Current Research in Acoustics at the ISVR

Jeremy Astley (rja@isvr.soton.ac.uk)
ISVR sits within the Faculty of Engineering and the Environment (FEE)
Staff and students (excl. SOECIC & ISVRC.)

- Undergraduate: M.Eng./B.Eng./B.Sc. (~130)
- Graduate: M.Sc. (~40)
- M.Phil./Ph.D. (~110)
- Academic: 41
- Research: 27
- Admin/tech: 5

Institute of Sound and Vibration Research
FEE: research grants awarded 2012-13

A good year for sound and vibration

Important National Developments 2012-13
• Centres for doctoral training (45% of EPSRC funds for PhD training) late 2013. 400 submissions, ~50 to be funded.
• Research Excellence Framework, census date late 2013
• Aerospace institute, £2b matched funding 2014-2020

Institute of Sound and Vibration Research
Research Groups

- Fluid Dynamics & Acoustics
- Dynamics
- Signal Processing & Control
- Human Sciences
  - Hearing & Balance Centre (HABC)
  - Human factors Research Unit (HRFU)
  - Subjective acoustics

Institute of Sound and Vibration Research
Fluid Dynamics and Acoustics

- Ultrasonics and bubble acoustics
- Anthropogenic noise
- Acoustic Metamaterials
- Virtual Acoustics and audio engineering
- Aircraft Noise – Rolls-Royce UTC

Institute of Sound and Vibration Research
StarStream

Funding: The Royal Society Brian Mercer award (their premier award for innovation)
Budget: £250k
Partners: A range of industries (who wish to remain confidential) have paid ~£300k so far since the award to access the technology
UoS staff: T G Leighton, P R Birkin

Description of Work: Cold water cleaning without additives
- Adds ultrasound and bubbles to a low volume stream of water (~2 litres per minute) to turn it into a system for cleaning better than a pressure washer, but saving orders of magnitude on the consumption of power and water
Geophysical quantification of seafloor greenhouse gas

Funding: The natural Environment research Council
Budget: £250k to ISVR; £600k to NOCS
Partners: National Oceanography Centre Southampton (NOCS)
UoS staff: T G Leighton, P R White, A I Best
T.G.Leighton@soton.ac.uk

Description of Work: development of acoustical and electrical tools to quantify seabed methane and methane hydrate
- There is probably more methane in the seabed than there is of all other conventional fossil fuels combined. Its presence has implications for fuel resources and climate change (one molecule of methane has 20x the ‘greenhouse’ effect as one molecule of carbon dioxide)

Methane gas bubbling up from the seabed
Turbulent exchanges: Aerosols, bubbles and gases

Funding: Natural Environment Research Council
UoS Staff: H. Czerski, T. Leighton, S. Gunn, P. White
Budget: £560k

Work:
To understand ocean bubble physics and the air-sea flux of gases & particles they cause

Overall aim:
To improve weather and climate models

Bubbles from breaking waves
SONIC (Suppression Of underwater Noise Induced by Cavitation)
Funding: EC FP7. Budget: €3.0M (total), €286k (UoS)
Partners: Rolls-Royce, WARTSILA, Navantia, GL, CETENA, TNO, HSVA, MARIN, INSEAN, CHALMERS, Newcastle University, ARTTIC
UoS staff: V Humphrey, P Joseph, S Turnock, P White vh@isvr.soton.ac.uk

Description of Work: WP2: Full scale observations
- On-board and off-board radiated noise measurements (to compare with scale model measurements and theoretical predictions)
- Set-up of database of noise measurements
- Develop empirical noise source models to feed into noise mapping

Research vessel and container vessel to be measured in project

Shipping Intensity in North Sea based on AIS data
Loudspeaker Arrays for Personalized Audio

Funding: Huawei Technologies
Budget: £420 (UoS)
Duration: 3 years
UoS staff: F Fazi, P Nelson, M Shin

**Description of Work:**
- Use of loudspeaker arrays for localized sound reproduction
- Creations of “private” listening zones
- Combination of hardware and software technological solutions
- Possible applications to consumer audio (portable devices)

![8-channel miniaturized loudspeaker array](image)

SPL of the sound radiated by a loudspeaker array
Rolls-Royce

Rolls-Royce UTC in Gas Turbine Noise

April 2013

7 Academic staff
4 Research fellows
11 EngD/PhDs

Institute of Sound and Vibration Research
Spectral Broadening in Aeroacoustics

**Funding:** EPSRC, Rolls-Royce  
**Budget:** £323k (EPSRC), £100k+ (RR)  
**Partners:** Rolls-Royce plc, German Aerospace Centre (DLR)  
**UoS staff:** A McAlpine, R H Self, G Gabard, B J Tester  
**am@isvr.soton.ac.uk**

**Description of Work:** *Investigate scattering of tonal sound fields by turbulence*

- Acquire new experimental database of spectral broadening measurements.  
- Develop and validate theoretical / computational models of spectral broadening.  
- Demonstrate how to exploit this new work in specific aerospace applications.

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**Aerospace applications**

- Fan / Turbine tones
- Open rotor tones

**Laboratory measurements of spectral broadening by turbulent jet**
Leading edge serrations with different periods $\lambda$ and depths $h$ on a flat plate airfoil have demonstrated potential for reducing turbulence interaction noise. The current project will:

- Study the fundamental mechanisms involved in noise generation by leading edge serrations on more realistic airfoils through the use of high fidelity numerical simulation and advanced measurement techniques.
- Investigate the practical application of leading edge serrations to reduce fan broadband fan noise in turbomachinery.
HARMONY (wHole AiRcraft Multidisciplinary nOise desigN System)

Funding: Technology Strategy Board (‘Building UK aerodynamic capability)
£5 m (total), £900k (UoS)
Partners: Bombardier Aerospace, Rolls-Royce, UoS, U Cam, AOL.
UoS staff: R J Astley, P Joseph, A McAlpine, G Gabard, RH Self, R Sugimoto, … rja@isvr.soton.ac.uk

WP1 Engine Noise control.
• Improved characterisation of fan tone and broadband noise sources
• validate computational models fan tone noise
• Improved prediction tools for fan BB noise

WP2 Nacelle Noise Control
• Modelling effect of boundary layers on sound propagation, lined intake ducts
• Improved theoretical/comp methods for liner splices and repairs
• Improved methods for nonlinear effects, 3D effects and flow distortion

WP3 Airframe Noise Control
• 3D preliminary design method for jet mixing noise
• LES for the prediction of installed jet noise
• jet/wing interaction noise, semi-empirical prediction method
SAGE3-ALTD (Aeroengine intake acoustic Liner Technology Development)
Funding: EC FP7 Clean Sky JTI
Budget: €709k (total), €100k (UoS)
Partners: Bombardier Aerospace, Universities of Southampton and Limerick
UoS staff: R Sugimoto, P Murray, R J Astley
rs@isvr.soton.ac.uk

Description of Work: Micro-perforate liner technology for turbofan intakes
- Develop a micro-perforate liner impedance model from test data
- Optimise intake liner for SDOF and micro-perforate liners

Predicting liner attenuation by using ACTRAN TM FE/IE code
**JERONIMO** (Jet noise of High Bypass Ratio Engine: Installation, Advanced Modelling and Mitigation)

Funding: EC FP7

Budget: €4.8M (total), €330k (UoS)

Partners: 13 Partners including: Airbus, RRD, Universities of Southampton and Cambridge

UoS staff: R H Self, J L Lawrence, ANO rhs@isvr.soton.ac.uk

**Description of Work:**

**WP1.1 Characterise the effect of core, bypass and flight stream velocities and temperatures on UHBR jet noise**

**WP2.1 Investigation of jet-flap interaction noise**

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Doak laboratory jet-surface interaction study
CRANE (Community and Ramp Aircraft NoisE)
Funding: EC FP7, European Industrial Doctorate
Budget: €1m (total), €500k (UoS)
Partners: LMS, University of Southampton, RR Deutschland, KUL
UoS staff: G Gabard, R J Astley gabard@soton.ac.uk

Training and research on numerical methods for flow acoustics:
- Special methods for large-scale problems (installation effects)
- High-order methods (frequency and time domain)
- Description of complex geometries.

CAD geometry for an intake simulation
Mesh topology for an intake simulation
CAA simulation for installation effect using LMS Virtual.Lab.
CAA simulation of an APU outlet with LMS Virtual.Lab.
Dynamics Group Research Areas

- Structural dynamics at higher frequencies/SEA
- Railway noise and vibration
- Biodynamics
- Pipe modelling/water leak detection/ buried objects
- Non-linear isolators
- Adaptive Tuned Vibration Absorbers ....

Institute of Sound and Vibration Research
AERONAUTICS  

Aeroacoustic tests on 1:10 scale train bogies at ISVR

ACOUTRAIN (Virtual certification of acoustic performance for freight and passenger trains)

Funding: EC FP7, 2011-14
Budget: €3.2M (total), €240k (UoS)
Partners: UNIFE, SNCF, DB, Bombardier, Alstom, UoS and 9 others
UoS staff: D J Thompson

Objective: Introduce (partial) acoustic virtual testing into certification of new trains
- Develop improved models for sources (rolling noise, aerodynamic, etc) and for pass-by noise prediction
- Implement and validate virtual testing in context of certification

New software for predicting pass-by noise (ISVR)

Aeroacoustic tests on 1:10 scale train bogies at ISVR
MOTIV (Modelling Of Train-Induced Vibration)
Funding: EPSRC, 2013-17
Budget: £850k (total), £280k (UoS)
Partners: Universities of Cambridge, Nottingham and Southampton
UoS staff: D J Thompson (& M F M Hussein) djt@isvr.soton.ac.uk

Objective: Develop improved models for ground vibration and ground-borne noise from trains
- Improved excitation models including non-linearity
- Boundary Element model to account for tunnel-soil-pile interaction
- Integration in software
Noise prediction tools for vacuum cleaners

Funding: DTI (Knowledge Transfer Partnership) for 18 months
Budget: 103k (UoS)
Partners: Hoover Candy Group and University of Southampton
UoS staff: N S Ferguson, P F Joseph, P Hackett (KTP Assoc.) nsf@isvr.soton.ac.uk

Description of Work:
- Identify noise sources
- Apply passive control methods for the noise and vibration
- Develop a prototype and transfer knowledge to industrial partner

Motor noise: tonal plus broadband

Before and after

Motor bucket design

Up to 4 dBA sound power reduction
**MHiVEC** (Mid-High Frequency Modelling of Vehicle Noise and Vibration)

**Funding:** EC FP7 Marie Curie Industry-Academia Partnerships and Pathways (IAPP)
**Budget:** € 910k (total), € 157k (UoS)
**Partners:** University of Nottingham, Nottingham Trent University, CDH AG, inuTech GmbH
**UoS staff:** Jamil Renno

**Description of Work:** develop a modelling and simulation tool for the vibro-acoustic response of a complete car body (Body-in-Blue: BiB) over the full frequency range up to 20 kHz based on the Discrete Flow Mapping (DFM).

- **Range Rover shock tower:** colour scale shows thickness.
- **Kinetic energy at 9 kHz – DFM includes geometric details and is 18x faster than FE.**
Signal Processing and Control

Research Themes

• Active control of sound and Vibration.
• Biomedical and Neural Signal Processing
• Bioacoustics and sonar
• Active metamaterials
• Condition Monitoring

Institute of Sound and Vibration Research
Engineering Nonlinearity:
Exploitation of advantages of nonlinearity in engineering design

Funding: EPSRC Programme Grant
Budget: £5,100k (total), £267k for first 2 years of 5 year programme (UoS)
Partners: Universities of Bristol, Sheffield, Cambridge and Swansea
UoS staff: Steve Elliott, Maryam Tehrani sje@isvr.soton.ac.uk

Description of Work: Extend dynamic range of vibration power harvester, based on nonlinear feedback systems inspired by the cochlear amplifier

Saturating nonlinearity in feedback paths due to outer hair cells compresses dynamic range
Active Vibration Isolation for the Maritime Environment

Funding: BAE Systems, DSTL, EPSRC
2012 Budget: £350k
UoS staff: M. Reynolds, I. Zazas, S. Daley S.Daley@soton.ac.uk

Description of Work: Efficient Low Frequency Vibration Isolation Systems
- Draws on earlier DARPA work based on Magnetically Levitated Raft
- Most recent work uses locally resonant active metamaterial concepts
- Multiple global patents covering the designs are in place

Prototype Acoustic and Elasto-Dynamic LR Metamaterials
Early Fully-Active Mount Design Using Electromagnetic Levitation
Enhanced Low frequency Band-Gap with Active Control of Multiple Resonators
Active Vibration Control of Parametrically Excited Systems:
Funding: EPSRC first Grant
Budget: £125k
Investigator: Maryam Ghandchi Tehrani
Partners: Agusta-Westland and Arup

Description of Work: Extend the control algorithms to periodic-time-varying systems

\[ \ddot{x}(t) + 2 \zeta \omega \dot{x}(t) + \left( \omega^2 + q \cos \Omega t \right) x(t) = 0 \]

Feedback control is used to stabilise an unstable system under parametric resonance.

Control of parametrically excited systems
Advanced algorithms for tomography
Funding: EPSRC (£29,735) Nikon Metrology (£35,000), AWE (£10,000)
UoS staff: Thomas Blumensath + Thomas.Blumensath@soton.ac.uk

In collaboration with: Nikon Metrology, the Manufacturing Technology Centre (MTC), the National Physics Laboratory (NPL), the Atomic Weapons Establishment (AWE), the Collaborative Computational Project in Tomographic Imaging (CCPi) and the University of Southampton’s μ-VIS Imaging centre.

Image reconstruction techniques for challenging x-ray computed tomography
- Develop advanced algorithms for x-ray ct reconstruction in challenging imaging settings (limited access, reduced number of views, short exposure)
- Calibration of reconstruction algorithms for metrology

![Image showing reconstruction methods comparison](image-url)
Imaging human brain connections

Thomas Blumensath

In collaboration with the University of Oxford’s Brain Imaging Centre (FMRIB), the human connectome project (http://www.humanconnectome.org/) and the University of Southampton's Institute for Complex Systems Simulation.

Signal and Image Processing for the human connectome project
- Develop novel algorithms to partition the human brain into functional areas based on resting-state functional Magnetic Resonance Image Data
- Measure and model the information exchange between these regions

Cortical surface partitioned into functional regions

Estimating information exchange between regions in the brain and brain network modeling
Research in Human Sciences

- Human Factors Research Unit
- Hearing and Balance Centre (HABC)
- South of England Cochlear Implant Centre
- Subjective Acoustics

Institute of Sound and Vibration Research
Designing better hearing aids using physiologically inspired speech enhancement
Funding: EPSRC
Budget: £770 (total), £368 (UoS)
Partners: Universities of Southampton and Cambridge
UoS staff: S Bleeck, M Wright, T Blumensath

**Description of Work:**
- **investigate neural representation of sound in the auditory brainstem of guinea pigs**
- Create novel sparse coding algorithms based on dynamically adaptive dictionaries
- Adapt these algorithms for use in real world hearing aids and evaluate the performance

The challenge: understanding speech in noise

Word recognition scores demonstrate the problem: Hearing impaired people struggle to understand speech in noise. Automatic speech recognition is even worse.
ICanHear: Improved Communication through Applied Hearing Research

Funding: EU Marie Curie Initial Training Networks (ITN)
Budget: £3.4M (total), £660 (UoS)
Partners: Southampton, Bochum, Leuven, Zurich, Kopenhagen, Siemens, Cochlear
UoS staff: S Bleeck, T Blumensath

bleeck@gmail.com

- Training network to educate the next generation of leaders in their field
- develop solutions that will improve the performance of hearing instruments.
- tight integration of academic and industrial partners.
- strong translational focus, by providing fellows with skills to move from academic research to product development.

The challenge: understanding speech in noise

The work plan: interacting themes
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The challenge: understanding speech in noise

The work plan: interacting themes
C4CI (Compositions for Cochlear Implantees)
Funding: Arts & Humanities Research Council UK
Budget: £109k (2010-12) £99k (2012-13)
UoS staff: RM van Besouw, BR Oliver, DR Nicholls, R Polfreman
SM Hodkinson, ML Grasmeder, M Wald, MP White
rvb@isvr.soton.ac.uk

Description of Work: Development and evaluation of a computer-based music aural rehabilitation program with and for cochlear implant (CI) users
- Through consultations, workshops and a 6-month randomized controlled crossover trial with adult CI users
- With audio/video contributions from artists including Cliff Richard, 10cc and Philip Selway (Radiohead)
Minimising risks arising from exposure to whole-body vibration and shock in high speed craft

Funding: Ministry of Defence
Budget: £257,972
UoS staff: M.J. Griffin, Y. Qiu

Description of Work: Define methods of measuring the static and dynamic characteristics, and the vibration and shock performance, of seats in high speed craft
- Measure the relevant characteristics of 12 high speed craft seats
- Provide characteristics for use in seat assessment and seat modelling

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dynamic stiffness</td>
<td>1 – 30 Hz</td>
</tr>
<tr>
<td>Transmissibility</td>
<td>1 – 30 Hz</td>
</tr>
<tr>
<td>Load deflection</td>
<td>0 – 800 N</td>
</tr>
<tr>
<td>Drop test</td>
<td>VDV = 22 ms(^{-1.75})</td>
</tr>
</tbody>
</table>
Vibration and Noise Control of an Excavator
Funding: XCMG (china) ;  Budget: £141,500; UoS staff: Y Qiu, J Dixon
yq@isvr.soton.ac.uk

**Description of Work:**

- Experimental study of sound and vibration transmission of excavator in field and laboratory
- Modelling of cab-seat-driver dynamic system to minimise vibration transmitted to driver in accordance with relevant ISO standards
- Noise path analysis and development of optimal control solutions to reduce interior and exterior noise to meet relevant international regulations

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**Diagram:**

- Seat-human system
- Cab-seat-mass system
- Cab-seat-driver system
- A cab-seat-driver model
- Coherency
- Sound pressure level (dBA)
FURTHER INFORMATION

www.isvr.soton.ac.uk

or email: rja@isvr.soton.ac.uk

also

the ISVR 50th Anniversary symposium, will be held at ISVR on
Thursday July 11th and Friday July 12th
(www.southampton.ac.uk/engineering/ISVR50)
Streamlines of acoustic intensity for mode \((m,n) = (20,1)\)
[unlined, computed using Actran DGM, time dom. LEE]

Axisymmetric \(M=0\), Scarfed \(M=0\), Scarfed \(M=0.54\)

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