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Future Trends in Noise Control Technology

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FUTURE TRENDS IN NOISE CONTROL TECHNOLOGY

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National Academy of Engineering Workshop: **Advances in Noise Control
Engineering**

October 19 and 20, 2021

Presentation available at Herrick E-Pubs: <http://docs.lib.purdue.edu/herrick/>

See also: <https://www.youtube.com/watch?v=1voc1-2ZUYQ>



FUTURE TRENDS



- **Noise Control \neq Acoustics**
- **Noise Control = “Constrained” Acoustics**
- **Constraints:**
 - Safety
 - Cost
 - Weight
 - Volume
 - Robustness
 - Manufacturability
 - Low embedded energy
 - Recyclability
 - Odor

FUTURE TRENDS



1. **Targets**
2. **Measurement Procedures**
3. **Predictive Tools**
4. **Noise Control Methods**

1. Targets



▪ Perception-based Engineering

- Human in the loop
- Auralization based on machine design (e.g., NASA auralization of aircraft flyovers)
- Virtual prototyping and simulators

▪ Not just reducing levels, but shaping the acoustic environment →

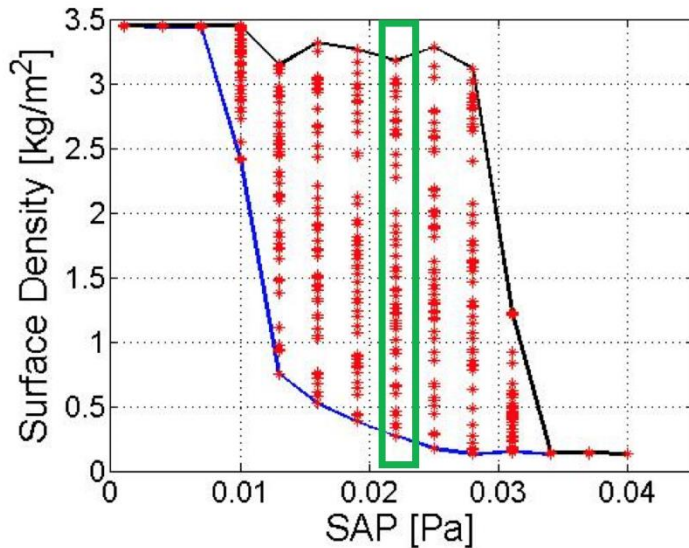
▪ More sophisticated sound quality models – including impact of non-acoustic parameters (thermal, illumination, etc.)

▪ “Branding” of interior and exterior sound designs

• Soundscapes

- Design of urban sound environments based on characteristics of community and intended outcomes

■ Sound Package Lightweighting*



LIGHTEST Combinations

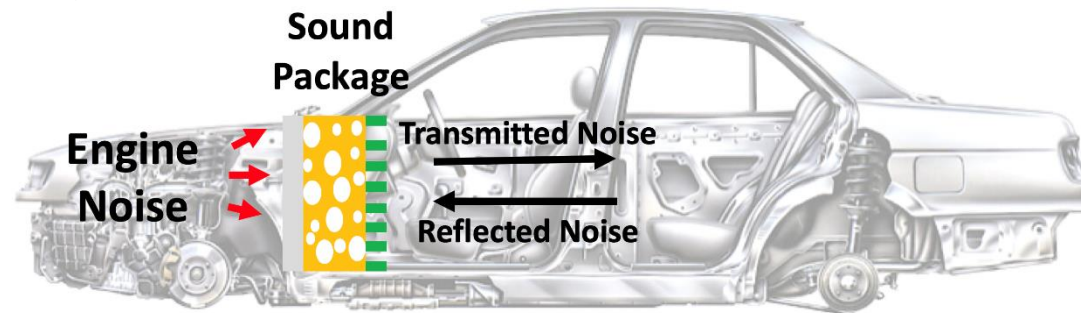
Heaviest Combinations

Possible Combinations

- Vary mass/unit area and flow resistivity of fibrous layer and MPP surface treatment
- Balance barrier and absorption performance

Total surface density for various SAPs (No leakage)

* Hyunjun Shin and J. Stuart Bolton, "Weight minimization of automotive sound packages in the presence of air leaks," Paper 1469 *Proceedings of InterNoise 2018*, Chicago, August 2018.



1. Targets



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2. Measurement Procedures



- **Developments of holography**
 - **Real-time, time-domain**
 - **Advanced equivalent source methods**
 - **Radiation mode-based procedures**
- **Pressure-Sensing – eliminate microphones: fiber optics, laser scattering to sense local density fluctuations**
- **Wireless transducers**
- **Whole field dynamic vibration measurement to replace single point laser Doppler methods – optical image processing**
- **Very large-scale data acquisition – hundreds/thousands of channels**
- **Very large-scale environmental noise measurements using smart-phones and the public**

2. Measurement Procedures



- **Material property estimates based on acoustic measurements**
 - **Model-based fitting of absorption and impedance**
 - **Bayesian estimation to determine appropriateness of model and interdependence of parameters**
- **Machine learning**
 - **Explore large experimental data sets**
 - **Low order models for “interpolation” to reduce need for large scale survey measurements**

3. Predictive Tools



▪ Finite Element Methods

- Convenient incorporation of radiation modes
- Incorporation of more complete acoustical material models
- Incorporation of uncertainty quantification – to compete with Statistical Energy Analysis

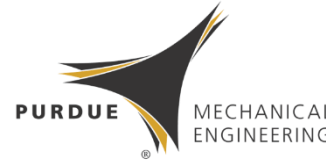
▪ Finite Difference Time Domain methods

- Incorporation of realistic boundary conditions and poroelastic material models

▪ CFD/CAA

- Fan noise is ubiquitous
- Finally design fans that are optimally quiet with realistic inflow conditions
- Micro-scale modeling of porous materials and thin absorbers at molecular level including sorption and slip effects

4. Noise Control Methods



▪ Active Noise Control (is back)

- Processing power and electronic devices are everywhere
- Incorporation of human perception models to shape sound fields to create pleasant environments
- Enable weight reduction of conventional sound packages
- Enable localized communication and quiet zones
- Electric Vehicles – road noise and aerodynamic noise, plus torque ripple are the major issues

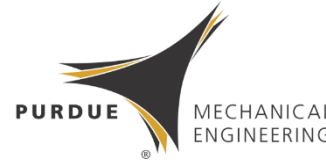
4. Noise Control Methods



▪ **Advanced Noise Control Materials** →

- **MPP's – very attractive functional attributes – multilayer barriers & absorbers**
- **Carbon fiber composites**
- **Very thin absorbers (internal degrees of freedom)**
- **Hybrid metamaterials**
- **3D printing of acoustical materials**
- **Multi-functional acoustic materials**
 - **damping plus absorption**
 - **absorption plus barrier**
- **Custom manufacturing of noise control materials**

4. Noise Control Methods



■ Advanced Noise Control Materials

➤ What's important about a noise control material?

➤ **Cost**

➤ **Safety**

➤ **Weight**

➤ **Volume**

➤ **Recyclability**

➤ ...

➤ ...

➤ **Acoustical Performance**

4. Noise Control Methods



▪ Advanced Noise Control Materials

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■ Hybrid Metamaterial



(12) **United States Patent**
Varanasi et al.

(10) **Patent No.:** **US 9,163,398 B2**
(45) **Date of Patent:** **Oct. 20, 2015**

(54) **SOUND BARRIER SYSTEMS**

USPC 181/290, 284, 292

See application file for complete search history.

(71) Applicant: **Purdue Research Foundation**, West Lafayette, IN (US)

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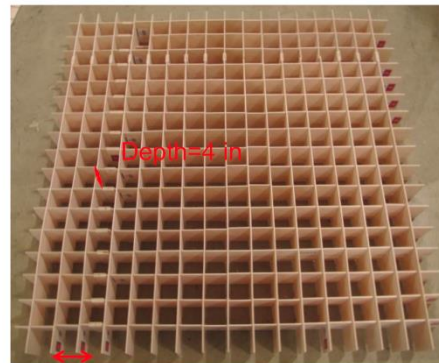
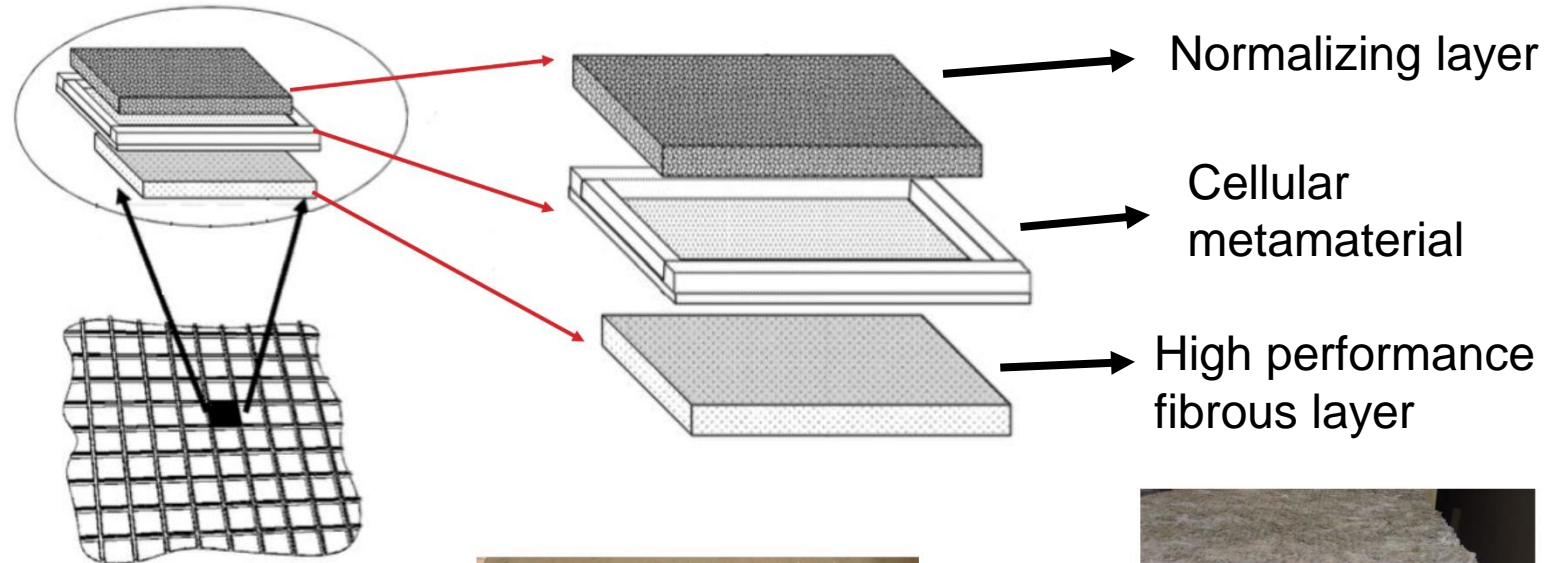
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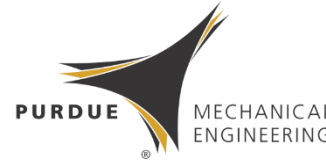
(73) Assignee: **PURDUE RESEARCH FOUNDATION**, West Lafayette, IN (US)

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Hybrid Metamaterial



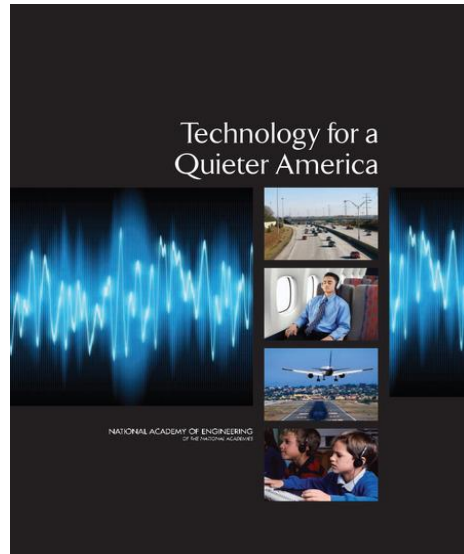
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 - **damping plus absorption plus thermal**
 - **absorption plus barrier plus thermal**
- **Custom manufacturing of noise control materials**

ADDITIONAL READING



Technology for a Quieter America

Available from National Academies

www.nap.edu/catalog/12928/technology-for-a-quieter-america

Thanks to Yutong (Tony) Xue for help with the presentation