect of hemispherical surface on noise suppression of a supersonic jet
Coombs, Jesse; Schembri, Tyler; Zander, Anthony *36*

09:40 Modelling the vibroacoustic behaviour of expansion chamber silencers for fluid-filled pipe systems
De Candia, Steven; Moore, Stephen; MacGillivray, Ian; Skvortsov, Alexei *36*

10:00 Transmission, reflection and energy exchanges for waves in finite one-dimensional PT-symmetric periodic structures
McMahon, Darryl *36*

D3-AM2-S2: Noise and vibration control 2

Chair: James McIntosh

11:00 Static insertion loss, transmission loss and noise reduction testing of an acoustic louvre
Hayne, Michael; Tan, Dexter; Devereux, Richard; Mee, David J. *37*

11:20 Lightweight noise barriers: The real-world effects of panel surface mass and absorption on acoustic performance
Chen, Kanvin; Beresford, Timothy (presenter) *37*

11:40 Case studies of innovative window and balcony design for traffic noise mitigation
Cheung, Frank S.M.; Li, Leo Y.C.; Lai, Andy K.Y.; Chan, Henry C.K. (presenter) *38*

Closing ceremony – Horizon Ballroom 1 – 12:00-12:40

ABSTRACTS

Plenary: Dr Irene van Kamp

96 **Update of the WHO evidence reviews and their implications for policy and research**

van Kamp, Irene
RIVM (National Institute for Public Health and the Environment). Netherlands

ABSTRACT
It had been a while since the first World Health Organization (WHO) guidelines for health protection against environmental noise were published in 1999. Since then many new studies on the health effects of environmental sound exposure at home have been performed and an update of the WHO environmental noise guideline saw light in November 2018. The earlier guidelines were primarily focused on transportation noise. At the European Ministerial Conference at Parma in 2010, the need for guidelines for other sources, such as wind turbines and leisure noise was emphasized. In order to achieve this, reviews were prepared on the main health outcomes, including annoyance, sleep, cardiovascular disease, cognitive effects, mental health, adverse birth outcomes, hearing impairment and the effectiveness of noise interventions in terms of human response and health. These systematic literature reviews cover the period between 2000 and 2014 and were published in a special issue of the International Journal of Environmental Research and Public Health (IJERPH) in 2017 and 2018). This paper provides an overview of the evidence, including an update since 2014 for some key endpoints. The implications of the findings for noise policy and management are briefly discussed. Finally, some trends and research needs in the field of sound and health are presented.

Keynote: Nick Wimbush

94 **Noise in planning and environmental impact assessment in Australia**

Wimbush, Nick
Planning Panels Victoria

ABSTRACT
Planning and environmental impact assessment is essentially the consideration of change; whether directed and facilitated, in planning, or received as in the case of impact assessment of proposals and strategies. Change nearly always involves the consideration of those who are there, and those who may come. The generation of sound and the regulation of noise in policy and legislation is in theory a relatively simple undertaking. Standards or other criteria are set to protect human health from noise; measurements are made of the existing environment and predictions of the change in environment made; and assessed against the agreed standards to determine if there will be unacceptable noise. Predicted exceedances of standards can be mitigated or projects redesigned to meet the relevant standard. Why then is noise, whatever the source, whether windfarms, traffic, industrial, music or any other, often a hotly contested issue in planning and project impact assessment? This paper explores the broader socio-economic and socio-political environment around the social license to emit sound and generate noise.Using examples of projects primarily from Victoria it explores our current approach to noise in planning and impact assessment and discusses key challenges to evidence-based decision making.

D1-AM2-S1: Policy, regulations & standards

17 **AS 1055: 2018 revision**

Tickell, Colin
Chair Standards Australia Technical Committee EV-010

ABSTRACT
Australian Standard "AS 1055-2018 Acoustics – description and measurement of environmental noise" was published in late 2018 as the latest revision to the long-running series of standards of the same name, with the previous revision being dated 1997. This revision has followed the Standards Australia project approval and development system and was approved as a project in 2015 for completion by Standards Technical Committee EV-010 Acoustics, Community Noise. This revision consolidated the previous three-part and three volume standard into one single volume. The Standard applies primarily to noise emitted from industrial, commercial and residential premises. It excludes the setting of environmental noise criteria. Such levels are set by regulations or organizational policy. A number of changes were made to the standard to bring it into line with the latest relevant international standards and instrumentation and measurement techniques. This paper provides a brief explanation of how Australian Standards are currently developed or revised, as well as a review of the contents of the Standard for users and some of the reasoning behind the changes to the previous versions. New methods of how to allow for façade reflections and the informative appendix on assessment of impulsive noise are also discussed.

34 **The relevance of the 2018 WHO noise guidelines to Australasian road traffic noise objectives.**

Parnell, Jeffrey (1); Peng, Jeffrey (2)
(1) New South Wales Department of Planning, Industry and Environment, Australia
(2) Transport for New South Wales, Australia

ABSTRACT
Road traffic noise criteria are generally established by regulators with reference to exposure-response relation-ships. The release of the World Health Organisation (WHO) Noise Guidelines for the European Region in 2018 therefore had global relevance as it purported to present the most contemporary guidance on road traffic noise impacts. Consistent with European Union reporting requirements, the day-evening-night composite noise metric was referenced. In order to understand the implications of this WHO document on policies across Australasia it is necessary to undertake comparisons using a common noise descriptor. There are a range of noise metrics in use across the jurisdictions,

however currently there is no robust process of converting the local noise metrics to the day-evening-night composite noise metric This paper uses a large data set of New South Wales (NSW) road traffic noise measurements collected from medium and highly trafficked routes as the basis for the development of such a process. This in turn allows comparison not only to the WHO studies, but also to ISO 1996-2:2017 and to the exposure-response studies that have underpinned the setting of noise objectives in NSW since 1999. In this respect, the conversion protocol has also provided for older studies to be reconstructed and compared to more contemporary studies.

64 **Road traffic noise impacts and property turnover**

Hinze, Benjamin (1); Laurence, Nicol (2)
(1) Ambient Maps Pty Ltd, Brisbane, Australia
(2) State Machine, Brisbane, Australia

ABSTRACT
It is generally accepted that adverse impacts from road traffic noise will be reflected in lower property values and rental prices for affected apartments and houses. However, the impact that road traffic noise has on rental property turnover rates is not as well established. This study explored that question by modelling the road traffic noise levels across six suburbs in Queensland and correlating the calculated noise levels with rental turnover rates. The results suggest that the properties fronting major roads, which are exposed to higher noise levels, generally have greater turnover rates than properties with lower road traffic noise levels within the same suburbs. It is suggested that renters underestimate the impacts of road traffic noise on their day-to-day lives, causing them to relocate in a shorter amount of time than renters of similar properties with lower noise exposure levels.

D1-AM2-S1: Policy, regulations & standards

10 **Noise from amplified entertainment venues**

Palmer, Ross
Palmer Acoustics (Australia) Queensland

ABSTRACT
Under the offence provisions of the Queensland EPA Act 1994 an occupier of a premises may generate noise from an outdoor event of up to 70 dB(A) at a nearby noise sensitive receptor, between the hours of 7am and 10pm, and between 10pm and midnight of up to 50 dB(A) or background +10 dB(A) (whichever is the lessor). This has often been seen to be the operating limit but is in reality the level at which penalties can be applied. With current technology of music systems being employed in music festivals the focus is to generate high sound pressure levels at low frequencies (40 to 80 Hz), with very little mid to high frequency sound. At these frequencies the "A" scale correction (-26 dB) applied to the music means that the dB(A) reading from a sound meter does not represent audibility. The result is a sound that is well under the Queensland EPA offence limits, meets the expectations of the patrons; and yet can travel 10 km and be clearly audible but not measurable as a dB(A). Based upon experience in managing noise from music festivals this paper presents a case for the use of dB(C) for the management of environmental noise from entertainment venues and the use of lower performance criterion to protect residential amenity.

85 **Expected ambient noise levels in different land-use areas**

Fitzell, Robert John
Robert Fitzell Acoustics, NSW, Australia

ABSTRACT
The planning-stage prediction of environmental noise impact at a regional level, for both stationary and stochastically varying noise systems, is impeded by an absence of independent benchmarking for expected ambient noise levels in those areas. This paper presents a retrospective review of historical records of ambient noise measurement carried out between 1990 and 2015. The records were sorted into classifications based on the land area usage at the time. The findings aim to assist development of a benchmark for ambient noise based on land usage, consolidated into statistical parameters, and includes a discussion of the associated variances. The data is analysed to develop a method for prediction of levels that could reasonably be expected for different land area uses, including variance. The objective of the prediction is to facilitate effective high-level planning, enabling the estimation of magnitude of noise impact likely to arise from a major infrastructure or changing land use development project in differing land use sectors within a region.

D1-AM2-S2: Underwater acoustics 1

25 **Sediment characterization from acoustic echo sounding using an artificial neural network**

Ni, Haiyan (1,2,3); Ren, Qunran (1,2); Wang, Wenbo (1,2,3); Lu, Licheng (1,2); Ma, Li (1,2)
(1) Key Laboratory of Underwater Acoustic Environment, Chinese Academy of Sciences
(2) Institute of Acoustics, Chinese Academy of Sciences
(3) University of Chinese Academy of Sciences

ABSTRACT
In 2018, an experiment was conducted for sediment characterization off the coast of Qingdao, China, using hydrographic systems. In this experiment, single-beam and multibeam echo sounders were towed along the ship track, which was approximately 120 km long and covered three main sediment types, i.e., clayey silt, sandy silt, and silty sand. This study emphasizes the potential of using an artificial neural network (ANN) and the multibeam backscatter data for performing acoustic sediment characterization. The index of impedance (IOI) of the sediment as inverted from the single-beam sonar data is shown to be consistent with the core sampling distribution, which is used to label the mean angular response curves extracted from the multibeam data in ANN training. First, the ANN is trained to map the relation between the mean angular response curves and IOI using a training dataset; then, it is applied to a testing dataset to predict the IOI of the sediment. For data processing, 80% of the available data are used for training, whereas the remaining 20% are used for testing. The preliminary results denote that the prediction accuracy on testing dataset can up to 90% within the absolute error tolerance of 0.1, showing the feasibility of using an ANN for performing sediment characterization using multibeam data.

35 **Interchangeability of two existing formulations of sound propagation in isothermal surface ducts**

Zinoviev, Alex
Defence Science & Technology Group, Edinburgh, South Australia

ABSTRACT
Sound propagation in isothermal ducts is traditionally described by a formulation based on the n2-linear sound speed profile (SSP) where the acoustic field is expressed via Airy functions. The present author recently suggested an alternative formulation based on the n2-exponential SSP with acoustic field described by Bessel functions. In this paper, it is shown that the n2-exponential SSP is a better approximation of the linear SSP, but both approximations are valid, as their difference with the linear SSP is small. Also, vertical pressure profiles are calculated by several methods combining elements of the two approximations. It is demonstrated that the methods involving exact calculations of the horizontal wavenumber produce most accurate results. Overall, it is shown that the two formulations are mutually interchangeable and their various elements can be combined together and utilised in acoustic propagation modelling depending on convenience of their use in a particular environment.

36 **Acoustic propagation in realistic 3D nonlinear internal waves**

Duncan, Alec (1); Shimizu, Kenji (2); Parnum, Iain (1); MacLeod, Rod (3); Buchan, Steve J (4)
(1) Centre for Marine Science and Technology, Curtin University, Perth, Western Australia
(2) Civil Engineering, Kobe University, Japan
(3) Defence Science & Technology Group, HMAS Stirling, Rockingham, Western Australia
(4) RPS MetOcean, Jolimont, Western Australia

ABSTRACT
Nonlinear internal waves are a feature of many continental margins, particularly those with large tidal ranges such as Australia's Northwest Shelf. This paper extends previous work on the effects of idealised nonlinear internal waves on acoustic propagation at mid-frequency sonar frequencies to the case of a realistic, fully three-dimensional, time evolving internal wave field. The internal wave field was modelled using MITgcm, which is a state of the art, three-dimensional, non-hydrostatic hydrodynamic model. Time evolving, three-dimensional sound velocity fields were calculated from the MITgcm temperature and salinity outputs and used as input to the Bellhop3D acoustic propagation model, which was used to calculate the variations in transmission loss that occurred as a nonlinear internal wave train crossed the acoustic transmission path. Results were broadly consistent with those obtained previously using the idealised internal wave train but predicted somewhat smaller changes in transmission loss between horizontally focussed and defocussed conditions of up to 18 dB com-pared to changes of up to 30 dB obtained with the idealised internal waves. Analysis of more events is required in order to test the robustness of this result.

6 **Estimates of coherent leakage of sound from ocean surface ducts for first and higher order modes**

Jones, Adrian D. (1); Zinoviev, Alex (1); Duncan, Alec (2); Zhang, Zhi Yong (1)
(1) Defence Science & Technology Group, Edinburgh, South Australia
(2) Centre for Marine Science and Technology, Curtin University, Perth, Western Australia

ABSTRACT
In earlier work, the authors established that the coherent leakage of sound from a mixed layer surface duct could be estimated for the first acoustic mode with reference to the analysis of Furry (in D. E. Kerr, ed., Propagation of Short Radio Waves, McGraw-Hill, 1951). By further consideration of Furry's analysis, is it straightforward to arrive at the conclusion that leakage rates for any mode, when expressed as a dB loss over the distance of a surface skip for a limiting ray in the duct, will be expected to be a function of two ratios: frequency as a proportion of duct trapping frequency, and the ratio of sound speed gradients in the duct and below. Based on this expectation, algorithms have been prepared to estimate the rate of leakage of the coherent signal from a surface duct, for the first mode and for higher order modes. The effectiveness of the algorithms is demonstrated by comparison of leakage estimates against values obtained by a nominally exact iterative technique.

22 **Long-range average reverberation intensity attenuation characteristics in shallow water**

Hou, Qiannan (1); Wu, Jinrong (1); Ma, Li (1)
(1) Key Laboratory of Underwater Acoustic Environment, Institute of Acoustics, Chinese Academy of Sciences

ABSTRACT
Reverberation experiments in shallow water showed that reverberation average intensity could be described as a stage function composed of two proximate linear function with different slopes in terms of logarithm of time. In the former section, reverberation came from close range, where the reverberation gradient for logarithm of time was smaller. In the latter section, reverberation came from long range, where the gradient was much larger. The demarcation of this stage function is not dependent on signal pulse length or signal frequency, but dependent on the characteristics of the waveguide. The simulation illustrated this by analysing the effective normal modes varying range. The characteristics of two-way propagation and backscattering intensity both controlled the position of the cut-off point. The experiment also shows that the demarcation has a close relationship with sediment. For the shallow water with tough sediment, the demarcation of reverberation average intensity attenuation characteristics exhibits a lag performance.

Keynote: Stephen Moore

72 **Acoustic signature control on maritime platforms**

Moore, Stephen
Defence Science & Technology Group, Fisherman's Bend, Victoria, Australia

ABSTRACT
The Acoustic Signature Management Branch in Defence Science and Technology Group (DST) develops technical solutions to control the active and passive acoustic signatures of Royal Australian Navy platforms. The aim is to improve the operational effectiveness and survivability of the Navy's current fleet, and the Branch also provides technical advice during the acquisition of new platforms. This paper presents an overview of the active and passive acoustic signatures of maritime platforms and the main factors that influence the signatures. Research by the Acoustic Signature Management Branch on modelling and analysis of acoustic signature generation and transmission is discussed with examples of collaborative research programs with academic and commercial partners.

D1-PM1-S1: Environmental noise

86 **Noise impact and its magnitude**

Fitzell, Robert John
Robert Fitzell Acoustics, NSW, Australia

ABSTRACT
This paper researches and proposes criteria for the assessment of environmental noise impact. Limitations in current methods of assessment are particularly evident when considering moving and stochastically varying noise systems, and when considering impact from development that may be a change to land usage. The paper proposes a statistically based method of impact prediction and assessment based on Emergence and benchmarks the findings against long-established principles of impact assessment. The paper demonstrates that Emergence, and therefore impact, is a complex parameter unable to be simply evaluated using stationary noise level metrics. The paper identifies important aspects of noise impact that are omitted by current noise impact assessment procedures and recommends both a methodology and associated acceptance criteria for a more rigorous impact assessment method, considering both active and passive aspects of impact.

61 **Noise in a big city - Is Jerusalem different?**

Broner, Norm
Broner Consulting Pty Ltd

ABSTRACT
Jerusalem is a capital city encompassing three religions and nearly 1 million inhabitants. The city is constrained in area and construction activities including new roads, new light rail lines and office and residential buildings are ongoing. In addition, there are unique sources of noise complaints that need to be dealt with such as muez-zin calls five times a day from mosques and music before the Sabbath from synagogues which have a noise impact on some neighbours. The acoustic challenges due to all these noise sources in Jerusalem will be explored in this paper.

49 **Remotely piloted aircraft systems (RPAS) noise in an urban environment**

Latimore, Mark (1); Moyo, Clyton (1); Fenner, Belinda (1); Zissermann, Paul (1)
(1) Environment and Community Branch, Air Navigation Services Group, Airservices Australia, Canberra, Australia

ABSTRACT
Disturbance from Remotely Piloted Aircraft Systems (RPAS) will become more prevalent as their recreational and commercial use increases in urban environments. Noise from RPAS can be very distinct, with tonal qualities that sensitive individuals can find particularly annoying. This is an issue faced both within Australia and worldwide. In 2018, the Australian Government's Department of Infrastructure, Transport, Cities and Regional Development (the Department) provided approval to a commercial operator to perform a trial of drone deliveries of food and household items at specific locations in the south of Canberra. In 2019, the delivery services were approved for four northern Canberra suburbs and two suburbs in South Brisbane. The trial in south Canberra in 2018 had mixed reviews from the community and prompted the need to implement quieter drone technologies in an urban environment. A review of noise regulations has been initiated by the Department that addresses both RPAS and the new concept of urban air mobility (UAM) systems. This paper explores the existing regulatory framework in Australia and discusses appropriate noise certification standards and noise metrics. Noise modelling results are also presented for a hypothetical UAM operating scenario in the Melbourne central business district (CBD).

63 **Indiscernible noise – a review of acoustic criteria for impulsive noise event in presence of background noise**

Sheikh, Mahbub (1); Evenden, Craig (1); Terlich, Matthew (2)
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(2) Air and Noise Team, GHD. Brisbane, QLD, Australia

ABSTRACT
Discernibility in presence of background noise is a complex aural phenomenon and not explicitly defined in scientific literature. Policymakers often aim to control music and mechanical equipment noise egress by set-ting noise emission criteria as "inaudible" during the night period when background noise is relatively low. However, the quantification of "indiscernible" in relation to "typical" background noise is not well defined in the literature. As commonly understood by acousticians, a subject noise source will not significantly contribute to the ambient noise environment when the source level is 10 dB or more below the background noise level. Subjective perception of such noise depends on myriad of factors including the temporal and spectral content of the noise, noise sensitivity and cognitive perception of the subject and the subjective perception in context. The indiscernibility of sound in an outdoor setting becomes even more complex when the subject noise source is of impulsive character (i.e. gun shots etc.). It is of interest to investigate whether the "Background - 10 dB" rule ensures the indiscernibility to the majority of subjects in an outdoor context, when a noise source is located outside or inside of a building in the vicinity of a sensitive receptor. This paper presents a literature review on the indiscernibility noise criteria of an impulsive noise source,

located at indoor or outdoor environment, in the presence of background noise. The findings will be especially of interest for Defence and law enforcement building design to ensure the safe operation of the facility and address the acoustic amenity of receivers in the surrounding environment.

31 The use of probabilistic noise modelling in the design of open cut mines

Procter, Tim (1); Brown, A. Lex(1)
(1) Griffith School of Environment, Griffith University, Brisbane, Australia

ABSTRACT
Community, regulatory and environmental pressures have resulted in the development of an iterative approach to mine plan design. This is a staged approach that considers how noise, air and water quality and ecological impacts of different mine plan options affect the viability of the mining development. The traditional deterministic noise modelling process is used to predict the area of noise affectation of a predefined mine plan resulting in the acquisition of affected properties. The deterministic modelling process typically includes a sensitivity analysis to understand the uncertainties associated with the impact of operational changes, machine selection and changes in meteorological conditions on the area of noise affectation. The results are expressed as a range of predicted noise levels at each receiver location. Contemporary iterative mine plan design processes consider the economic operability of the mine, the environmental impacts of the operation, as well as the community acceptance of the development before determining an acceptable area of affectation. Rather than determine the area of affectation for a predefined mine plan, the iterative approach requires the planners to de-sign a mine plan that can operate within an acceptable area of affectation. Probabilistic noise modelling is then used to investigate the operational changes required by the mine for the noise levels to remain within the acceptable area of noise affectation as temporal and spatial conditions change. As with traditional deterministic modelling methods, probabilistic noise modelling includes meteorological conditions, ground properties, terrain features, source sound power and directivity, and receiver geometry. However, in probabilistic noise modelling the results are expressed as a percentage of time that different operational changes, such as equipment relocation or shut down, may be required so that the acceptable area of affectation is realised. This paper outlines the application of probabilistic noise modelling for the iterative design of open cut mining operations.

D1-PM1-S2: Underwater acoustics 2

29 Investigation of temporal coherence and related issues during the Littoral Continuous Active Sonar 2016 trial

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ABSTRACT
In traditional pulsed active sonar (PAS) systems, the projector transmits for a short interval and most of the operating cycle is spent listening for echoes. Continuous Active Sonar (CAS) transmits continuously and relies on the modulation of the transmission to distinguish the (weak) echoes from the (very strong) direct transmission. In theory, detection performance in the presence of noise and direct transmission interference is improved by increasing the integration period of the detector. In reality the useful integration period is limited to the period that the channel is (approximately) stationary or coherent. Exceeding the coherence length can result in reduced detection performance due to destructive interference in the detector. Channel coherence length is known to be time-variable and it is important to guard against the use of channel characterisations that are no longer valid. In this paper we explore these effects using data from the Littoral Continuous Active Sonar 2016 (LCAS' 16) trial, with a goal of understanding the relationship between coherence length and detection performance. Finally we explore how detection performance is affected by choice of integration length.

93 Acoustic velocity signatures of airguns - preliminary results

Killeen, Damien (1); Duncan, Alec (2),
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(2) Centre for Marine Science and Technology, Curtin University, Perth, Western Australia

ABSTRACT
Arrays of airguns are routinely used as sound sources for seismic surveys of the seafloor substrate. While their acoustic pressure signature is well understood, less is known about the acoustic velocity signature of airgun arrays. By gaining a better understanding of airgun acoustic velocity signatures, the impact they have on marine fauna that rely on acoustic velocity to 'hear' can be more accurately assessed. This presentation outlines a data set gathered by CMST in order to characterise airgun acoustic velocity signatures, and presents preliminary results of the analysis conducted to date.

53 An improved correlation of bubble size distribution with the measured acoustic spectrum for a turbulent bubble plume

Chen, Li
Defence Science & Technology Group, Fisherman's Bend, Victoria, Australia

ABSTRACT
Bubble size distribution is of great interest in many engineering applications. Measuring this quantity in a turbulent bubble plume presents a challenge to conventional techniques, such as photography and ultrasonic imaging. This paper presents an improved correlation of bubble size distribution in turbulent bubble plumes with the measured sound spectrum. The improved correlation includes both the effect of sound attenuation through the bubble plume and the effect of the formed bubble sizes on the magnitude of the generated sound. An iterative method is also used in the solution process. The model is applied to highly turbulent bubble plumes generated at different facilities. It has been found that the total flow rates predicted by using the improved correlation agree well with the measured data and confirm that the magnitude of bubble formation sound is indeed dependent upon the flow conditions.

98 **Exploring the classification of acoustic transients with machine learning**

Padfield, Nick
Defence Science & Technology Group, HMAS Stirling, Western Australia

ABSTRACT
Machine learning techniques are so numerous that it can be difficult for a machine learning novice to put them to use in their specific discipline unless they have third-party work to study. There is not a lot of previous work in the discipline of underwater acoustics, but the potential for benefits in classification and detection are clear. This paper describes how desktop tools have been put to work on a transient classification task using a few machine learning techniques. The paper shows how the most complex techniques may seem to be the most intuitively appropriate, but can be overkill for this application. A much simpler detector/classifier is demonstrated and advice for fellow researchers in the discipline is provided.

D1-PM2-S1: Transportation noise 1 - Road traffic noise

57 **Investigation of uniform and non-uniform traffic distribution on road traffic noise prediction for multi-lane roadways**

Hall, Nic (1); Wassermann, John (presenter, 1); Jeffrey, Peng (2); Jeffrey, Parnell (3)
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(2) Transport for New South Wales, Australia
(3) New South Wales Department of Planning, Industry and Environment, Australia

ABSTRACT
Road traffic noise prediction is routinely undertaken as part of environmental impact assessments to assist government planning authorities to understand the potential noise impact that could arise from proposed road infrastructure development projects. Typically, road traffic noise models developed in New South Wales detail all lanes of a roadway and assume uniform distribution of traffic volume and vehicle mix across the lanes of each carriageway. In this work, the effects of uniform and non-uniform traffic distribution on road traffic noise prediction for multi-lane roadways are investigated. Models with all lanes detailed are compared to simplified two-lane models for a range of receiver setback distances and shielding arrangements.

79 **Comparison of equivalent continuous noise levels and day-evening-night composite noise indicators for assessment of road traffic noise**

Peng, Jeffrey (1); Parnell, Jeffrey (1,2); Kessissoglou, Nicole (1)
(1) School of Mechanical and Manufacturing Engineering, The University of New South Wales, Sydney, Australia
(2) New South Wales Department of Planning, Industry and Environment, Australia

ABSTRACT
Environmental road traffic noise exposure indicators adopted by Australasian road authorities, corresponding to equivalent continuous sound levels specified over different assessment time periods within a 24-hour period, are compared with 24-hour composite indicators comprising day-evening-night and day-night assessment periods that place higher importance on night-time noise impact. The aforementioned equivalent continuous sound levels specified over different assessment time periods and composite noise indicators are calculated using measured hourly road traffic noise levels at representative locations in urban and rural areas in New South Wales. Further, the corresponding road traffic data (full classification vehicle counts and vehicle speeds) are used as inputs to the well-established CNOSSOS-EU, CoRTN and FHWA-TNM road traffic noise prediction models, from which the equivalent continuous sound levels and composite noise indicators are then predicted. Using the noise indicators, measured noise levels and predicted noise levels from the three road traffic models at roadside locations along an urban arterial road and an interstate freight route are compared.

44 **Long term acoustic performance of different asphalt configurations**

McIntosh, James (1); Wong, Felice (1); Macha, Pascal (2); Buret, Marc (3)
(1) Victorian Department of Transport, Australia
(2) Vipac Engineers & Scientists, Australia
(3) Environment Protection Authority Victoria, Australia

ABSTRACT
VicRoads (now Victoria's Department of Transport) and Vipac Engineers & Scientists have been conducting a long-term asphalt noise trial since early 2013. Noise levels for five different asphalt configurations have been measured using the Close Proximity Method and On-Board Sound Intensity Method. One of the trial sections is an Open Graded Asphalt (OGA) initially treated by horizontal grinding of the top 1 to 2 mm of the surface, resulting in a smooth, negative texture. Early tests have shown that the overall noise levels for this section were consistently lower than those for the standard OGA by up to 3 dB. The acoustic performance of the pavements over a period of nearly six years is presented.

47 **RONDA CPX trailer measurements in Queensland**

Chung, Michael (1); Hinze, Benjamin (2); Kim, David (1); Macabenta, Neil (1)
(1) Renzo Tonin & Associates, Surry Hills, New South Wales, Australia
(2) Ambient Maps Pty Ltd, Queensland, Australia

ABSTRACT
RONDA (ROad Noise Data Acquirer) is a CPX trailer conforming to ISO 11819-2 for the measurement of tyre-pavement noise. The trailer is of the open frame type without an enclosure. Tyre-pavement noise measurements along a major motorway in Queensland were recently undertaken to quantify noise levels for various pavement types along the motorway, which includes a variety of concrete and asphalt pavements. Measurement data was analysed to determine the tyre-pavement noise levels for each specific pavement type. It was found that tyre-pavement noise levels were not tightly grouped for the pavement types measured due to varying pavement conditions including levels of wear, presence of expansion cracks and road repairs.

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48 Signature whistles of Indo-Pacific bottlenose dolphins (Tursiops aduncus) in the Fremantle Inner Harbour, Western Australia

Erbe, Christine (1); Salgado-Kent, Chandra (1,2,3); Winter, Simone (1); Marley, Sarah (4); Ward, Rhianne (1) Duncan, Alec (presenter, 1)
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(2) Centre for Marine Ecosystems Research, Edith Cowan University, Joondalup, Western Australia
(3) Oceans Blueprint, Coogee, Western Australia
(4) Institute of Marine Sciences, University of Portsmouth, United Kingdom

ABSTRACT
A community of ~21 Indo-Pacific bottlenose dolphins (Tursiops aduncus), plus calves, resides in the Swan Canning Riverpark, Perth, Western Australia. A complete photo-identification catalogue has been maintained for close to a decade. Regular visual monitoring of individuals in this community can be laborious and expensive. Bottlenose dolphins elsewhere have been shown to emit so-called signature whistles, by which individual animals can be identified. Passive acoustic listening is an efficient monitoring tool in the marine environment and hence an attractive option for monitoring individuals within this small dolphin community—if individual photo-ID can be matched with signature whistles. Archived underwater acoustic recordings and photographs of individual dolphins at the surface were matched chronologically. Dolphins were always present in groups rather than individually. Consequently, to assess whether distinctive whistles could be associated with certain individuals, the likelihoods that catalogued individuals were present when specific whistle types were heard were computed by calculating the percentage of the total number of occasions individual dolphins were in the study area when the whistle was produced. While a larger sample size is needed to capture all individuals in diverse groupings, this study provides the first step in developing a passive acoustic monitoring program for individuals in this small community.

26 **A passive acoustic survey for marine mammals conducted during the 2019 Antarctic voyage on Euphausiids and Nutrient Recycling in Cetacean Hotspots (ENRICH)**

Miller, Brian S. (1); Calderan, Susannah (1); Miller, Elanor (1); Širović, Ana (2); Stafford, Kathleen M. (3); Bell, Elanor (1); Double, Michael C. (1)
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(2) Texas A&M University Galveston, USA
(3) University of Washington, Seattle Washington, USA

ABSTRACT
The 2019 ENRICH Voyage (Euphausiids and Nutrient Recycling in Cetacean Hotspots), was conducted from 19 January – 5 March 2019, aboard the RV Investigator. The voyage departed from and returned to Hobart, Tasma-nia, Australia, and conducted most marine science operations in the area between 60°S – 67°S and 138°E – 152°E. As part of the multidisciplinary research programme, a passive acoustic survey for marine mammals was undertaken for the duration of the voyage, with the main goal to monitor for and locate groups of calling Antarctic blue whales (Balaenoptera musculus intermedia). Directional sonobuoys were used at 295 listening stations, which resulted in 828 hours of acoustic recordings. Monitoring also took place for pygmy blue, (B. m. brevicauda), fin, (B. physalus), sperm (Physeter macrocephalus), humpback (Megaptera novaeangliae), sei (B. borealis), and Antarctic minke whales (B. bonarensis); for leopard (Hydrurga leptonyx), crabeater (Lobodon carcinophaga), Ross (Ommatophoca rossii), and Weddell seals (Leptonychotes weddellii), and for odontocete (low frequency whistles) vocalisations during each listening station. Calibrated measurements of the bearing and intensity of the majority of calls from blue and fin whales were obtained in real time. 33,435 calls from Antarctic blue whales were detected at 238 listening stations throughout the voyage, most of them south of 60°S. Southeast Indian Ocean blue whale song was detected primarily between 47° and 55°S while the southwest Pacific blue whale song was recorded between 44° and 48°S. Most baleen whale and seal calls were detected along the continental shelf break in the study region but some were also detected in deeper waters. Marine mammal calls were uncommon on the shelf, which did not have any ice cover during the survey. Calling Antarctic blue whales were tracked and located on multiple occasions to enable closer study of their fine-scale movements and calling behaviour as well as enabling collection of photo ID, behavioural, and photogrammetry data. The passive acoustic data collected during this voyage will allow investigation of the distribution of Antarctic blue whales in relation to environmental correlates measured during ENRICH, with a focus on blue whale prey.

82 **Surface generated underwater noise in open and enclosed waters**

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(2) School of Geosciences, University of Sydney, Sidney, Australia

ABSTRACT
Measurements of surface noise in open and enclosed waters show differences in spectral characteristics, particularly at frequencies below a few hundred hertz. This paper compares measurements in Woronora Dam, a freshwater reservoir south of Sydney, with those from the partly enclosed waters of Spencer Gulf and with measurements in the open ocean. It also discusses possible reasons for the differences and the insights these give to mechanisms of sound generation by breaking waves. The lowest measured noise levels in Woronora Dam were well below those usually measured at sea. Very low frequency noise caused by a non-linear effect of surface wave interaction peaked at higher frequencies than at sea, consistent with the higher frequency peak in the surface wave spectrum. Noise from breaking waves at frequencies above 100 Hz showed a similar dependence on wind speed as observed at sea for locally measured wind speeds, but levels were much lower for the same wind speeds and did not show the low frequency (below a few hundred hertz) component evident at sea.

56 **Icebergs and storms in the Southern Ocean as sources of low frequency noise along Australian southern coasts**

Zhang, Zhi Yong (1); Gavrilov, Alexander (2)
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(2) Centre for Marine Science & Technology, Curtin University, Perth, Western Australia

ABSTRACT
Owing to the cold waters south of the Antarctic Circumpolar Current, sound from sources near the ocean surface can efficiently couple into the sound channel and be ducted northwards to far distances. Recent research has shown ice-breaking and iceberg calving in Antarctica and the Southern Ocean as significant contributors to low frequency noise in the south Indian, Atlantic and Pacific Oceans. The Southern Ocean is also well known for its strong westerly winds (known by sailors as the "furious fifties" and "screaming sixties") due to the combination of air flow from the Equator towards the South Pole, the Earth's rotation, and the scarcity of landmasses to serve as windbreaks. It was suggested 30 years ago that strong winds in the Southern Ocean were the distant sources of low-frequency noise observed in the deep temperate oceans at low latitudes. In this paper, we examine the characteristics of low-frequency ocean noise recorded off Australian coasts and their relationship with ice-breaking and winds in the Southern Ocean. Significant correlation was found between the low frequency noise levels and wind speeds south of the Antarctic polar front for some but not all situations. Whilst more comprehensive analysis is needed to draw definite conclusions, wind storms in the Southern Ocean may contribute to the low frequency noise floor observed at sites off Australian coasts where the sound propagation path from Antarctica is not blocked by land or shallow seabeds.

Plenary: Professor Jian Kang

11 **Urban sound planning – a soundscape approach**

Kang, Jian
UCL Institute for Environmental Design and Engineering, The Bartlett, University College London, United Kingdom

ABSTRACT
In the field of environmental acoustics, the conventional approach, i.e. reduction of 'sound level', does not always deliver the required improvements in quality of life. Soundscape, by considering sound environment as perceived, in context, with an interdisciplinary approach, represents a step change. This paper explores a soundscape approach in the urban sound planning process. A framework is first proposed for designing soundscape in urban open public spaces, considering four key components: characteristics of each sound source, acoustic effects of the space, social/demographic aspect of the users, and other physical conditions. Consequently, the design potentials for the four key components, namely sounds, space, people and environment, are demonstrated. Designing/planning tools/models for soundscapes are then presented, including an auralisation software package for design modification and public participation, and an artificial neural network model for predicting acoustic comfort based on various design variables. Finally, the potentials and scope of soundscape approach are discussed, in terms of increasing safety, cultural preservation, and management of the various noise sources such as delivery sounds and traffic sounds.

Keynote: Adjunct Professor John Davy

4 **Structural connections and the sound insulation of cavity walls and double glazing**

Davy, John Laurence
RMIT University & CSIRO, Victoria, Australia

ABSTRACT
Structural connections between the wall leaves of double leaf cavity walls can reduce the sound insulation of the wall. Structural connections, which are rigid enough, can move the mass-air-mass resonant frequency to a higher frequency and decrease the sound insulation of the wall in the important low frequency region. At mid and high frequencies, the sound insulation of large air gap double glazed windows is controlled by vibration transmission between the two glass panes via the window frame. This problem can be partially overcome by using primary and secondary glazing rather than sealed double glazed units.

D2-AM2-S1: Transportation noise 2 - Aircraft noise

65 **Citywide noise mapping for ANEF Contours**

Hinze, Byenjamin (1); Tsakiris, Janos (1); Zhao, Jessica (1); Tang, Wei (1)
(1) Ambient Maps Pty Ltd, Brisbane, Australia

ABSTRACT
Aircraft Noise Exposure Forecast (ANEF) contour maps are typically developed for major airports only. It is uncommon for such maps to be developed for smaller metropolitan airports, regional airports and aerodromes. Furthermore, flight paths that are outside the vicinity of airports are not generally considered when developing the noise models used to generate ANEF contours. It was suspected that the aircraft noise exposure levels around smaller metropolitan airports, regional airports and aerodromes, as well as metropolitan areas away from major airports, may be comparable to those documented in the published ANEF contours for the major airports, albeit with a smaller footprint. To investigate this, we acquired data for aircraft movements across Australia and New Zealand during May and June 2019, as captured by a flight tracker provider. This data, sampled at 15 second intervals, captured the plane type, altitude, speed and other parameters used to develop aircraft noise models for Australia and New Zealand using SoundPLAN, with all flights modelled as moving point sources. Greater Melbourne is nominated for our study comparison.

42 **Assessing the environmental impacts of aircraft noise**

Moyo, Clyton (1); Latimore, Mark (1); Fenner, Belinda (1); Zissermann, Paul (1)
(1) Environment and Community Branch, Air Navigation Services Group, Airservices Australia, Canberra, Australia

ABSTRACT
Aircraft noise is one of the most community-recognised environmental effects of aviation, with the potential to cause community annoyance and adverse effects on health. Airservices is required under the Commonwealth Environmental Protection and Biodiversity Conservation (EPBC) Act to assess the potential environmental significance of any 'actions' it takes including changes to air traffic management (ATM) practices. However, the EPBC Act does not prescribe any thresholds for potential environmental significance in relation to aircraft noise. Consequently, Airservices has developed its own internal criteria for the environmental impact assessment of proposed changes to aircraft operations, in order to determine if these impacts will be potentially significant (within the meaning of the EPBC Act) and if they will be potentially noticeable to local communities. The purpose of the criteria is to prescribe a standardised environmental impact assessment process for all changes to aircraft operations implemented by Airservices, and to inform Airservices community engagement process. This paper describes in detail Airservices current criteria for environmental significance in relation to proposed ATM changes.

41 **Competing considerations for aircraft noise monitor placements**

Fenner, Belinda (1); Latimore, Mark (1); Moyo, Clyton (1); Zissermann, Paul (1)
(1) Environment and Community Branch, Air Navigation Services Group, Airservices Australia, Canberra, Australia

ABSTRACT
Airservices Australia has one of the most geographically spread aircraft noise monitoring networks in the world, with over 40 long-term noise monitors installed at eight major airports across the country. In Australia, aircraft noise monitoring is conducted to meet a number of objectives, including provision of information to the com-munity, determining impacts from procedures and trials, or validating noise modelling results. Ministerial Direction M37/99 (Cth) requires Airservices to install, maintain and operate noise and flight path monitoring systems at major Australian airports. There is often community confusion around the objectives of Airservices aircraft noise monitoring system, with a perception that this system has a compliance and enforcement function in relation to aircraft noise. This affects the community's perception of the role of aircraft noise monitors and where they should be placed. When installing long-term noise monitors, Airservices has to consider a range of factors, including compliance with international standards, Airservices corporate objectives, the specific purpose of the individual noise monitor placement, and community perspectives. This paper discusses the dynamics and interplay of these factors in Airservices decision-making process for long-term noise monitor placements.

20 **Experimental investigation of contra-rotating multi-rotor UAV propeller noise**

McKay, Ryan (1); Kingan, Michael (1); Go, Robin (2)
(1) Department of Mechanical Engineering, University of Auckland, New Zealand
(2) Dotterel Technologies, Auckland, New Zealand

ABSTRACT
Unmanned aerial systems (UASs) are an increasingly popular technology with a rapidly expanding range of uses. Contra-rotating propellers are used as propulsors on some multi-rotor unmanned aerial vehicles (UAV). Contra-rotating propellers have the benefit of reducing the UAV's plan size and adding redundancy in case of component failure. However, contra-rotating propellers are notoriously noisy in other applications, but the noise from contra-rotating multi-rotor UAVs has not been studied. This paper presents results from an experimental investigation of a single static contra-rotating propeller mounted in an anechoic chamber. The effect of propeller diameter, propeller spacing, and blade number were investigated. The rotational speed of the upstream and downstream propellers was varied over a large range to generate a data set containing noise and efficiency measurements at many different operating points.

71 **Benchmarking a quasi-steady method for predicting propeller unsteady loads**

Howell, Richard (1,2); Dylejko, Paul (1); Croaker, Paul (1,3); Skvortsov, Alex (1)
(1) Maritime Division, Defence Science & Technology Group, Melbourne, Victoria, Australia
(2) YTEK Pty, Ashburton, Victoria, Australia
(3) School of Mechanical Engineering, University of New South Wales, Sydney, Australia

ABSTRACT
Aircraft and ships suffer from unwanted noise and vibration due to propeller unsteady loads. When trying to achieve low levels of propeller noise and vibration during design, the designer must balance these against often conflicting goals such as required thrust and fatigue strength. During trade-off studies, there is value in having a range of validated modelling tools that can be used over a range of timescales with different levels of fidelity. Simplified physics-based models are often useful because they allow for a large investigation of the parameter design-space and they can also provide insights into what are the most important in-flow characteristics and design parameters. This paper brings together a range of simplified techniques that assume a quasi-steady state, to assess the tonal unsteady propeller loads resulting from an ingested non-uniform wake. As a first step in validating this approach, predicted results are compared against previously published experimental measurements of two model propellers at the David Taylor Research Centre (DTRC). Results show that under the right conditions, this approach can give good predictions. The instances where the methodology does not predict the response well are also demonstrated.

D2-AM2-S2: Building acoustics & vibration

16 The effects of mass-air-mass resonance on the Rw + Ctr performance of wall systems

Pirozek, Peter
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ABSTRACT
In Australia, the Building Code minimum requirement for inter-tenancy walls between dwellings is expressed in terms of "$R_w + C_{tr}$ not less than 50" for airborne noise (BCA, 2019). Inter-tenancy walls come in a range of configurations, including lightweight plasterboard wall systems (with timber or steel studs), pre-cast concrete walls, concrete block walls (core-filled and unfilled), Autoclaved Aerated Concrete (AAC) panels and brick walls. In these latter wall systems, the walls are generally finished with a layer of plasterboard on both sides, either direct (daub) fixed, fixed on furring channels or on a separate stud. This paper presents some laboratory test results conducted by USG Boral on AAC block and core-filled light-weight masonry block wall systems. The results are analysed in terms of the effect of the Mass-Air-Mass resonance on the $R_w + C_{tr}$ of the wall system. Injudicious / poor / unlucky choice of air cavities and plasterboard weight can result in Mass-Air-Mass resonances that can significantly reduce the $R_w + C_{tr}$ performance of the wall system, so that even though additional weight is added to the wall system it never-the-less reduces the $R_w + C_{tr}$ value.

97 Mass-air-mass resonance cavity suppression using Helmholtz resonators

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ABSTRACT
Densification of housing is leading to the construction of more medium-rise, multi-tenancy buildings. In order to minimise material and building cost but achieve the required structural performance, it is attractive to use lightweight construction methods based on materials such as plasterboard and light timber framing (LTF). LTF construction is traditional in NZ but where it is used for inter-tenancy walls in medium and high density housing we are finding that transmission of noise between dwellings is becoming a major problem. In this exploratory research project we report on initial encouraging results of using Helmholtz Resonators (HR) to reduce the loss of insulation in lightweight cavity walls in the region of the mass-air-mass (M-A-M) resonance. This resonance results from the two wall leaves enclosing an air spring on which they can resonate. Often the wall insulation in this critical low frequency band is significantly poorer than if it were only a single leaf wall. Such walls, although meeting code requirements, can be subjectively undesirable when insulating against sounds from low frequency loudspeakers which are a ubiquitous feature of modern living. So far the work has comprised using 3D printed HRs tuned to the M-A-M resonance and coupled into an experimental cavity to demonstrate proof of principle.

101 Acoustics behaviour of CLT structure: transmission loss, impact noise insulation and flanking transmission evaluations

Loriggiola, Fabrio (1); Dall'Acqua d'Industria, Luca (presenter, 1); Granzotto, Nicola (2) ; Di Bella, Antonino (2)
(1) Isolgomma SRL, Albettone, Italy
(2) University of Padua, Italy

ABSTRACT
Design and construction of CLT structures is now known throughout the world thanks to its known properties, its high thermal resistance to low energy consumption and its low environmental impact. For these reasons, the studies and research on the acoustic performance analysis of these wood panels have also been very successful in recent years. This document aims to present the continuation of the investigative work carried out by Isolgomma on CLT structures, completing the study on the acoustic behaviour of floors with wall and flanking transmission analysis. Therefore, the results of the laboratory acoustic characterization of the CLT walls are presented with the application of different techniques for improving the possible performances, according to the standards of the ISO 10140 series. Furthermore, the considerations related to the study carried out on the joints of the structures are reported. CLT on a large-scale test configuration, according to the standards of the ISO 10848 series. Through this analysis it was possible to obtain the vibration reduction indices both of the bare CLT structure and of the isolated structure through the insertion of a specific anti-vibration rubber mat.

27 Effectiveness of the rubber ball compared to the tapping machine as the impact source to measure the impact sound insulation properties

Polwaththe Gallage, Hasitha Nayanajith (1); Palmer, Ross (1); Eric, Huang (1); Roger, Hawkins (1)
(1) Palmer Acoustics (Australia) Queensland

ABSTRACT
ISO 16283-2: 2015(E) describes how a standardised tapping machine and a rubber ball are used as impact sources to determine floor impact sound insulation. These standard impact sources do not exactly replicate all the possible types of real floor impacts. According to the ISO 16283-2: 2015(E), the tapping machine is effective to asses a variety of light, hard impacts such as footsteps from walkers wearing hard-heeled footwear, while the rubber ball is more effective to assess heavy, soft impacts such as from walkers in bare feet or children jumping. However, only the standard tapping machine approach is used to measure the impact sound insulation proper-ties of building floors in Australia. This paper explores the effectiveness of the rubber ball compared to the tap-ping machine as the impact source. In this study, the floor impact sound pressure levels were measured in the receiving room with different types of impact sources; standard tapping machine, rubber ball, human walking, running and jumping on different types of floors; timber, tile, vinyl and hybrid. The results show that rubber ball more closely replicates the impact sounds produced by the human activities such as from walking, jumping and running. Moreover, it is evident that when the building floor is a tile floor, a tapping machine produces higher sound pressure levels at higher frequencies than either hard-heeled or heavy/soft impacts.

9 **A practical approach to building isolation**

Valerio, Douglas G.
Mason Industries, Inc., New York, USA

ABSTRACT
As a result of worldwide acoustical consultant specifications, entire buildings have been isolated for over 60 years. Base Building Isolation has its merits, turning marginal properties (based on their proximity to rail systems) into multipurpose high-end developments free of vibration and re-radiated noise. This discussion will focus on Low Dynamic Stiffness (LDS) Structural Isolation Bearing Pads and the relationship between the acoustician, design team and manufacturer and focus on installation and construction. The acoustician, design team and manufacturer are more than capable of measuring, designing, detailing and complying with building codes to establish the proper natural frequency of support and the design criteria for construction. It is during construction when the acoustical integrity of the structure is most fragile, where the resulting vibration reduction is compromised by unforeseen short-circuiting of the isolation system, which is a function of location and the ability to inspect the isolation plane. This discussion will also focus on existing projects and understanding that the complications of any Base Isolation project are educating the contractors, being on site, and being vigilant about identifying and mitigating short circuiting before substantial completion. The intent is to identify common concerns and offer practical solutions to typical problems.

D2-AM2-S3: Underwater acoustics 4

102 **Investigation of underwater hull radiation due to machine noise**

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(2) Centre for Marine Science and Technology, Curtin University, Perth, Western Australia

ABSTRACT
This paper presents the preliminary modelling and analysis of noise radiation due to the operation of machines in a compartment of an underwater vessel. The underwater vessel is modelled as a submerged cylindrical enclosure with ring stiffeners and two bulkheads. The compartment considered is between the two bulkheads. To simulate the structure-borne and airborne noise transmission and radiation, the machine noise is characterised by forces applied along the compartment in three directions and by acoustic sources located inside of the compartment. Two analytical models and three numerical models are developed. The structural and acoustic responses of the models are analysed. For a benchmark example case, the analytical and numerical results are compared with the experimental data measured in a lake.

5 **Low-frequency underwater acoustics sensitivity calibration in a chamber**

Li Peng (1,2); Yin Yilong(2)
(1) University of Chinese Academy of Sciences
(2) Institute of Acoustics, Chinese Academy of Sciences

ABSTRACT
The primary calibration of the low frequency hydrophone in an enclosed volume (chamber) using the comparison principle is proposed. Simulated results using the element program is presented, using the transducer as a projector and the hydrophones as receiver. An experimental test with 14 points in the circumferential direction of the closed cavity, and three positions taken in the depth direction (totally including 42 test positions) was carried out to measure the magnitude of the open-circuit voltage at a number of frequencies between 5 Hz and 1 kHz. The sound pressure field is evenly homogeneous and the sound pressure non-uniformity is quantified to be less than 0.5dB within the tested region, demonstrating the accuracy of the sensitivity calibration system.

39 **The sounds of electric ferries**

Parsons, Miles James (1,2); Parsons, Sylvia Karin (2); Duncan, Alec (2); Erbe, Christine (2)
(1) Australian Institute of Marine Science, Perth, Western Australia
(2) Centre for Marine Science and Technology, Curtin University, Perth, Western Australia

ABSTRACT
Biological and anthropogenic sounds can dominate estuarine and riverine soundscapes, with the latter often impacting the presence and behaviour of the former. As a result, to reduce anthropogenic noise, there is an increasing push to use alternative methods of propulsion, such as electric powered vessels, once more com-mon in their golden age (roughly 1880-1920) before petrol- and diesel-powered motors became dominant. Two 10-m solar-electric vessels operated in the Swan River, Western Australia, provide one example of this alternative. Here, passive acoustic sensor moorings were deployed to the riverbed, to map the local soundscapes, including sounds of passing vessels. At two sites, a 100-m wide passage north of Heirisson Island, Perth, and a broader area to the island's east, numerous vessels were recorded passing near or directly above an Ocean Instruments' ST300STD SoundTraps. The electric ferries displayed significantly lower acoustic energy, particularly in lower frequencies, compared with petrol and diesel-powered vessels.

Keynote: Dr Kym Burgemeister

70 **Acoustic design for the Melbourne Metro Tunnel project**

Burgemeister, Kym (1); Digerness, Joseph (2); Fong, Ken-Yi (1); Setton, Philip (3); Thompson, Derek (3)
(1) Arup, Melbourne, Australia
(2) Arup, New York, USA
(3) WSP, Melbourne, Australia

ABSTRACT
The Melbourne Metro Tunnel Project is currently under construction, and is one of Australia's largest public infrastructure projects with a project value of over $11 billion. It includes 5 major new underground railway stations, and a pair of 9-kilometre single-track tunnels running underneath Melbourne's inner-north-west suburbs, CBD, and inner south-east suburbs. The tunnel alignment is near to a range of sensitive residential and commercial receivers and particularly sensitive medical and research precincts in Parkville and at RMIT. The acoustics, noise and vibration

engineering is being undertaken by a team of 10 engineers (Arcadis Arup WSP JV) and includes 5 key areas of work: design of tunnel acoustic treatments for control of in-carriage noise, vibroacoustic design to control ground-borne noise and vibration affecting sensitive receivers, station acoustic design, noise control for fixed station infrastructure, and construction noise and vibration management. This paper provides an overview of these key aspects of the acoustic design for the project, and provides an in-sight into the key design challenges and design approaches adopted by the acoustic engineering team, as well as the practical aspects of working on a large infrastructure project with multiple stakeholders and approval routes.

D2-PM1-S1: Transportation noise 3 - Railway noise & vibration

68 The effect of Track Decay Rate on in-carriage noise for resilient track fixings

Setton, Philip (1); Burgemeister, Kym (2); Digerness, Joseph (3); Fong, Ken-Yi (2); Wedd, Nick (2)
(1) WSP, Melbourne, Australia
(2) Arup, Melbourne, Australia
(3) Arup, New York, USA

ABSTRACT
The Track Decay Rate (TDR) of a railway track is a key factor influencing wayside and in-carriage railway noise, particularly in tunnel environments. Highly-resilient track fixing systems are commonly used in tunnels to mitigate ground-borne noise and vibration (GBNV), but also result in low TDRs, and increased noise radiation from the rail component of the wheel-rail interface. Toward & Thompson (2012) indicate that the change in noise emission for different track fixing systems is proportional to the logarithm of the ratio of TDRs. This relationship suggests a large increase in noise emission for typical soft rail fixings, when compared to ballasted track. Measurements of TDR of tracks with a range of fixing systems (ballasted, slab-track with resilient fixings, and floating-slab-track) have been undertaken according to DIN EN15461:2008 as part of the in-carriage noise predictions for a new railway tunnel in Australia. The TDR corrections are validated against measurements of in-carriage noise undertaken on the same network and show that current assumptions are overly conservative. Reasons for these differences are discussed, and alternative methodologies are proposed to predict in-carriage noise for trains on resilient track fixings in tunnel environments.

78 Ground-borne noise & vibration propagation measurements and prediction validations from a railway tunnel project

Karantonis, Peter (1); Weber, Conrad (1); Hayden, Puckeridge (1)
(1) Renzo Tonin & Associates (NSW) Pty Ltd, Surry Hills, New South Wales, Australia

ABSTRACT
On projects where there is limited or only high-level information relating to how vibration propagates between an underground rail tunnel and receivers inside buildings, the uncertainty associated with ground-borne noise and vibration predictions can be large and therefore large prediction safety factors (engineering margins) are often used. During the detailed design stages of projects, such large safety factors can be costly in terms of the required mitigation measures. On a recent underground railway tunnel project, a quantitative approach was applied with the aim of improving estimates of the combined coupling loss and amplification for typical buildings types and the conversion of vibration into noise inside buildings, to better advise the design team of the level of design risk associated with predictions. Field tests were conducted to measure the vibration propagation of a hydraulic hammer operating inside partly constructed railway tunnels, to the outside and inside of buildings above the tunnels, with the aim of improving estimates of coupling loss and amplification factors and the conversion of vibration into noise inside buildings. Field measurements were used to reduce the uncertainty associated with this aspect of ground-borne noise and vibration predictions, and to ultimately inform the rail track design.

8 Curving noise from the Western Australian freight rail network: wayside monitoring and mechanism analysis

Li, Binghui (1); Zoontjens, Luke (presenter, 1)
(1) SLR Consulting Australia Pty Ltd, Perth, Western Australia

ABSTRACT
Curving noise from freight rail movements in the Perth metropolitan area have been investigated using Transport for New South Wales (TfNSW)'s Wayside Noise Monitoring System (WNMS) at a test location (Site A) with an approximately 400-m radius rail curve section. The trackside noise, rail vibration and wheelset position and steering angle as measured by the WNMS kit have been analysed in detail alongside supporting measurements of environmental noise and vibration. The predominant mechanisms for curving noise have been further analysed and identified. The correlation between high curving noise events and rolling stock types has also been investigated, followed by discussions on possible effective at-source noise control measures. This study found that on the basis of monitoring data being consistent with previous research elsewhere, the principle mechanisms of curving noise at the test location are most likely steering-controlled.

62 Comparison of rail noise modelling with CadnaA and SoundPLAN

Puckeridge, Hayden (1); Braunstein, Timothy (1); Conrad, Weber (1)
(1) Renzo Tonin & Associates (NSW) Pty Ltd, Surry Hills, New South Wales, Australia

ABSTRACT
Railway noise in Australia is commonly modelled using the SoundPLAN software package and the Kilde Report 130 calculation methodology. This paper investigates an alternative approach for rail noise modelling using the CadnaA software package and the more recent Nordic Prediction Method 1996. When modelling changes in source noise levels in CadnaA, it is necessary to create separate rail objects for each change. Modelling situations with source corrections due to changing train speeds, curves and track corrections requires different approaches. Processes for modelling rail noise in CadnaA are developed in this paper and the results compared to noise levels calculated using SoundPLAN and Kilde Rep 130. The comparison between the two models demonstrates that CadnaA produces results that are in close agreement with a SoundPLAN - Kilde Rep 130 model. It was found that in some situations CadnaA is capable

of modelling noise levels more accurately than SoundPLAN.

D2-PM1-S2: Room acoustics 1 - Design & methods

33 Ray-tracing computer-aided-design tools in auditoria design – past and future

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(2) Marshall Day Acoustics Pty Ltd, Collingwood, Victoria, Australia

ABSTRACT
How to give an audience the best experience of a performance, including the best acoustic and sightline conditions, has always been one of the most important aspects of auditoria design. Ray-tracing techniques have been used in both acoustic and visual design, taking advantage of the ray-like transmission of sound and light. The methods initially developed from 2D manual ray tracing, with paper and pen, to 3D computer-aided software such as Odeon and CATT. Recent 3D ray tracing implementation using Grasshopper in Rhino allows reflection coverage and sightline condition analysis to be carried out with real-time manipulation and feedback. These tools continue to become easier to use and also provide more accurate results. The development of these tools, along with the increasing speed of computer processors, enables a more user interactive approach to design and iterative development of an optimized outcome. In rooms as acoustically and architecturally complex as music auditoria, it allows for true collaborative development of the physical room characteristics by the design team, with the acoustics and other functional characteristics considered since the early design stage. In the near future these tools will be extended, for example, to combine ray-tracing tools with a virtual reality design environment, or to automatically optimize the design with parametric design tools, to achieve the best acoustic and visual results. This paper follows the history of ray tracing and takes a glimpse at what lies ahead.

43 Improving shape design of auditoriums with real-time feedback based on parametric modelling, simulation and machine learning

Wang, Chunxiao (1); Lu, Shuai (presenter, 1)
(1) Shenzhen University, China

ABSTRACT
Auditoriums require both acoustic performance and aesthetic values, while the efficiency of current design process should be improved for architects to better realize these two goals. In this paper, a new design process of auditoriums integrating parametric modelling, acoustic simulation and Support Vector Machine is proposed, implemented and verified to provide architects with real-time architectural and acoustic feedback in the early design stage. This paper contains three parts: 1) a parametric model of auditoriums that can generate various auditorium designs automatically; 2) an interface connecting modelling and acoustic simulation software, which facilitate architects' acoustic evaluations on auditorium designs; 3) an acoustic aiding tool that provides architects with suggestions on design revision. The results indicate that the new design process and relevant design tools can provide reliable outcomes within 1 min for most cases. Moreover, it enables architects to revise an acoustically unacceptable shape into a desirable one independently. Thus architects' efforts in attempting infeasible design ideas could be largely saved, and desirable designs are more likely to be achieved.

76 Lateral reflections in the Sydney Town Hall; preservation of room acoustics in a historically significant venue

Ottley, Matthew
Marshall Day Acoustics, Sydney, Australia

ABSTRACT
Sydney Town Hall was constructed in the late 19th Century and is of heritage significance. The main hall, known as Centennial Hall, is a traditional 'shoebox' hall and features one of the largest pipe organs in the world, the 1890 'Grand Organ'. The acoustics of the space are held in high regard and the space was the home of the Sydney Symphony Orchestra prior to construction of the Sydney Opera House. In the 1970's two side boxes (small rooms within the space) were installed at ground level in Centennial Hall in order to narrow the hall and provide increased lateral reflections from musicians on the stage to audiences in the Eastern Gallery (the seating section at rear of the hall on first floor level). In 2018 a proposal was explored to remove the two side boxes, primarily in order to increase seating capacity of the venue. This paper details the acoustic investigation carried out to determine the likely effect the removal of these boxes will have on the acoustics of the space, particularly with regards to reflections via the boxes to the Eastern Gallery. The assessment included measurement of the 3D reflection sequence from various stage positions to various seating positions, as well as 3D acoustic modelling of the venue, with and without the side boxes. The proposal raises questions regarding the value and protections available to the acoustics of rooms with heritage significance.

73 Using acoustic cameras with 3D modelling to visualise room reflections

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(1) WSP Australia, Melbourne, Australia

ABSTRACT
Advances in beam-forming microphone array (acoustic camera) technology has made acoustic cameras more accessible for use within acoustic consultancy. Recently we had the opportunity to use acoustic cameras in conjunction with 3D room scanning to investigate acoustic conditions in an orchestra rehearsal studio. The acoustic camera data was used to assist in visualising the frequency response, reflection patterns and overall reverberant response within the room and as an aid for tuning room elements such as ceiling reflector panels. This paper describes the process of using acoustic cameras in conjunction with 3D room scanning and CAD modelling to visualise room reflections for acoustic analysis. It will also discuss the potential of related technology, such as the use of 3D modelling and the potential for interactive visualisations using virtual reality (VR) tools.

D2-PM1-S3: Signal processing

21 2D tomographic imaging of active sonar echoes using a non-uniform FFT technique

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(1) Maritime Division, Defence Science & Technology Group, Edinburg, South Australia
(2) Intelligence, Surveillance and Space Division, Defence Science & Technology Group, Edinburgh, South Australia

ABSTRACT
Two-dimensional (2D) sonar tomography is a technique used to obtain 2D images of underwater objects using a sequence of one-dimensional projections of the objects and a form of the so-called Back-Projection Algorithm (BPA). Two of the more popular approaches are the Polar-Coordinate BPA and the Rectangular-Coordinate BPA. In this paper we propose to use the 2D Non-Uniform Fast Fourier Transform (NUFFT) in a new form of the BPA to image underwater objects using sonar echoes. As usual for tomographic techniques, imaging performance is determined by the availability of sufficiently high-resolution projections and aspect coverage of the object. We demonstrate that the image inversion step based on the novel NUFFT can significantly improve imaging performance of sonar tomography in terms of image resolution, contrast and computational cost, in comparison to the two common approaches. The system requirements and data preparation are also discussed.

30 Use of robust Capon beamformer for extracting audio signals

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(1) Department of Mechanical Engineering, University of Western Australia
(2) Defence Science & Technology Group, Australia

ABSTRACT
The need to extract a single audio signal of interest from a multi-source and noisy environment is common across many disciplines. Use of sensor arrays with adaptive beamforming is a preferred approach for obtaining high quality audio signals in many applications. One of such applications is applying the microphone array technology to extract signals of interest for the purpose of condition monitoring in an industrial site. In that work, we employed a so called Robust Capon Beamformer (RCB) to perform the signal extraction. The adaptive algorithm in RCB was originally developed to deal with the uncertainty existing in the signal model. This uncertainty is also known as signal mismatch. There is an important parameter called the error allowance in the algorithm to regulate the robustness of the beamformer. For an application of signal direction of arrival or localization, which RCB was originally proposed for, the appropriate value of the error allowance is purely defined by anticipated errors in steering vectors. For an application of audio signal extraction, however, the appropriate value of the error allowance has been found to be related also to other factors in the system, such as signal to noise ratio, signal direction of arrival, and the distance between the source and the array. In this paper, we examine the influence of those factors to the appropriate value of the error allowance in the context of machinery condition monitoring through numerical simulation, and provide an empirical formula for choosing the appropriate value of the error allowance in that context.

32 Cepstral coefficient feature extraction for active sonar classification

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ABSTRACT
The effectiveness of acoustic classification is highly dependent on the features that can be extracted from a given signal. It is possible to employ a range of features simultaneously during classification to improve accuracy and redundancy, though certain features can degrade performance when used together. Mel Frequency Cepstral Coefficient (MFCC) and Linear Predictive Cepstral Coefficient (LPCC) algorithms provide a method for acoustic feature extraction through the processing of the short term power spectrum of a signal. Features generated using these coefficients may enhance classification performance in active sonar applications due to their robustness against background noise in low frequency bandwidths (20-2000Hz). This paper discusses the integration of these features into the Binary Classification Research Tool (BCRT); a research tool for the testing of feature and classifier performance. The analysis examines their compatibility with established feature sets as well as their overall potential in the area of sonar classification. Through testing on a range of underwater signals, MFCC features were found to have strong isolated performance and to increase classification accuracy when combined with established feature sets. LPCC features had a poor performance in isolation but achieved the highest classification accuracy when combined with other feature sets.

40 Use of a deep convolutional neural network and beamforming for localisation and diagnosis of industry noise sources

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ABSTRACT
Many industries rely on the continual and unimpeded operation of turbines, pumps, pulleys, fans, motors, gearboxes, and other associated fixed and mobile plant equipment. As such, reliable and remote condition monitoring and fault localisation can improve safety, prevent unnecessary downtime and reduce maintenance costs. Current methods of condition monitoring such as acoustic emissions (AE) testing can prove difficult to automate and require careful analysis by a trained analyst. This research investigates the use of adaptive beamforming for source localisation and signal extraction in conjunction with a convolutional neural network classification system based on spectrogram plots. Furthermore, it tests the effects of reducing the number of microphones in the microphone array on the deep network classification accuracy. This technology has been investigated with the use of 12-volt computer fans as an analogue for rotating machinery, with the primary challenge of reliably separating and classifying the unique spectral signal of each fan. The outcome of this research from over 450 test samples demonstrates damage detection accuracy consistently above 97% based on available data when adequate beamforming resolution and array gain

are achieved. This technology shows promise for use in an automated monitoring system for industrial applications, with available scope for further refinements.

D2-PM2-S1: Wind turbine noise

66 **Comparison between perceptual responses to traffic noise and wind farm noise in a non-focused listening test**

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ABSTRACT
Despite the clear benefits of renewable energy, the rapid expansion of wind energy has resulted in widespread community complaints regarding wind farm noise (WFN). As the impact of WFN on sleep and health is not well established, road traffic noise (RTN), with well-known sleep disturbance effects, is likely to be a useful environmental noise comparator. This study investigated the self-reported annoyance to short- and long-range WFN and RTN via a non-focused listening test. Twenty-five participants from a WFN-naïve sample population took part in the listening test. A total of six stimuli were presented in random order for 10-min each, while participants were engaged in a reading task. Five WFN and RTN stimuli were presented at a sound pressure level (SPL) of 33 dB(A) for comparison with the sixth 'no noise' background control stimulus, which had an SPL of 23 dB(A). After each stimulus, participants responded to questions regarding annoyance, awareness, acceptability for sleep and loudness. Participants were also instructed to order the samples from the least to the most annoying. Short- and long-range WFN and short-range RTN were consistently rated as the most annoying ac-cording to sample ordering. There were significant differences between subjective responses to noise samples versus the 'no noise' control, however, no significant differences in subjective reports toward specific noise samples.

80 **Wind farm infrasound detectability and its effects on the perception of wind farm noise amplitude modulation**

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ABSTRACT
Some residents attribute adverse effects to the presence of wind farm (WF) infrasound. However, dominant features of windfarm noise such as infrasound, tonality and amplitude modulation span the average human hearing threshold, so attribution to infrasound is problematic. This study used a combination of pre-recorded noise stimuli, measured at 3.2 km from a wind farm, in laboratory-based listening tests to investigate human perception of infrasound and amplitude modulation at realistic sound pressure levels in a group of 14 participants. Although a small sample size warrants cautious interpretation, preliminary results suggest differential effects between self-reported non-sensitive versus noise-sensitive participants, where the latter detected infrasound above chance. Infrasound did not affect the perception of amplitude modulation. Larger studies remain needed to clarify these findings.

D2-PM2-S2: Room acoustics 2 - materials

75 **20 years of micro-perforated (transparent) sound absorbers**

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ABSTRACT
In 1975 the theory of microperforated sound absorbers was introduced by D.-Y. Maa. The first optically transparent sound absorbers have been applied in the late 1990s. In 2000 a nearly invisible micro-perforation was introduced to transparent sheets making these highly sound absorptive. Over the twenty years different set-ups made of micro-perforated layers, porous materials as well as plate resonators have been investigated. In this contribution applications of various set-ups with micro-perforated stretched foils will be presented. Applications in different spaces will be shown. Day-light ceilings, mirror ceilings as well as absorbers in front of glass will be shown.

12 **Walk-through auralization framework for virtual reality environments powered by game engine architectures, Part II**

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ABSTRACT
This paper aims to present a Virtual Reality (VR) Acoustic application that allows a user to experience the effect of changing the acoustic properties of surface materials in a room, while freely moving in a VR scenario. In a previously issued paper (Part I), the background and description of the software were presented in detail. While a brief introduction is also described in this paper, the focus of this work is to compare a real case study of an existing classroom with the same simulated room in VR. A comparison between the Ambisonics Room Impulse Response (ARIR) measurements and 3D simulated ARIRs using CATT is presented, while providing an overview of the potential use for such application. In addition to the integration of the VR acoustic application in Unity3D, a link to an online video to provide a subjective listening experience of the same room is also shared.

D3-AM1-S1: Cognition & indoor environment

69 **Co-teaching in (refurbished) flexible learning spaces: Promoting quality acoustics for learning and collaboration**

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ABSTRACT
The modern learning environment revolution is well underway. Government investment in new and refurbished educational spaces is at an all-time high, but how are we equipping teachers with the necessary skills to use these spaces? In particular, how can teachers manage the commonly stated challenge of 'noise', especially in refurbished innovative learning spaces that are often configured according to pragmatic factors that do not include consideration for acoustics. Co-teaching in flexible learning environments is being encouraged, but good acoustic design and effective pedagogy and organisation are essential to allow this contemporary educational approach to prosper. This cross-disciplinary paper, co-written by an acoustical engineer and education researchers, explores the new spaces from the teacher's perspective, including how they perceive the acoustic environment. This research project goes beyond just the physical acoustic conditions of the space - it also provides evidence about how teachers' practices in pedagogy and classroom organisation can be positively informed through knowledge of acoustics, and the ways in which this can enable teachers to more effectively use the innovative learning space to support student learning and engagement.

87 **Learned helplessness: effect on future performance from noise and negative past performance.**

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ABSTRACT
Learned helplessness can occur when individuals learn that their behaviour is independent of a situation and hence this leads to an effect on future behaviour. This study examined if it was possible for noise, similar to workplace noise, to induce learned helplessness. The findings highlight the complex interaction between noise, performance and motivation.

95 **Improving speech privacy and acoustic comfort in offices**

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(1) Soft dB Inc, Québec

ABSTRACT
Sound masking systems (SMS) were introduced in the 1970s to improve speech privacy in open plan offices by establishing a constant, controlled minimum background sound level. Today, most SMS contain timer programs. These attempt to balance the need to raise sound levels during busy periods for greater speech privacy, whilst lowering the sound level during calm periods for acoustic comfort. However, in modern offices, occupancy levels vary more unpredictably during the day, and from one day to another, reducing timer system efficiency. To address this, an Adaptive Volume Control (AVC) algorithm has been developed, which is based on real-time statistical analysis of the sound pressure level; and uses the difference between the L10% and L99% to adjust the sound level. Using measurements of 5-day noise levels in three different types of open-plan offices, this paper quantifies the variations in speech privacy and acoustic comfort efficiency resulting from different minimum background sound levels controlled by SMS that are (a) fixed-level, (b) timer-controlled, and (c) AVC-controlled. Depending on office occupancy, results demonstrate that occupant acoustical comfort was improved by up to 50% and speech privacy was improved by up to 15% compared to the timer-controlled levels.

37 **Restaurant acoustic comfort assessment methods**

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ABSTRACT
Restaurant noise, in terms of its 'comfort' for both diners and staff has been a topic of discussion for some years amongst older members of society and there are a number of technical papers on the subject. The Australian Acoustical Society (AAS) has a café and restaurant rating acoustic index (CRAI) based on a subjective ranking from 1 to 5. But an objective method of rating and assessment is preferred to allow effective comparison be-tween sites, and different methods may be available. This paper provides an objectively based rating system based on the difference between the measured sound level in a dining location and the maximum ambient sound levels required for normal speech by males and females. Other aspects of architectural acoustics, such as reverberation time, and spectral content have yet to be included but can be added if the rating develops further. The rating is from 0 to 20, with the highest rating number relating to acceptable hearing and speech com-fort. It is not intended to be a definitive work on the subject but intended to get to an improved and objective approach, which may or may not become an agreed standard method.

D3-AM1-S2: Noise control 1

3 **Analytical models of acoustic scattering by an infinite air-filled steel cylindrical shell in water under plane-wave excitation**

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ABSTRACT
When a submerged fluid-filled cylindrical shell is ensonified, both structural vibrations (affected by the internal fluid) and standing waves in the internal fluid (caused by the shell) are excited and some of their eigenfrequencies may be comparable. Results obtained using three analytical models for different aspects of scattering by an infinite shell are presented. The first model produces a spectrum of scattering due to an incident orthogonal plane-wave and exhibits all resonances. The second model predicts approximate eigenfrequencies of the structural vibrations. The third model predicts approximate eigenfrequencies of the internal standing waves. For a steel shell submerged in water, changing the shell interior from vacuum to air creates fluid modes but causes negligible difference to the structural

modes. For a shell of radius 3.25 m, the spectrum from 0 to 5000 Hz contains 18 structural resonances and approximately 3600 fluid resonances. The bandwidths of the structural resonances decrease from around 100 Hz to 3 Hz as frequency increases, while those of the fluid modes are around 1 cHz.

14 **The effect of hemispherical surface on noise suppression of a supersonic jet**

Coombs, Jesse (1); Schembri, Tyler (1); Zander, Anthony (1)
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ABSTRACT
High pressure gas venting operations, known as blowdowns, such as from natural gas pipelines, are known to produce significant noise. One device which has shown some potential for noise abatement is a hemispherical acoustic reflector, which has been observed to be effective for pressure ratios from 2 to 4. However, typical pipeline venting operations occur at pressure ratios far exceeding this. Therefore, the present study aims to experimentally investigate the influence of hemispherical noise reduction reflector on sonic jet flows at pressures more typical of pipeline venting operations. Results of experimental noise measurements from blow-downs with and without two different size acoustic reflectors are presented. The smaller acoustic reflector was found to strongly interact with the jet, in a manner making it unsuitable for extended use without a significant increase in structural support. The larger reflector showed levels of noise reduction on par with those seen at lower pressures. This suggests that acoustic reflectors of suitable scale, when appropriately structurally sup-ported, are a suitable noise reduction method for the high pressure venting typical of blowdown operations.

52 **Modelling the vibroacoustic behaviour of expansion chamber silencers for fluid-filled pipe systems**

De Candia, Steven (1); Moore, Stephen (1); MacGillivray, Ian (1); Skvortsov, Alex (1)
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ABSTRACT
Silencers for exhausts, pipe systems, and ducts often include an expansion chamber, which causes an impedance change in the pipe and transmission loss across the silencer. In pipe systems conveying a dense fluid, the elasticity of the expansion chamber wall can be an important factor affecting the vibroacoustic behaviour of the silencer. This paper describes analytical and finite-element modelling of a silencer conveying such a dense fluid. The analytical approach used a fluid-filled beam model to describe the propagation of plane waves in the fluid, the structural response of the pipe, and Poisson coupling between the fluid and the structure. The finite element model was developed with the ANSYS Mechanical solver to conduct a fully coupled fluid-structure modal and harmonic response analysis. Results demonstrated that the analytical model was sufficient for predicting the transmission loss below the cut-on of transverse modes in the fluid and circumferential modes in the pipe. A significant advantage of the finite element model was the ability to model an internal rubber lining and also to identify how out-of-plane motion of expansion chamber flanges contributed to the transmission loss of the silencer.

51 **Transmission, reflection and energy exchanges for waves in finite one-dimensional PT-symmetric periodic structures**

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ABSTRACT
Time reversibility of waves within a periodic structure constrains their properties but allows both elastic and inelastic scattering. Time reversible elastic scattering leads to Bloch-Floquet waves (BFW) exhibiting passing and stopping bands for an infinite periodic structure, and time reversible inelastic scatterers likewise exhibits passing and stopping bands but only for a particular domain of parameters. Physical realizations of time reversible inelastic scatterers have exploited parity-time (PT) symmetry with two parts, each of which is time irreversible while mirrored such that their PT combination is symmetric. The second propagation domain for inelastic scattering (called "broken" PT-symmetry) is entirely a passing band that transmits and reflects more wave energy than in the input wave. In the "broken" domain for m=2n scatterers, where n is any odd integer, amplification peaks at the same discrete wavenumbers as well-known Bragg reflections. A property of PT-symmetric scatterers at the boundary of its two domains is unidirectional "invisibility" where there are no reflections for one of the two possible incident wave directions. A PT-symmetric periodic structure is shown here to also have bidirectional "invisibility" at certain discrete wavenumbers.

D3-AM2-S1: Aeroacoustics

13 **The Influence of flexible tabs on high speed jet noise**

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ABSTRACT
Flexible tabs have been shown to be effective for noise reduction in a number of low speed aerodynamic ap-plications, including aerofoils, and cylindrical bluff bodies, both square and circular. Although regular, non-flexible tabs have been investigated for the control of high speed jet noise, the application of flexible tabs does not appear to have been investigated previously. Therefore, the influence of flexible tabs on the noise produced by high speed jets issuing from circular nozzles was experimentally investigated. Single microphone measurements of the noise from air jets at flow speeds of Mach 0.8 and 1 with 3 different configuration flexible nozzles were obtained for a range of observation angles from 90 to 150 degrees from the jet axis. These results are presented as spectra and overall sound pressure levels. For the configurations of flexible tab nozzles and observation angles investigated the flexible tabs were found to increase overall sound pressure levels in all cases.

60 **Embedded large eddy simulation method for predicting flow-induced noise**

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ABSTRACT
Prediction of flow-induced noise is of considerable interest in a range of applications. Computational fluid dynamics (CFD) using the Large Eddy Simulation (LES) approach offers the possibility of obtaining acoustic predictions directly from time-resolved pressure fluctuations. However, the application of LES in design studies remains limited by its high computational cost. One approach to reduce the cost is Embedded LES (ELES), in which LES is applied only in user-selected regions of interest which are known to dominate noise production, while applying the Reynolds-Averaged Navier Stokes (RANS) equations elsewhere. To test this concept, ELES has been implemented in the open source OpenFOAM CFD code, and the method was applied to model the trailing edge noise due to flow around a NACA0012 aerofoil. Simulations were run using ELES, with LES calculations limited to a region surrounding the trailing edge of the aerofoil. For comparison, a full LES covering the whole flow domain was also carried out, with both compared against published experimental results. For the ELES, the finite volume mesh contained approximately 13 million cells, whereas for full LES, the mesh contained approximately 40 million cells. All other modelling settings were kept the same. From the predicted pressure fluctuations, the trailing edge surface pressure and far-field pressure spectra were obtained. The results obtained using ELES were in good agreement with the full LES results at a fraction of the computational cost, thus providing a way forward for developing more affordable LES for flow noise predictions.

74 **Prediction of small-scale rotor noise using a low-fidelity-model-based framework**

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ABSTRACT
A model framework for rapid assessment of the noise generated by small-scale rotors, such as those found on small Uninhabited Aerial Systems (UAS), is presented. The acoustic signatures of two commercially available 2-blade rotors in hover conditions are considered, namely the DJI-CF 9.4x4.3 and APC-SF 11x4.7 which have a diameters 0.24 m and 0.28 m, respectively. The model framework is based mainly on semi-imperial models with limited inputs from Computational Fluid Dynamics (CFD) based solutions. Supplementing the models using CFD-based solution inputs leads to a improved acoustic signature prediction. The predicted noises of both narrow-band and broadband are compared with the experimental measurements, and the agreement is found to be reasonable.

D3-AM2-S2: Noise control 2

50 **Static insertion loss, transmission loss and noise reduction testing of an acoustic louvre**

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ABSTRACT
Previous research by the authors into the testing and performance quantification of acoustic louvres shows that while performance indicators such as static insertion loss, transmission loss and noise reduction are frequently used by louvre manufacturers, they may not accurately represent the in-situ sound insulation performance. To examine the relationship between static insertion loss, transmission loss and noise reduction, a single stage acoustic louvre has been tested in accordance with standard and non-standard test methodologies. The testing included reverberant-to-reverberant testing using a transmission loss suite; this is the most common method utilised by manufacturers for testing of acoustic louvres. Other test methodologies were chosen to replicate the typical installation of acoustic louvres and involved reverberant-to-free-field in the external wall of a reverberation chamber and at the outlet of a duct discharging into free-field conditions. The results obtained for each test methodology are compared with relevant theory and each other to determine the advantages and disadvantages of each performance indicator and test methodology. The results show that static insertion loss obtained using reverberant-to-direct testing provides the most detailed information about the sound insulation performance of an acoustic louvre.

77 **Lightweight noise barriers: The real-world effects of panel surface mass and absorption on acoustic performance**

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ABSTRACT
Current practice in noise barrier design places strong emphasis on the selection of barrier materials with relatively high panel surface mass. Common rules-of-thumb suggest minimum surface masses of between 8 and 15kg/m2. For rooftop mechanical plant equipment screens, there may be a desire to utilise materials which are lighter and easier to install; such as solid aluminium, or aluminium composite material (ACM) sheet. Such materials may have a surface mass as low as 4kg/m2. Based on the results of full-scale physical testing, this study investigated the insertion loss effects of varying the panel mass, internal sound absorption, and barrier configuration for typical screened-off plant enclosures with open tops. Comparisons were made between the physical test results and SoundPLAN computer modelling, which showed the computer modelling significantly overestimated the barrier losses. It was found, for the measured plant enclosure configurations, there was an almost insignificant performance increase in doubling the surface mass of the enclosure material from 5.4kg/m2 to 10.8kg/m2. The introduction of sound absorption into the

enclosure showed good barrier loss improvements. The introduction of a secondary front screen also proved beneficial at reducing noise spill under the plant screen.
Finally, a simple algorithm is presented in this paper for estimating the reduction in noise barrier performance for lightweight barriers, based on a correction for the transmission loss through the barrier material.

23 Case studies of innovative window and balcony design for traffic noise mitigation

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ABSTRACT
Traffic noise is one of the critical environmental issues in a modern city. High-rise residential buildings need to be provided with good sound mitigations in order to reduce the noise from traffic. Other than building a big roadside noise barrier, some passive mitigation measures at the residential unit itself could be a good choice for controlling traffic noise ingress without compromising natural ventilation. Different types of specially designed acoustic windows and balconies have been studied to cater address the noise problem. Tests have been carried out to quantify the acoustic performance of those windows and balconies.

PAPERS BY THEMES

Wind turbine acoustics

AUTHOR INDEX

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