Engineering a Quieter America

NOISE CONTROL ENGINEERING EDUCATION

DISCUSSION SESSION IN SAN DIEGO AT NOISE-CON 2019
August 27, 2019

Final Report

A discussion session organized by

The INCE Foundation

hosted by

Noise-Con 2019

Tamar Nordenberg, rapporteur

edited by

Adnan Akay, Gregg G. Fleming, Robert D. Hellweg, George C. Maling, Jr., and Eric W. Wood

Institute of Noise Control Engineering of the USA

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INTRODUCTION

This report summarizes a noise control engineering education session held on August 27 during the NOISE-CON 2019 conference in San Diego. The session, held in association with the National Academy of Engineering's ongoing Technology for a Quieter America (TQA) efforts, came 12 years after another TQA workshop on the same topic, held in October 2007, which was the partial basis for the 2010 TQA Report[1] Chapter 9, "Education Supply and Industry Demand for Noise Control Specialists."

Three overarching recommendations came out of the TQA Report:

Recommendation 9-1: Academic institutions should offer an undergraduate course in noise control engineering, broaden the scope of the engineering curriculum, and increase the pool of engineering graduates equipped to design for low noise emissions. The course could be offered as an elective in a bachelor's degree program or as part of a minor (e.g., in acoustics or interdisciplinary studies).

Recommendation 9-2: Graduate-level noise control courses should provide a balance between theory and engineering practice, without sacrificing academic rigor. The committee strongly encourages the establishment of graduate internships in industry and government agencies and thesis research programs to motivate students and build a cadre of future noise control engineers.

Recommendation 9-3: Federal agencies, private companies, and foundations with a stake in noise control should provide financial support for graduate students assisting with noise control engineering research or teaching. This support is crucial for the development of noise control professionals and noise control educators.

Opening remarks for the NOISE-CON 2019 session on noise control engineering education were provided by session chairs George Maling and Robert Hellweg. Next, Adnan Akay described the challenges faced by today's noise control engineering educators, and eight additional presentations followed—six by experts in academia, one by a consultant in the field, and another by an industry representative.

A key question during the NOISE-CON 2019 session was "Does demand for graduates in noise control engineering exceed supply"? The consensus: It does, given the very strong demand for graduates in the field. This conclusion aligns with a recent academic poll's findings that academic institutions receive many requests for noise control engineering graduates. Hellweg then moderated the closing discussion.

Another event on noise control engineering education was hosted by the National Academy of Engineering in Washington, DC, on Dec. 12–13. This workshop took a broad view

[1] National Academy of Engineering. 2010. *Technology for a Quieter America*. Washington, DC: The National Academies Press. https://doi.org/10.17226/12928.

of noise control engineering education—covering not only undergraduate and graduate education in universities, but also government agencies' activities in furtherance of noise control engineering education, as well as continuing professional education and K-12 engineering education. A report based on the workshop is in progress, with plans to also integrate material from this NOISE-CON 2019 session.

PRESENTATIONS

2.1 Opening Remarks

Robert Hellweg—Hellweg Acoustics
George Maling—NAE

Noise control engineering education session chairs Robert Hellweg (Hellweg Acoustics) and George Maling opened the session with general remarks about the National Academy of Engineering's Technology for a Quieter America efforts and its programs focused on nurturing the standout engineers of the future.

As a backdrop for the current NOISE-CON noise control engineering education session, Robert Hellweg made a few remarks about the National Academy of Engineering's Technology for a Quieter America (TQA) study, report, and follow-up workshops. After mentioning the four colleagues who, with him, make up the TQA follow-up team—Adnan Akay, George Maling, Eric Wood, and Gregg Fleming—Hellweg referenced the completed workshops following from the report, on these eight topics: national park soundscapes, motorcycle noise, cost-benefit analysis of noise barriers and quieter pavements, occupational noise exposure, progress in reducing product noise, technology transfer, commercial aviation-associated noise, and most recently, noise from unmanned aerial systems and vehicles. Another TQA follow-up workshop, on noise control engineering education, was planned for Dec. 12–13 in Washington, D.C., Hellweg stated. The December workshop would expand on the NOISE-CON session, and summaries of the NOISE-CON presentations would be included in the larger report covering the workshop, Hellweg noted before introducing George Maling for additional opening remarks.

First, George Maling highlighted a 2007 session on noise control engineering education, whose results were contained in a TQA report chapter and which set the stage for later meetings on the topic. One such meeting, the upcoming DecemberTQA workshop, is expected to include participants representing not only academia and industry, Maling noted, but also government agencies such as the Federal Aviation Administration, NASA, the U.S. Department of Transportation's Volpe Center, and the National Science Foundation's Engineering Directorate.

Maling next introduced NAE's four major programs related to engineering education:

- *Engineer Girl.* This program is designed to draw attention to opportunities in engineering for girls and women, who are strikingly underrepresented in the field.
- *Frontiers of Engineering.* At regular meetings, early-career engineers representing various disciplines discuss advanced engineering topics and explore opportunities for collaboration.
- *Global Grand Challenges.* Leading technological minds have identified 14 goals for improving life through engineering in the 21st century, and engineers are constantly working to help address these challenges globally. Maling noted that noise is not explicit among these 14 subjects of focus, but is nonetheless an important area, given how noise affects people and how they feel about their environment.

- *Grand Challenges Scholars Program.* Growing from NAE's 14 Grand Challenges, this program involving many universities around the world recognizes that engineers must work collaboratively with those representing a broad range of ideas and cultures to address the pressing issues facing society.

After providing this background, Maling shared the meeting's rules in support of high-quality recordings and, in turn, an accurate report summarizing the presentations and discussion. And he concluded his remarks by introducing speaker Adnan Akay, noting that Akay was founder, with NAE past president C.D. Mote, of the Noise Control and Acoustics Division within the American Society of Mechanical Engineers (ASME), and is provost for Bilkent University in Ankara, Turkey.

2.2 Opening Presentation: Challenges to a Quieter America & Noise Control Engineering Education

Adnan Akay—Bilkent University (Ankara, Turkey)

This opening presentation of the noise control engineering education special session provided an overview of the challenges faced in pursuit of a quieter America and the critical role of—and impediments to—adequate noise control education for addressing these challenges.

The *Technology for a Quieter America* report focuses on addressing noise exposure in a range of settings: in the home and the workplace, for example, and in urban areas and national parks. Among the noise sources considered in the TQA research and associated workshops are consumer and industrial products, as well as air and ground transportation methods.

Much work is in store "to quiet a whole country," presenter Adnan Akay pointed out, and steps toward a quieter America must consider the interests of a wide range of stakeholders, including industry and the general public. Technology, policy, and economics all come into play as major considerations in noise control, according to Akay, who said that, ultimately, "It all boils down to health and quality of life versus economics." Even the question of who owns the noise problem remains unclear, the speaker noted.

Focusing next on the noise control engineers' perspective, the presenter stated that these professionals are challenged with solving three types of noise problems—some routine and well-defined, which can be addressed by engineers educated in the basics of noise control; others more complicated, with complex systems and multiple objectives involved, which could require a PhD to solve; and still others elusive with no obvious solution.

Short of earning their PhDs, the typical mechanical—and in some cases electrical—engineers may take a course or two in noise control and acoustics and may pursue a master's degree or graduate certificate program. Options for noise control engineering education include non-degree programs such as those available through INCE, companies with in-house training, professional societies, and government agencies, Akay noted.

Given these ample options for preparing people to become quality noise control engineers, the question remains, why do noise issues still loom so large? Answers are complicated, Akay stated, and various factors could be at play: Are there too few noise control engineers? Do we lack the will to address these problems? Do we not care about a quieter America? Are incentives lacking for a quieter life? Is a quieter society too expensive to achieve? Does current technology fall short?

Speaking about the first factor, noise control engineers are indeed in short supply, and few students pursue advanced degrees in noise control engineering, Akay stated. Not enough students take even the basic courses, which are usually offered as electives; research funding for graduate students is deficient; and noise control engineering may be viewed as unexciting.

Akay recognized the significant deterrent to would-be noise control engineers that a computer science graduate can command twice the salary. The presenter also noted that the Bureau of Labor Statistics does not even list noise control engineering as a profession. Akay welcomed the session's industry participants to provide their perspective on the issue of market demand post-graduation and other, related issues. The speaker commented that K–12 education is an important opportunity to engage students, including underrepresented groups, to convey the appeal of the field of noise control engineering. And it is likewise important to make the field

attractive to undergraduate and graduate students. People want to enter a hot areas, Akay recognized faculty and graduate students can be in a position to introduce ideas, technologies, and approaches that can energize the field, and areas such as acoustics may appeal to students and professors alike.

After briefly covering a history of acoustics, noise control, and associated research and development, Akay highlighted that current research can animate the noise control field with its focus on innovative areas such as metamaterials, sensors, and noise shaping. "It is essential to incorporate new developments in sister technologies such as AI and deep learning into noise control engineering," he stated.

Speaking next from the perspective of policy, Akay stated that the public should be educated on noise control issues that affect them—not only on the health hazards of noise, but also on advances in related technologies. Figure 2.2-1 provides an idea of the evolution of noise control-related policies, from ancient history to modern times. The fact that noise remains a "big problem" today is evidenced, Akay noted, by articles such as "Is Noise Pollution the Next Big Public-Health Crisis?" in the May 13, 2019, issue of *The New Yorker* (depicted in Figure 2.2-2).

The speaker then showed Figure 2.2-3, with the Gartner hype cycle of emerging technologies that are drawing buzz, pointing out that noise control technologies are nowhere to be seen. Leveraging advances in the hot areas that *are* winning attention could go far to attract people to noise control engineering, Akay stated, as a complement to other previously mentioned approaches such as emphasizing to students—including young ones in K through 12—that noise control is important and can also be fun.

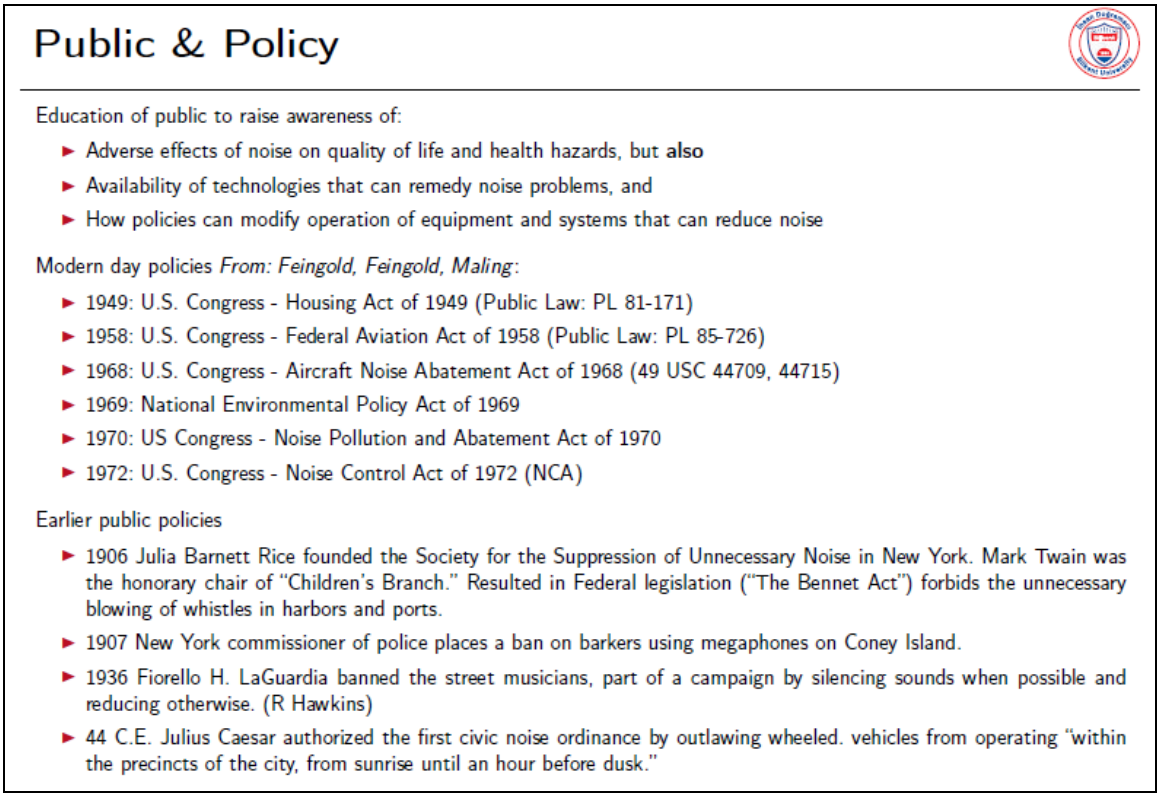
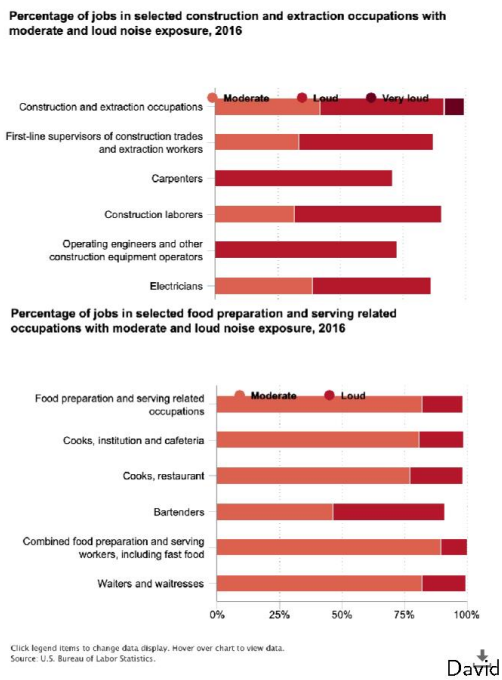


Figure 2.2-1 *The evolution of noise control policy*

Is Noise Pollution the Next Big Public-Health Crisis?

Noise is now seen as a factor in a range of ailments, including heart disease.



David Owen, May 6, 2019, The New Yorker. Illustration by Kati Szilagy

Figure 2.2-2 *Noise pollution in the news*

Gartner's Hype Chart

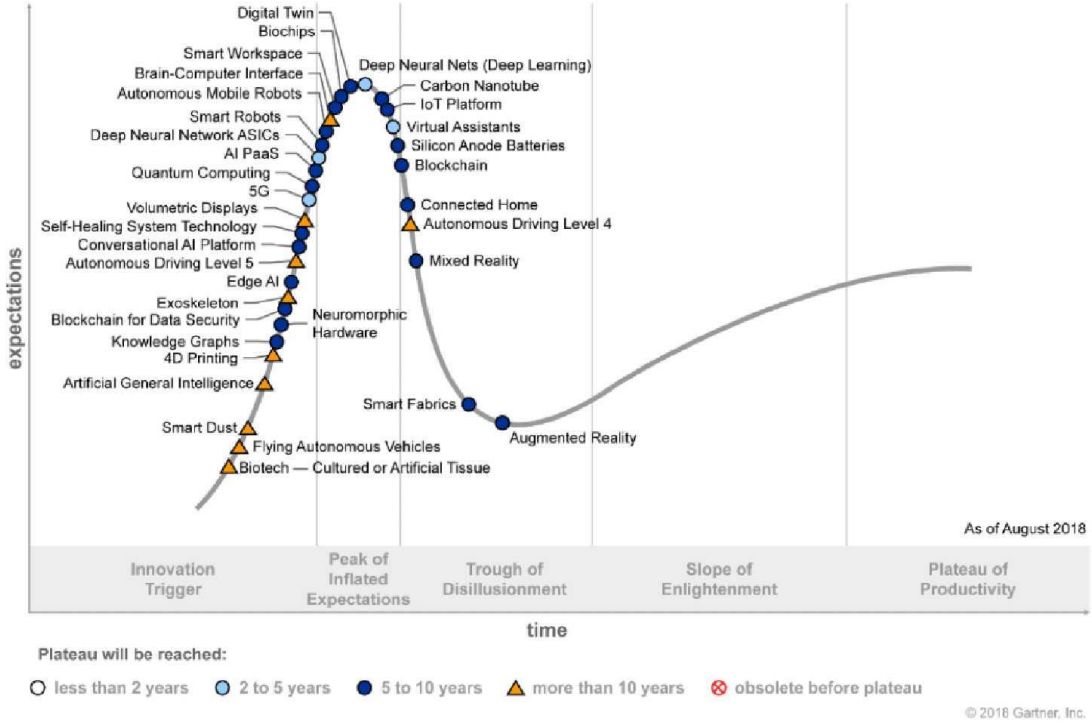


Figure 2.2-3 *Gartner chart of talked-about technologies*

2.3 Professional Noise Control Education

Andrew Barnard—Michigan Technological University

Options are many for those interested in a noise control education, with paths ranging from certificate-earning short seminars to INCE-USA's three-course series to university programs leading to bachelor's, master's, doctorate, and other degrees. Still, the supply of amply educated noise control specialists sometimes falls short of employer demand. Interest in noise control education could be boosted through efforts to heighten the field's appeal and, where graduate-level education is concerned, to emphasize the benefits of—and funding avenues for—these advanced degrees.

Speaker Andrew Barnard, associate professor of mechanical engineering at Michigan Tech, spoke about the wide array of opportunities for education in the field of noise control engineering. As depicted in Figure 2.3-1, options run the gamut in terms of time commitment and credentials. On one side of the spectrum, in a matter of hours, students can earn a certificate by attending professional seminars and webinars, while other students choose to devote years to university courses culminating in a degree such as a BS, MS, MEng, or PhD.

In laying out this diverse educational landscape, the presenter first discussed the offerings of INCE-USA. In his position as the organization's vice president of education, Barnard oversees its three-course series, which was developed by Courtney Burroughs based on his Penn State distance education courses in the field and which involves correspondence courses equating to nine graduate credits at a university. Importantly, successful completion of the three courses, including passing the associated exams, makes students eligible to waive the professional exam requirement for INCE Board Certification. Specifically, the courses in this INCE noise control engineering series are:

- Basics of Vibration and Acoustics, Including Measurement and Analysis (Instructor: Tyler Dare, Penn State)
- Noise Generation and Sound Propagation, Room Acoustics, Measurements, and Effects of Noise on People (Instructor: Corinne Darvennes, Tennessee Tech)
- Mechanical Noise Sources, Outdoor Noise, NVH Treatments, and Numerical Modeling (Instructor: Andrew Barnard, Michigan Tech).

With respect to professional seminars, the speaker discussed the example of the "PCB Piezotronics: Microphone Fundamentals and Advanced Applications" seminar he himself teaches, in which students learn about acoustics fundamentals toward obtaining good measurements. Figure 2.3-2 lists this and several other noise control training opportunities as summarized on the INCE-USA website. "Industry is hungry" for this type of knowledge, the presenter stated, given that many of those working in noise control engineering positions have focused on mechanical or electrical engineering and have little or no background in the noise control and acoustics areas that can prove "invaluable" to companies.

As middle ground between short seminars and the INCE-USA program, many mid-range workshop-type courses are available, said Barnard, who provided the example of a course offered by the Council for Accreditation in Occupational Hearing Conservation that is designed to train technicians as hearing conservation professionals.

Next, Barnard spoke briefly about his own university's noise, vibration, and harshness (NVH) program—considered a graduate program—that is housed within the school's mechanical engineering department. NVH program courses—some of them focused entirely, and others only partially, on noise and vibration—are listed in Figure 2.3-3. Michigan Tech offers a distance education program, the speaker highlighted, including a 100-percent distance doctoral education offering that is unique among universities. Barnard pointed out that some students are not pursuing a degree but take a course to brush up on a particular subject, and that all Michigan Tech noise control courses are offered "á la carte." "I think that's really helpful in our industry," the presenter stated.

Figure 2.3-4 addresses noise control engineering student supply and demand, which substantially differs between U.S. nationals and international students. The speaker has observed that, at his university, international graduate students are in very high supply, with demand rather high. While most of Barnard's international NVH grad students find employment, a challenge is presented by a recent "pullback of industry partners that want to support the Visa process."

In contrast, many government labs and defense contractors in need of noise and vibration experts who are U.S. nationals can find that specialists with sophisticated knowledge in the field are in short supply. One issue: Students such as those at Barnard's university are offered "exorbitant salaries" in their sophomore or junior years to work for companies such as Ford and General Motors, and they may not appreciate the benefits of graduate school and may be unaware of grad school funding opportunities. "I think there's some salesmanship on our part that could improve that situation," he stated.

In winding down his presentation, Barnard highlighted that noise control is not considered a trendy field in academia, which limits grant funding and in turn discourages faculty and administrators. Across the country, many noise control programs are disappearing, stated Barnard, adding, "I'm glad a lot of us are still holding on."

Much can be done to make noise control more alluring, the speaker pointed out. For example, in-vogue topics such as machine learning and AI can be linked with noise control instruction. People must also be matched with the right learning options for them, And, the fact that noise control is vital to product design must be driven home. For example, he said, noise control will be critical in the design of consumer products such as electric vehicles, a fact that holds appeal for students like his. "We're a people-first industry," Barnard noted, "which students like."

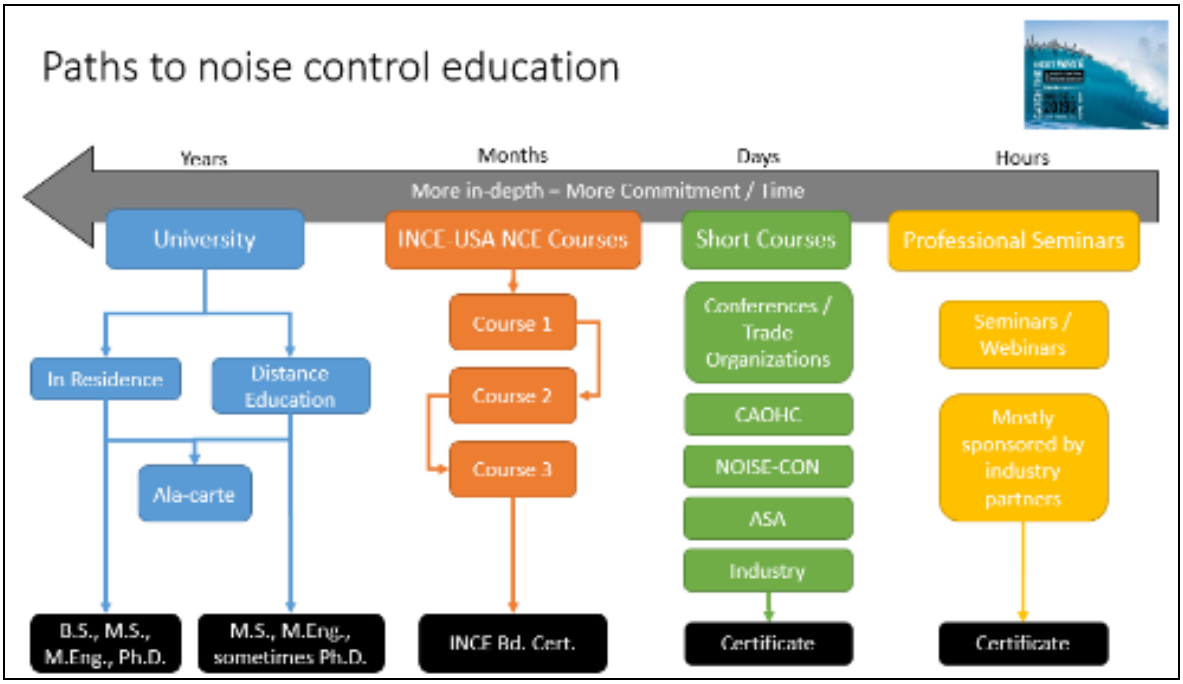


Figure 2.3-1 *Options abound in noise control education*

Figure 2.3-2 *Professional seminars require a limited time commitment*

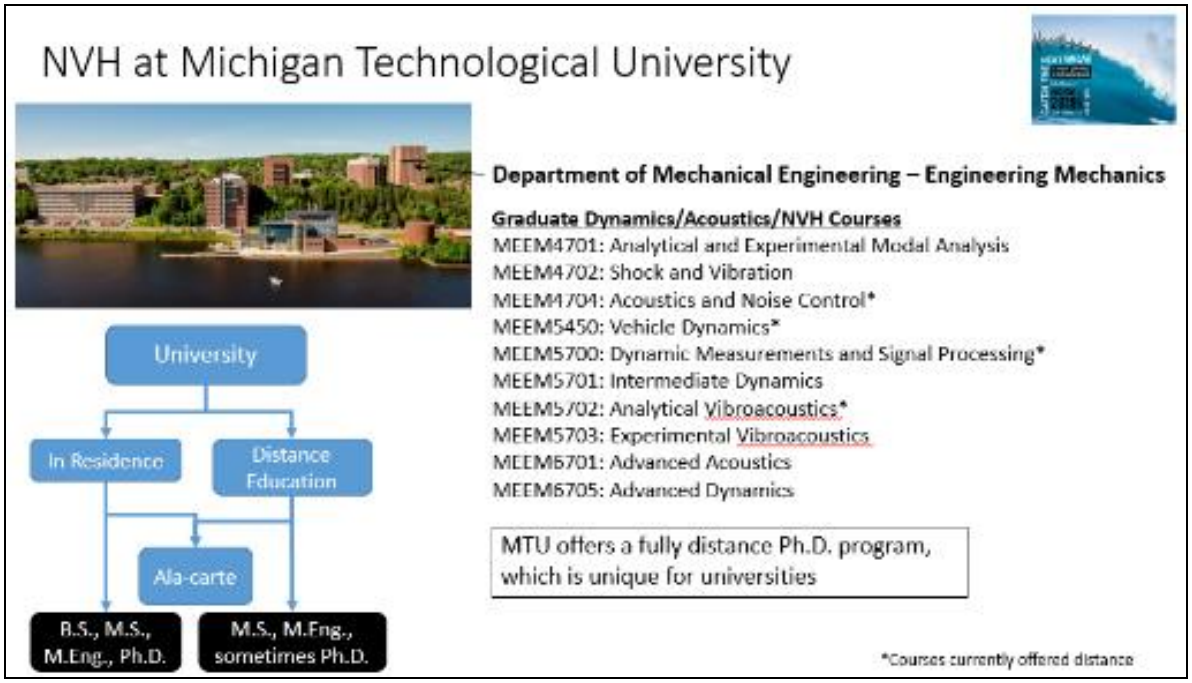


Figure 2.3-3 *Summary of Michigan Tech NVH courses*

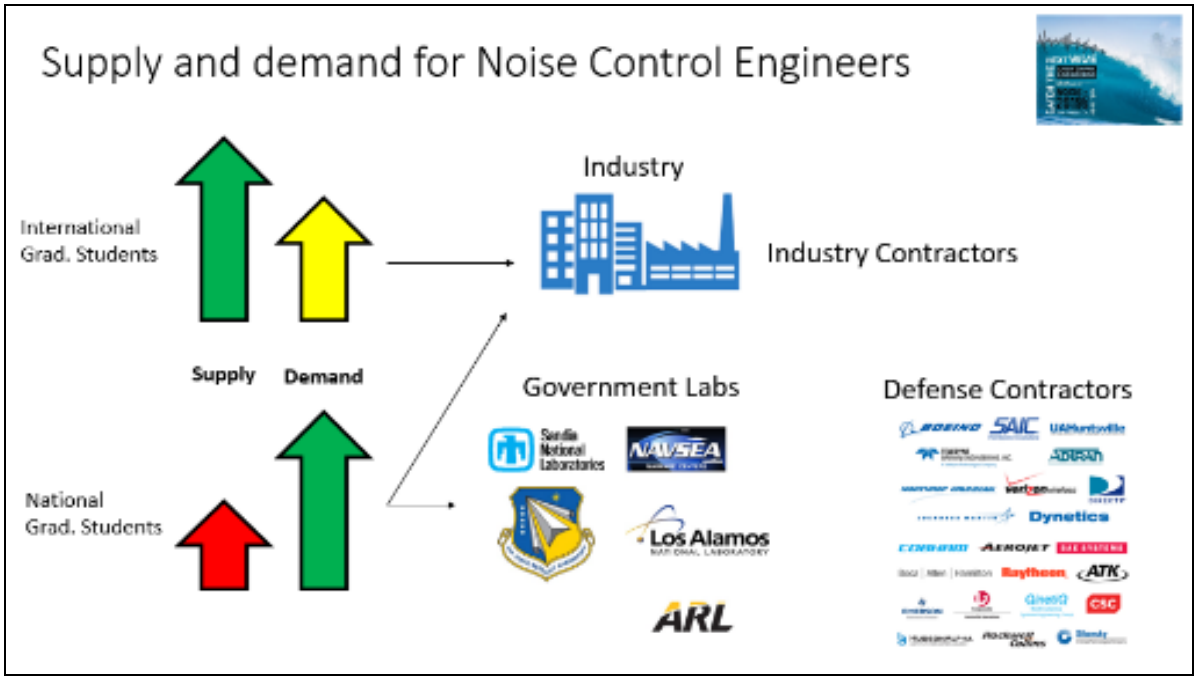


Figure 2.3-4 *Noise control engineers: supply/demand*

2.4 Noise Control Engineering Education from a Consulting Professional's Perspective

James Barnes—Acentech Incorporated

What can be done to attract more people to the field of noise control engineering? Factors that spark interest vary, but examining the moments that have drawn people to this career path can offer worthwhile clues toward enticing the field's next generation of experts.

Practicing noise control engineer James Barnes spoke from the industry perspective—a different frame of reference from the many academics presenting at the special session, he recognized—about possible approaches for attracting people to the field of noise control engineering.

The presenter started his presentation by recalling an MIT graduate course he took in wave propagation, during which his professor, well-known engineering mechanics expert Stephen Crandall, drove a sophisticated point home using a simple Slinky. "That really struck me because I'm a hands-on guy," Barnes stated.

Barnes next discussed an informal poll he had taken of Acentech employees—whose backgrounds vary but who generally have either undergraduate or graduate degrees directly related to acoustics—as a way of assessing what had prompted some others to pursue noise control engineering. Barnes asked these employees, basically, "What one or two most memorable, useful, educational experiences lit your path and caused you to work in this field?"

The presenter summarized a few interest-sparking experiences, including:

- Case studies at school and conferences kindled one woman's interest by providing real-life examples of how noise problems are solved.
- An exceptional grade on a college vibrations exam spurred one person, now an Acentech vibrations expert, to pursue his interest in theory and experiments.
- For another employee, an extraordinary high school teacher fueled an existing interest in music and the idea of melding that with an interest in engineering.
- An electrical engineering college student questioning whether she was pursuing the right field happened to see Leo Beranek's book *Concert Halls and Opera Houses: Music, Acoustics, and Architecture* in the library and was motivated by the book to change the course of her life. Barnes stated that he himself was inspired by Beranek's previous book, *Music, Acoustics, and Architecture*, while questioning his own graduate-level educational path.
- Another Acentech employee was motivated, as a college junior majoring in architecture and minoring in music, by a single lecture related to noise control and acoustics in the context of building systems engineering. Barnes noted that, during a graduate school course, his own awareness of building systems as a field in its own right was heightened by a chapter in Benjamin Stein's series of books on building systems.

Barnes highlighted a common thread running through some of these stories: an interest in music and emphasis on a good quality of life, and the discovery of acoustics and engineering as a related field that someone could enjoy while also making a living.

Coming full circle to highlight his early point about the power of a demonstration, Barnes himself demonstrated noise control design principles for an effective acoustical enclosure with a simple warning horn and the following elements: resilient foam mount, solid wood box, glass

fiber lining, and rubber gasket. The relative benefit of each element toward reducing the horn noise in the room was shown, which included the resilient mount under the horn to provide vibration isolation and to mitigate structureborne sound, heavy box to contain the sound, glass fiber to absorb the sound, and rubber gasket to seal the potential airborne sound leaks. He demonstrated that removing one or more of these elements could noticeably compromise the acoustic performance of the enclosure.

2.5 Short Courses and Noise Control Education in Asia

Stuart Bolton—Purdue University

Purdue University shares its noise control expertise by teaching short courses on-site at companies, universities, and conferences throughout the country and around the world. Purdue and other U.S. institutions are not alone in providing first-rate noise control educational opportunities, however; Korea and China, for example, offer exceptional noise control engineering degrees with assorted specializations.

Purdue University's short courses, and noise control education in Asia, were the topics of focus for the presentation by Stuart Bolton, a professor in Purdue's School of Mechanical Engineering.

Speaking first about the university's short courses, Bolton explained they are usually organized on an ad hoc basis, when a company desires to educate its employees in a certain area or a different opportunity presents itself, such as at another university or at a conference.

The presenter himself is involved with short courses on topics such as noise control, signal processing, sound field visualization, and acoustic materials and treatments, and has organized and/or presented about 20 single- or multi-day courses, as listed in Figures 2.5-1 and 2.5-2. "There are a variety of needs for short noise control courses that we can meet in various ways," he said. For example, in recent years he has brought his expertise in acoustics and noise control to the John Deere Technical Center in Waterloo, Iowa, as well as the company's Technical Center in India, and taught a short course related to microperforated materials at Shanghai Jiao Tong University. Bolton pointed out that, among the courses shown in green, representing conference venues, is the 1998 noise materials course he taught for the first time at the NOISE-CON 98 conference, at George Maling's urging, in particular.

Among these courses, Bolton gave 20 lectures about acoustics and industrial noise control at IIT Kharagpur, India, in collaboration with Prof. Amiya Mohanty. The course, taught over five days, was recorded and made available on YouTube as part of the agreement. The option exists today to make a high-quality recording and make it freely available, the speaker highlighted, adding that this possibility can present a conflict with the option of revenue-generating short courses.

Bolton next spoke about noise control education in Asia. Korea, as an example, holds two Korean Society of Noise and Vibration meetings each year. Many attend this Korean version of NOISE-CON and the meeting can boast two to three times the papers of the U.S. meeting. Korea also has universities with very strong acoustics and noise control programs, the speaker pointed out. Among these: KAIST (Korea Advanced Institute of Science and Technology), which Bolton said produces superbly prepared noise control engineers at the graduate level, some of whom come to the U.S. to earn their PhDs and land in companies such as 3M. Information is summarized in Figure 2.5-3.

China is "the other major player" in this regard, Bolton noted. About Hong Kong, the speaker pointed out that its Hong Kong Polytechnic University has a very strong acoustics program focusing on vibroacoustics. Purdue has a beneficial association with the academically excellent Shanghai Jiao Tong University, which emphasizes modeling and signal processing, according to Bolton, who also mentioned additional standout noise control-related programs at institutions in China, some of which are listed in Figure 2.5-4.

It was once thought that only the U.S. or Europe could provide high-level PhDs, Bolton said. But schools in China and Korea exemplify how other parts of the world may actually be outdoing these programs, said the presenter, suggesting additional engagement between the U.S. and the rest of the world could be beneficial.

Figure 2.5-1 *Presenter's various short courses over the years (slide 1 of 2*)

Figure 2.5-2 *Presenter's various short courses over the years (slide 2 of 2)*

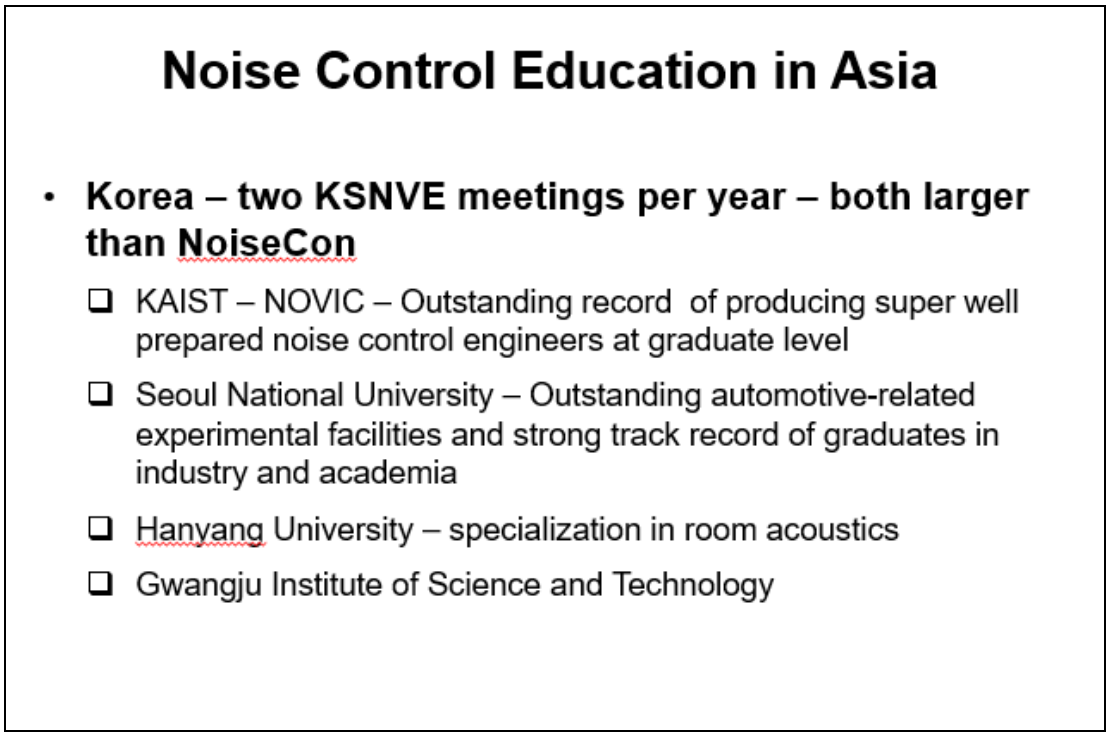


Figure 2.5-3 *Korea offers outstanding noise control education*

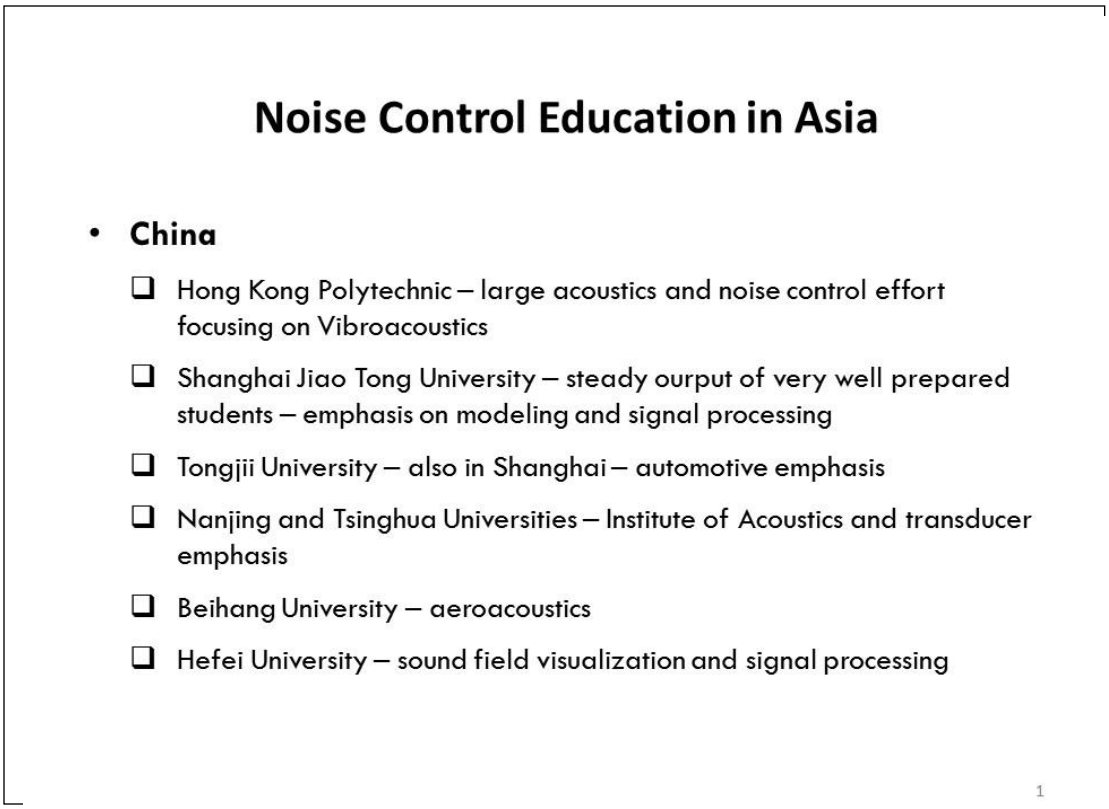


Figure 2.5-4 *China also stands out for its noise control engineering education*

2.6 Noise Control Engineering Education

Joseph Cuschieri—Lockheed Martin

Florida Atlantic University is among the academic institutions being challenged by cost pressures in the quest to provide a noise control engineering education that meets industry needs. Challenges such as abridged course requirements to cut academic costs can be met with effective steps in damage control, such as a university partnership with an expert advisory board and company-provided mentorship opportunities.

Presenter Joseph Cuschieri spent two decades in academia, including many years as a professor and two years as engineering associate dean at Florida Atlantic University (FAU), before joining industry 15 years ago. Figure 2.6-1 summarizes the speaker's career path. As part of his present position with Lockheed Martin, Cuschieri—also INCE-USA's current executive director—serves on the industrial advisory board chairperson for FAU's Department of Ocean and Mechanical Engineering.

The board advises the department on matters relating to its engineering curriculum, which includes noise control engineering and acoustics courses. From this perspective as a member of the industrial advisory board, Cuschieri directly observes the challenges associated with adequately educating students for noise control engineering careers. Some of these challenges are summarized in Figure 2.6-2. For its part, the state of Florida desires to attract young people to attend college and part of this is managing academic costs. Toward this goal, credit requirements at the university have been scaled down from 136 when the speaker was employed by the university to 128 currently (with a goal of further reducing the requirement to 121), making it challenging to retain specialized courses such as noise and vibration control, signal processing, transducer design, and underwater sound propagation within the shrinking program.

As a result of the trimmed program, whose requirements may continue to diminish, engineering program graduates can lack the level of noise control and acoustics knowledge desired by industry, Cuschieri stated. Against the backdrop of state pressures, the industrial advisory board works with the department to tailor FAU courses to address industry needs to the greatest possible extent. Still, a gap in noise control knowledge inevitably remains, which the presenter said can be addressed at least in part through companies' in-house training including mentoring. At Lockheed Martin, for example, young engineers are paired with experienced subject matter experts to support continued learning in noise control engineering and acoustics.

In concluding his presentation, Cuschieri stressed another topic: the regrettable lack of consideration to noise in product design. Correcting noise problems is exponentially more difficult after the fact, he stated, echoing the perspective of other presenters.

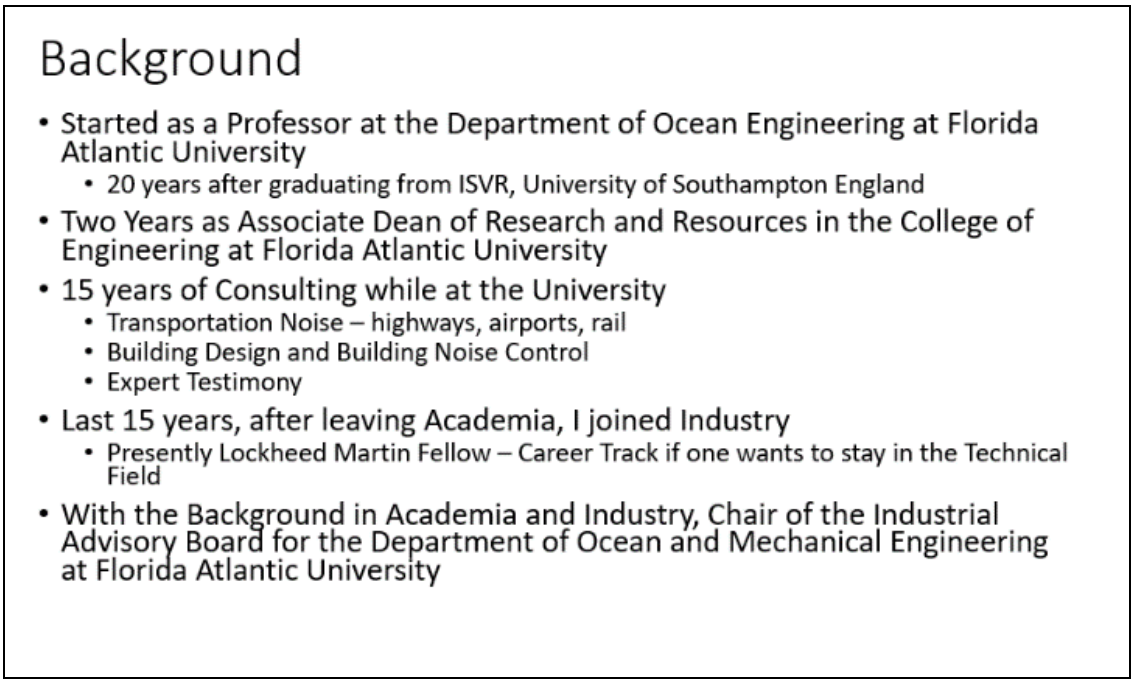


Figure 2.6-1 *Presenter Joseph Cuschieri's background, summarized*

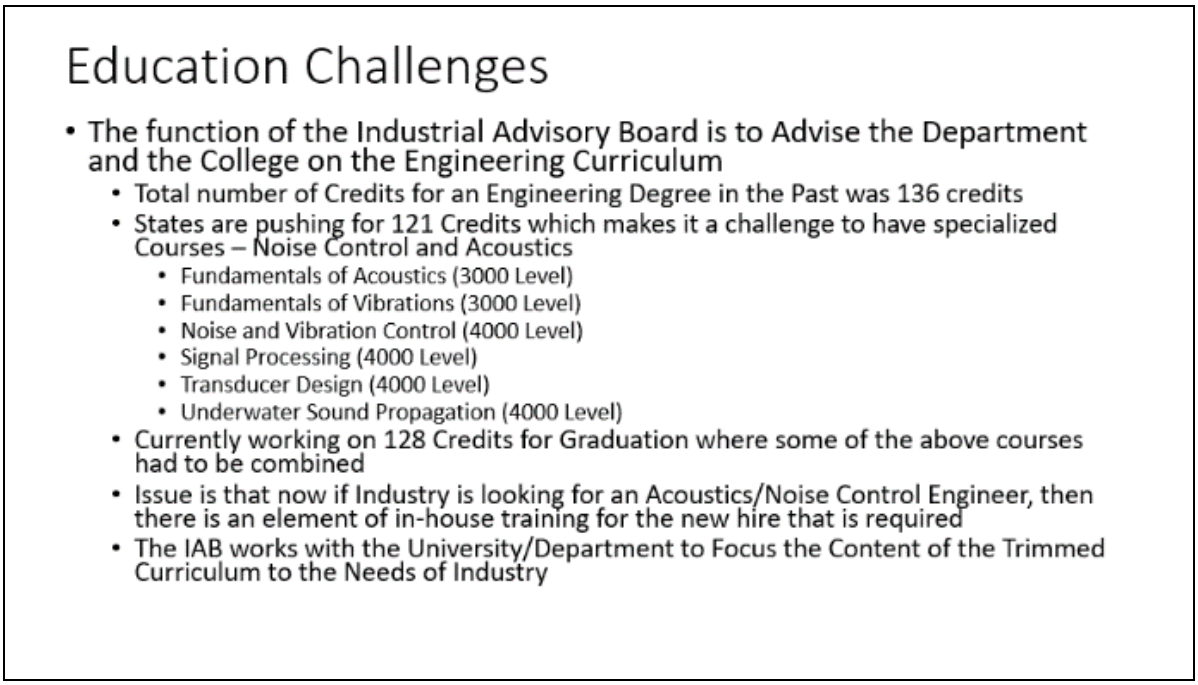


Figure 2.6-2 *Addressing challenges in the current cost-conscious climate*

2.7 Acoustics and Noise Programs at Georgia Institute of Technology

Kenneth Cunefare—Georgia Tech

Within Georgia Tech, whose mechanical engineering program is one of the largest in the U.S., several courses in acoustics and noise control arm primarily PhD students and a minority of MS students with an understanding of an array of noise control and acoustics subjects. Students ultimately work in a variety of industries, but very few land in acoustics- or noise-control-focused businesses—which seems to be fallout from a lack of research funding in this sphere.

Speaker Kenneth Cunefare discussed the acoustics program at Georgia Tech, including the scope of its noise control- and acoustics-associated courses, composition of the student body and faculty, and graduates' employment experience and associated challenges.

The acoustics program spans multiple schools across Georgia Tech, as listed in Figure 2.7-1, with the program's core within the mechanical engineering school. The mechanical engineering program is one of the country's largest of its kind, Cunefare noted, with more than 2,400 undergraduate students and over 800 graduate students, most of them pursuing PhDs. Of about 100 tenure-track and 30-plus research faculty, those shown in Figure 2.7-2 are most strongly connected with acoustics and noise control. (Recently, Massimo Ruzzene left Georgia Tech for a new position.) Cunefare is the sole faculty member undertaking extensive outside consulting, and the speaker also has the most significant connection with industry.

At the undergrad level there are classes in structural vibrations, acoustics and noise control that introduce students to a wide range of topics—human hearing, noise control technologies, and room acoustics among them. In turn, these courses feed into graduate courses providing a "deep dive" into specific noise control technology topics such as detailed design of walls, detailed room acoustics, measurements, intensity, and beyond. Figure 2.7-3 summarizes core acoustics/dynamics and noise control-related courses.

Next, the speaker discussed some details of each course: For example, the senior undergraduate technical elective course "Engineering Acoustics and Noise Control," offered each fall, is taught at the level of Colin Hansen's *Noise Control: From Concept to Application* textbook. The popular course enrolls more than 30 students each year. The graduate "Applied Acoustics" class, offered every other spring, is taught at the level of *Engineering Noise Control* by David Bies and Hansen, typically with 10 to 15 students. Other graduate classes in acoustics tend to be scheduled on a two-year cycle.

Cunefare then addressed the typical A&D graduate student profile at his school, which tends to break down as 80 percent PhD candidates—with 31 PhD students and 7 MS students as of the time of the speaker's presentation. The MS program does not generally feed into the PhD, the speaker pointed out; the majority of students come directly into PhD research. And, the speaker noted, about 60 to 70 percent of students are domestic students.

As for the employment experience of these MS and PhD students, Cunefare stated that domestic students have no barriers and are nabbed quickly. International students have more difficulty finding positions, with immigration challenges posing barriers to their certification to work in the United States and leading them in some cases to return to their home countries.

For those who are employed in the U.S., MS students enter consumer and other industries and in some cases pursue consulting. Among the 30 or so MS graduates over the last couple of years, two have joined noise control-related companies. As for PhDs, most have joined

academia, defense or national labs, or multinational corporations such as Apple; medical device and medical diagnostics companies; and startups. The speaker could recall only two that were employed in noise control or acoustics. This distribution is reflective of the lack of research support in noise control and acoustics, Cunefare emphasized: "The students just do not get the research support that would funnel them into our industry."

Figure 2.7-1 *Acoustics extends far beyond Georgia Tech's mechanical engineering school*

Figure2.7- 2 *Primary Georgia Tech faculty in A&D*

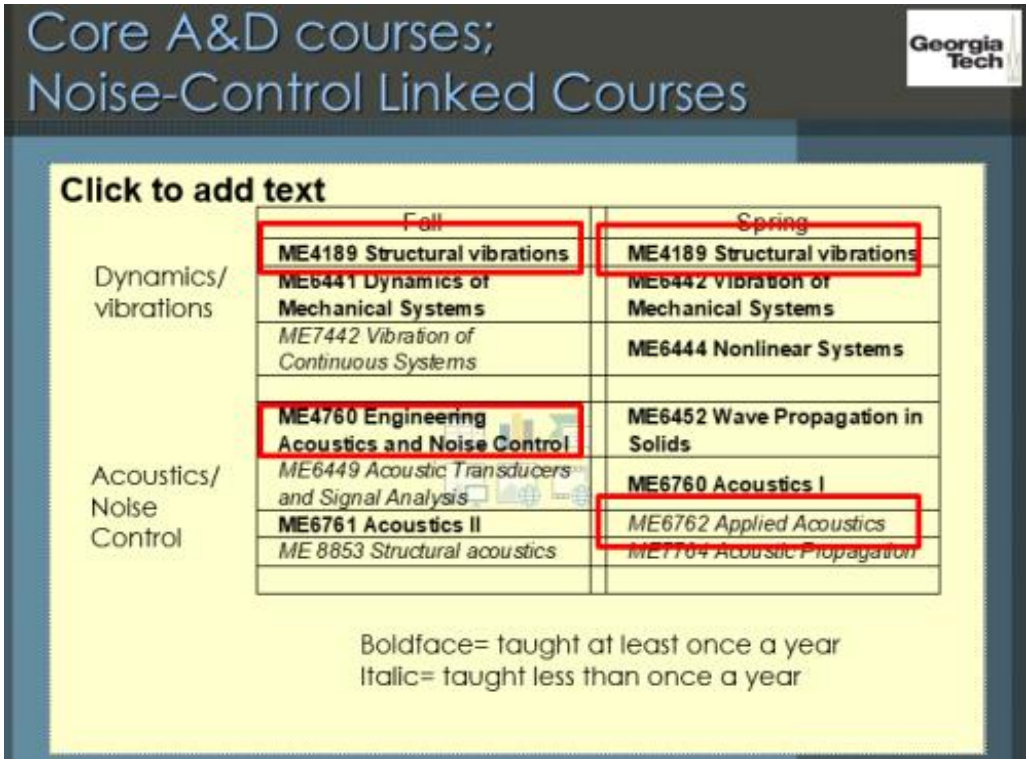


Figure 2.7-3 *Georgia Tech's core noise control-related A&D courses*

2.8 Acoustics and Noise Control within the Graduate Program in Acoustics at the Pennsylvania State University

Tyler Dare—Pennsylvania State University

Penn State University's graduate acoustics program offers various degrees and diverse core and elective courses, with distance education and hands-on learning opportunities as standout features and noise control engineering among its popular courses.

Tyler Dare, assistant research professor with Penn State University's Applied Research Laboratory, spoke about acoustics and noise control within the university's graduate acoustics program. He presented the perspective of Penn State's director of acoustics distance education, Dan Russell.

As summarized in Figure 2.8-1, Penn State offers an MEng degree, with primarily distance ed students; a traditional MS in acoustics that includes a thesis; a one-year non-thesis MS; and a PhD. Figure 2.8-2 lists the diverse research areas and applications covered at PSU, with bold indicating particularly active areas.

Penn State offers dozens of acoustics courses, with these included in the core curriculum:

- 501 – Elements of Acoustics and Vibration
- 502 – Elements of Waves in Fluids
- 505 – Laboratory (taught by Dare and restricted to resident students)
- 513 – Digital Signal Processing
- 514 – Electroacoustic Transducers
- 515 – Acoustics in Fluid Media
- 516 – Data Measurement and Analysis

PSU's noise control engineering course, offered every four years recently, is among a broad range of elective courses along with sound-structure interaction, flow-induced noise, aerodynamically induced noise, outdoor sound propagation, computational acoustics, nonlinear acoustics, ocean acoustics, architectural acoustics, spatial sound and 3-D audio, audio signal processing, and acoustics of musical instruments.

Dare focused next on the distance ed aspect of PSU's acoustics program, about which Dan Russell is "very passionate." Lectures for residence students are recorded live for distance ed students to watch at their convenience, although these remote students are encouraged to watch live if possible. Distance education students complete a capstone paper rather than a thesis. Some recent capstone topics appear in Figure 2.8-3 and, Dare pointed out, include traffic noise, locomotive noise, and airport noise. Traditional theses are also sometimes related to noise control, Dare stated, and have included Lane Miller's "An analysis of acoustic beam-forming with sparse transducer arrays for active control" and John Cunsolo's "Noise transmission from a small hermetic reciprocating refrigerant compressor" in 2018. PhD theses related to noise control tend to be less applied, the speaker noted, leaning toward topics such as supersonic signatures.

The two biggest non-graduate departments covering noise control are the aerospace and mechanical engineering departments, with the engineering science, mechanics, and increasingly the bioengineering departments also addressing the topic.

Dare next talked about the Center for Acoustics and Vibration, a consortium run by Steve Hambric whose missions are summarized in Figure 2.8-4. The consortium brings faculty, students, and industry together through video workshops, seminars held about twice a month, and an annual two-day workshop. Consortium sponsors are listed in Figure 2.8-5.

As for employment, Dare said that some students work for these sponsor companies, some pursue their PhDs and work in academia, and many others work in the defense industry, and particularly in Navy-related fields based on their experience in PSU's Applied Research Lab.

Penn State conducts some K-12 outreach, but its grade school appearances and on-campus STEM events focus on topics that are viewed as more captivating than noise control. (Perhaps the view of noise control as mundane could be changed, Dare noted.)

The speaker concluded by discussing Dan Russell's well-attended course in noise control engineering, which lately has been offered every four years (next offering: spring 2020). Many taking this course are not pursuing a degree; some are already INCE board-certified and wanting to refresh their knowledge, some are preparing to take the certification exam, and others are new hires in a company. Figure 2.8-6 lists engineering noise control course topics. Dare explained that distance students participate in hands-on noise control experiments by acquiring (often relatively unsophisticated and inexpensive) sound level meters and conducting demonstrations of free-field, critical distance, traffic noise, and other related topics. The students very much enjoy the hands-on learning, Dare stated, encouraging others to consider incorporating such real-world experiences into noise control engineering education.

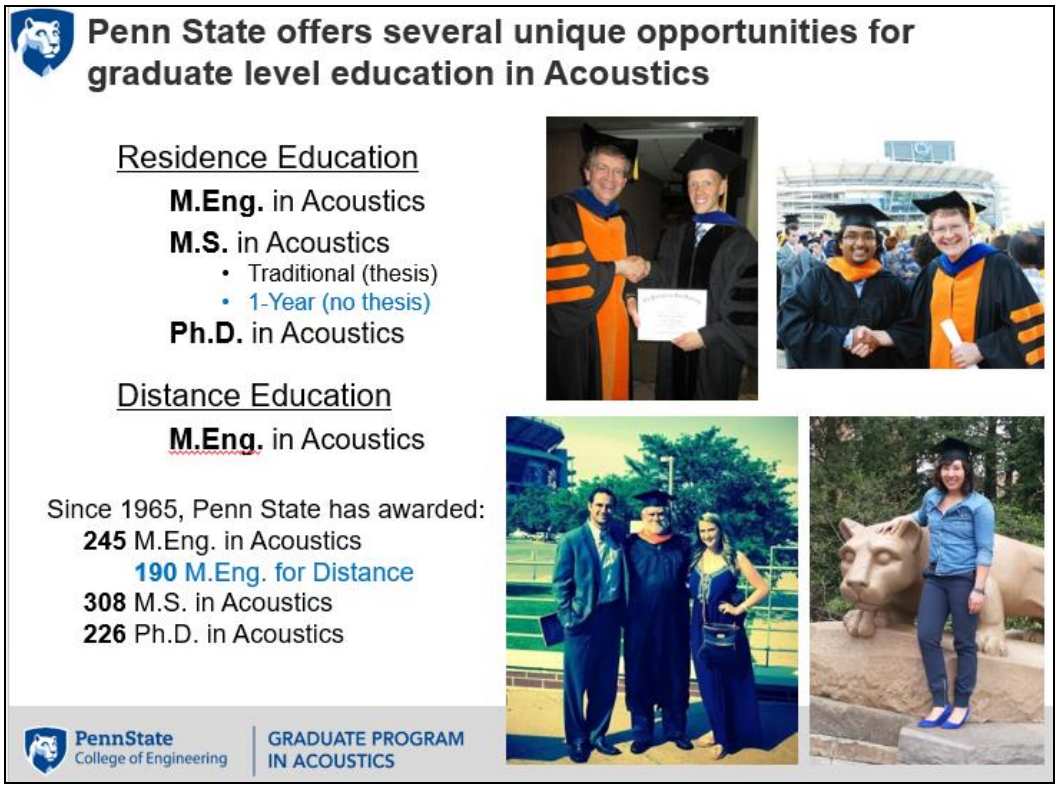


Figure 2.8-1 *Overview of Penn State's graduate-level acoustics education*

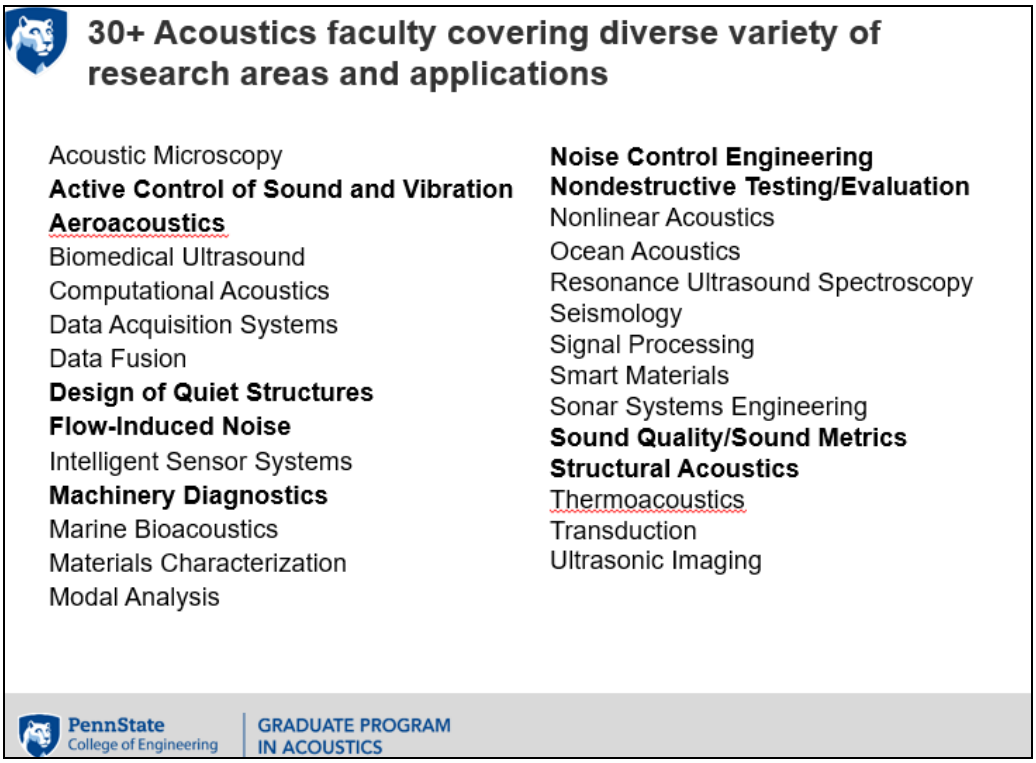


Figure 2.8-2 *Diverse research areas and applications in acoustics*

Figure 2.8-3 *Broad-ranging electives in acoustics*

Figure 2.8-4 *About the center for acoustics and vibration*

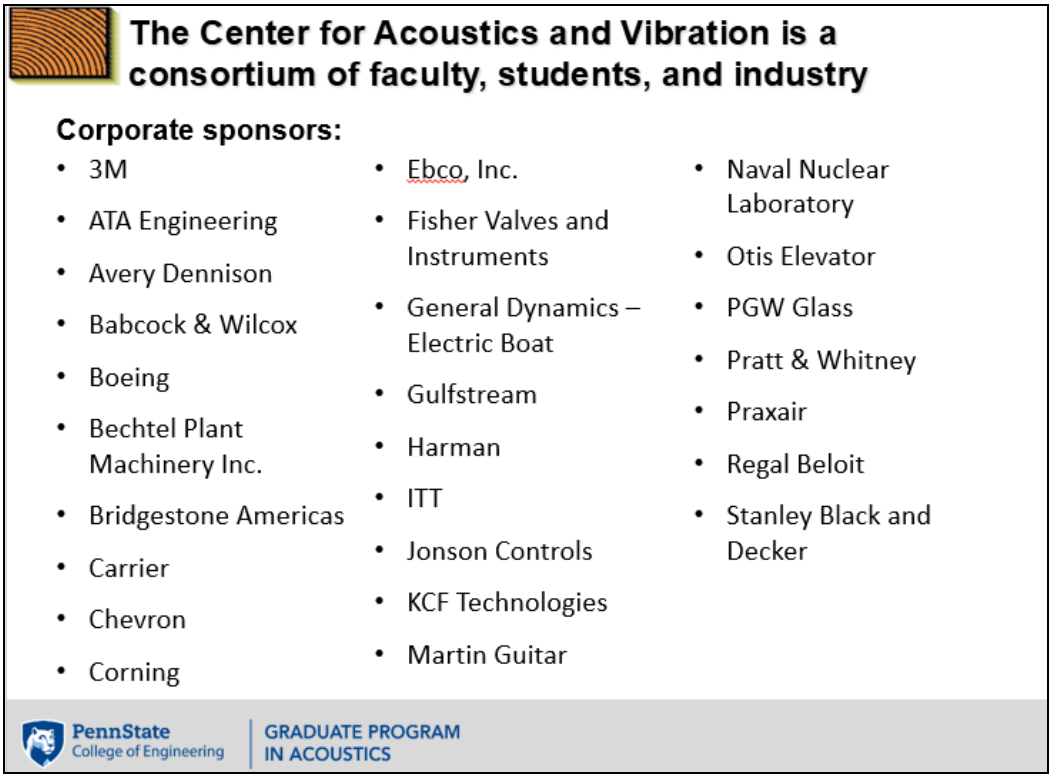


Figure 2.8-5 *Consortium's corporate sponsors*

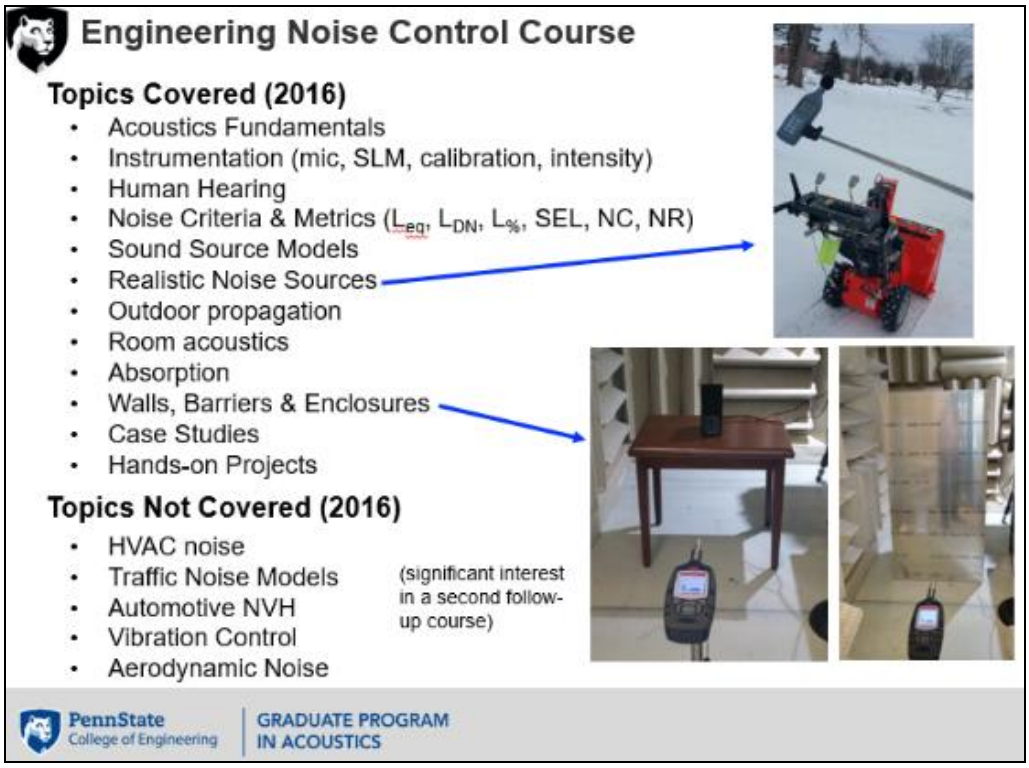


Figure 2.8-6 *Topics within engineering noise control course*

2.9 Noise Control at Purdue University

Patricia Davies—Purdue University

Purdue University offers diverse programs, courses, and research opportunities related to noise control and acoustics. The gamut of offerings runs from a small undergraduate acoustical engineering program to extensive course options within the mechanical engineering MS and PhD programs to an online education program to earn an MS or gain expertise on a single topic. Among its other features, Purdue stands out in noise control and acoustics for its Herrick Laboratories and extensive research partnerships with industry and government agencies.

Speaker Patricia Davies, Purdue University professor of mechanical engineering and psychological sciences and director of the school's Ray W. Herrick Laboratories, shared her perspective on Purdue's relevant degree programs and courses, the university's Herrick Labs, its focus on acoustics, and its graduate students' industry-sponsored research projects.

Early on, Davies introduced Purdue's very small and student-tailored undergraduate acoustical engineering program within the school's multidisciplinary engineering program, the basics and mission of which are covered in Figure 2.9-1. Industry internships can provide these undergrad students with important noise control or applied acoustics experience, Davies highlighted.

Next, Davies shared information about Purdue's mechanical engineering master's thesis and PhD programs as summarized in Figure 2.9-2. For the MS, students must take two math classes and five other classes—mostly in engineering—and additional credits are earned through MS thesis research projects, which are usually sponsored by government (the defense department, for example) or industry. PhD students complete three mathematics classes and seven additional classes; their research projects are generally sponsored by government, industry, fellowships, or teaching assistantships, or a combination of those. Purdue offers a direct-to-PhD program, as well, which may attract some students to complete a PhD who would have chosen instead to accept employment after earning their master's. In both the MS and PhD programs, students must take a seminar class, (one seminar is offered per week, and a student must attend 10 of them). This seminar requirement is meant to heighten students' appreciation of the field of mechanical engineering beyond acoustics, Davis explained.

Purdue also offers a strong online education program, the presenter stated, through which some students earn an MS (and very few a PhD) and others simply gain expertise in topics such as acoustics, vibrations and signal processing. Information is available at https://engineering.purdue.edu/ProEd/ Faculty at the university offers short courses, as well, on topics such as noise control, digital signal processing, sound field visualization, and acoustic materials and treatments. These courses, about which Stuart Bolton spoke in greater detail, are often taught on-site at companies wanting to bolster their employees' expertise; recently, these have been held at Cummins and John Deere, for example.

Classes in noise and vibration are listed in Figures 2.9-3 and 2.9-4. These include a noise control undergraduate class, but many undergrads also take more advanced courses. In addition to classic courses such as signal processing, numerical methods, vibrations, finite elements, and fluid dynamics, courses include speech, language, and hearing sciences classes related to Davies' main areas of research and expertise: sound perception and development of noise control criteria.

Davies next briefly discussed Purdue's faculty associated with noise, acoustics, and hearing, stating that collaborations within these topic areas and in associated areas are strong within and beyond the university's College of Engineering. "The environment at Purdue is really nice," she said, "because there are great opportunities to learn about different aspects of acoustics and related subjects, and it's a very rich environment for students wanting to gain a broad appreciation of this field."

Next, the presenter spoke about the Ray W. Herrick Laboratories dedicated mostly to graduate education and research. Lab research is not limited to noise and vibration, Davies noted. She pointed out that technology transfer in collaboration with industry has been a strong emphasis since the lab's establishment in 1958. There are plans for a "dream facility," with a new acoustics wing that expands upon the current facility's capabilities; the new acoustics chambers that will replace existing ones, such as the anechoic, semi-anechoic, and reverberation chambers, will be improved in various ways. They will be operable over wider frequency ranges, for example, and they will be larger, climate controlled, enable certified testing, and provide new testing capabilities. The school faces the challenge, however, of raising funds to replace the labs' aging components.

Industry-sponsored projects, which usually involve a team of faculty members, graduate students, and industry engineers, are key at Purdue, Davies reiterated. Government agencies such as the Department of Defense, NASA, and the National Science Foundation also fund projects, which also usually involve technology transfer and require extensive student interaction with the sponsors. In concluding her presentation, Davies summed up that a Purdue education builds on required classroom fundamentals, integrating experience that prepares people to solve broad and complex real-world problems.

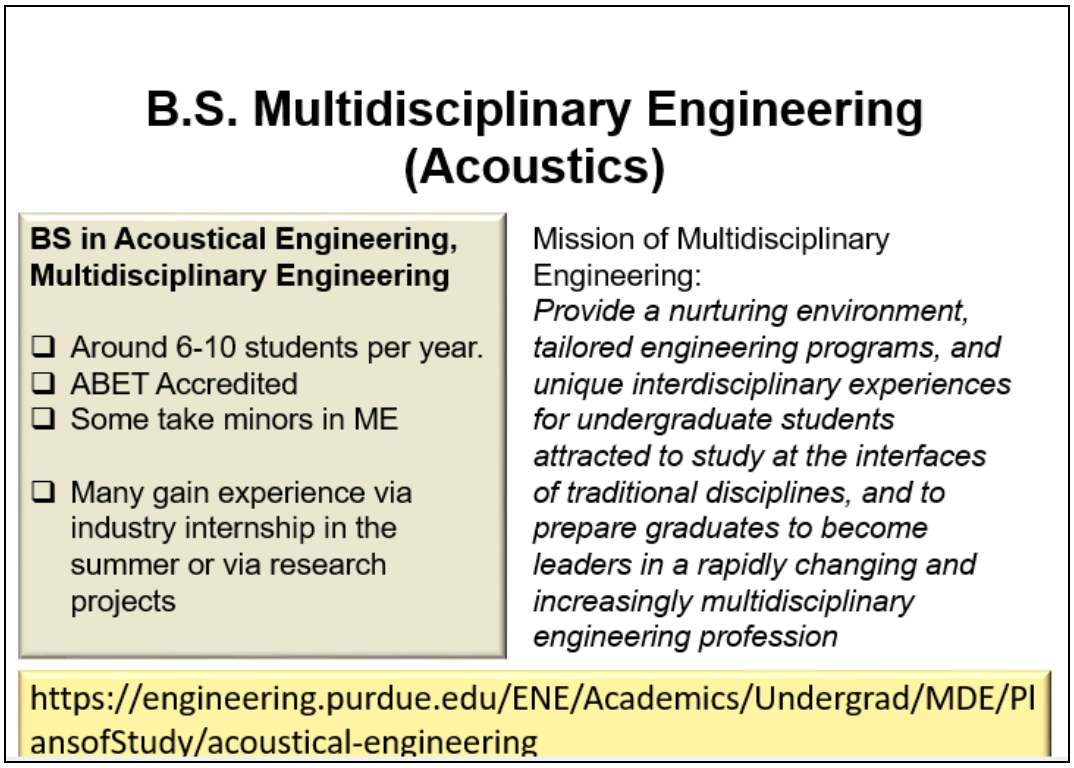


Figure 2.9-1 *Purdue's multidisciplinary engineering degree with acoustics focus*

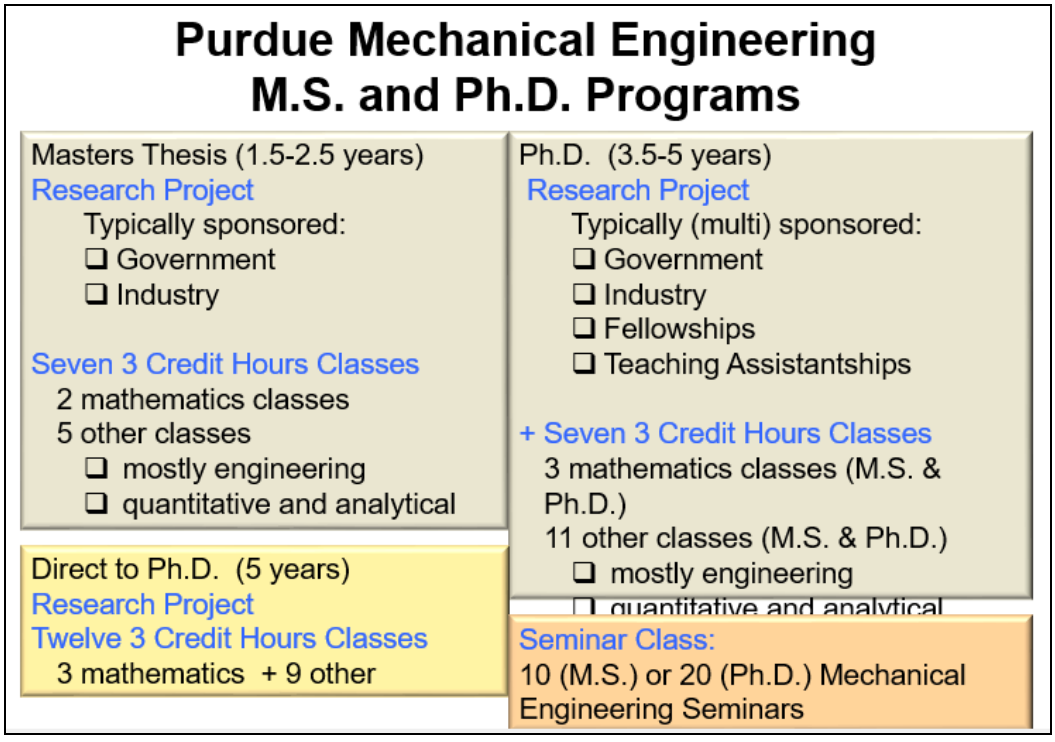


Figure 2.9-2 *Mechanical engineering master's, doctorate programs*

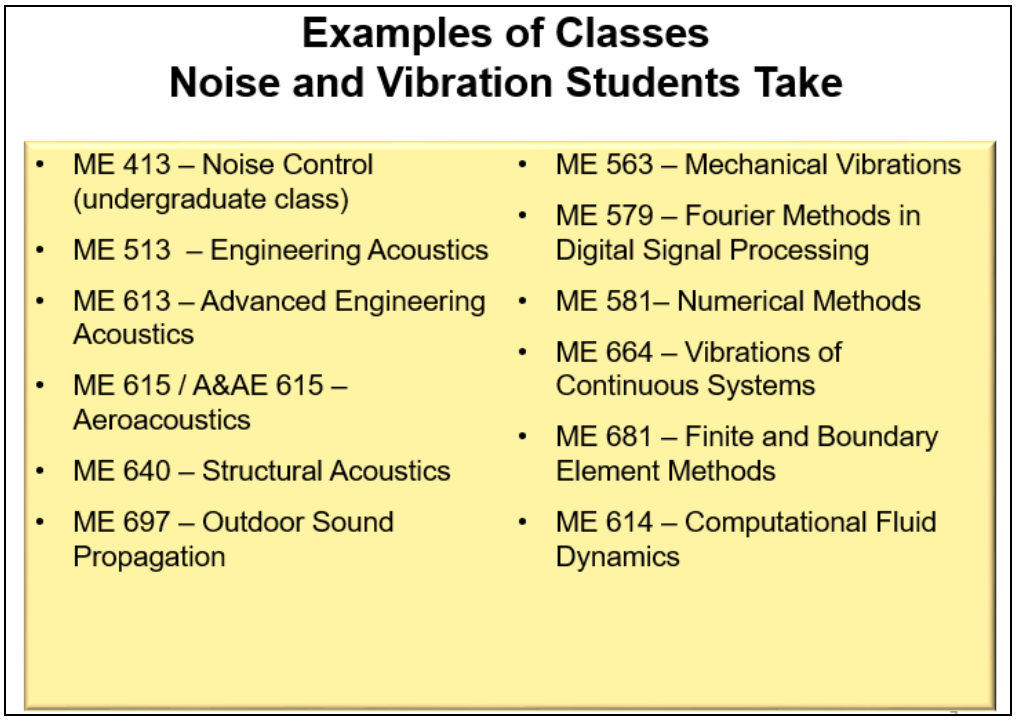


Figure 2.9-3 *Some classes in noise and vibration (slide 1 of 2)*

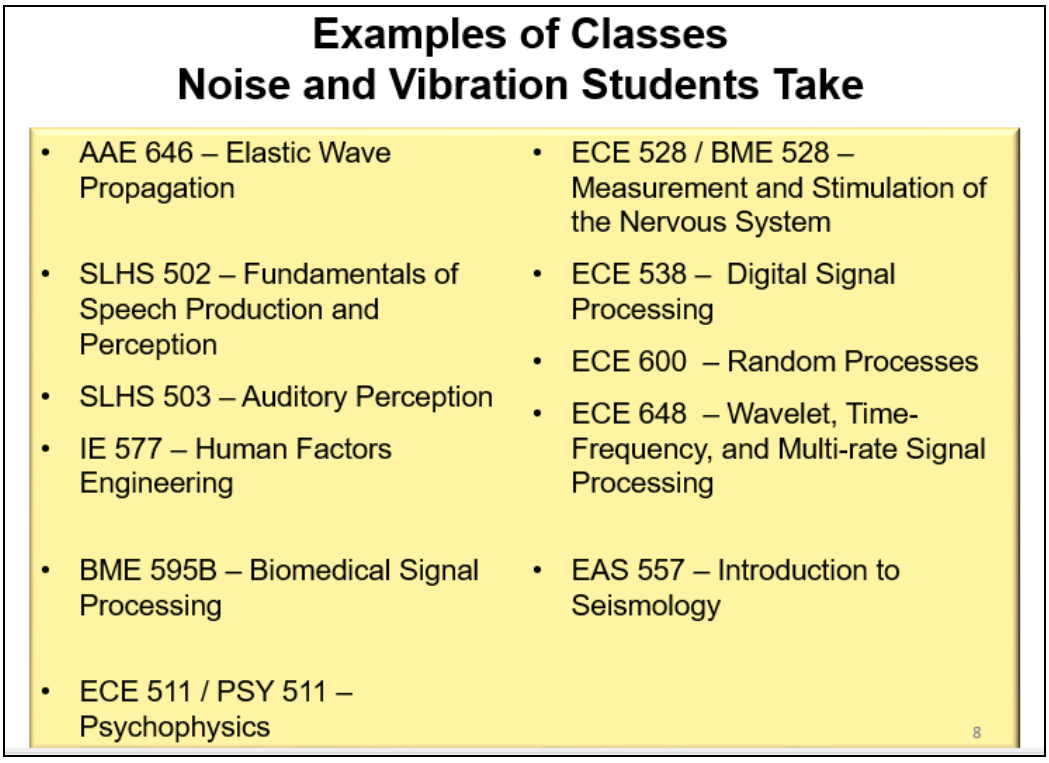


Figure 2.9-4 *Some classes in noise and vibration (slide 2 of 2)*

2.10 Noise Control Engineering Education at the University of Kentucky

David Herrin—University of Kentucky

The University of Kentucky's relatively small Noise and Vibration Program, within the school's mechanical engineering department, boasts an enviable record of graduate student employment by prestigious companies. Much of the credit may go to a unique university consortium via which industry members bring their vibro-acoustic challenges for student-developed solutions, while contributing funds that support these students' advanced education in the field.

David Herrin, with the University of Kentucky, spoke about noise control engineering education at his school, first laying the groundwork with a few statistics. About 30,000 undergraduate students attend the Lexington-based university, and 3,500 of them the school's College of Engineering. As for the Department of Mechanical Engineering, in particular, faculty numbers 41 for about 1,000 undergraduate and 120 graduate students. Research funding amounts to some $10 million per year.

Research areas in the mechanical engineering department come under five defined areas—aerospace, autonomy, bioengineering, energy and sustainable manufacturing—and, not unlike some other universities, acoustics/noise control is not one of these identified areas of research focus. The University of Kentucky does have at least a "modest" Noise and Vibration Program, however, the presenter stated. The program has three primary faculty members, as shown in Figure 2.10-1, with Herrin as the only one with a direct noise control focus.

Noise and vibration courses at the university include mechanical vibrations, engineering acoustics, boundary element methods in engineering, vibro-acoustic design in mechanical systems, and computational techniques in mechanical systems analysis. At the time of the presentation, the program had eight graduate students, seven of them PhD candidates and one pursuing an MS. MS students, Herrin explained, tend to be domestic students and find employment easily. PhD students—who are mostly international—also find positions, but with some extra effort.

Herrin turned next to the topic of the Vibro-Acoustics Consortium at his university, established nearly 20 years ago by Professor Andy Seybert and directed by Herrin himself since 2008. As of the date of the presentation, more than 20 companies participated in the consortium, as listed in Figure 2.10-2. By their support of the university's vibro-acoustics research projects, these companies have spurred the program's growth. The consortium has also allowed the school to obtain a hemi-anechoic chamber, which was built in 2002, and to acquire additional facilities and equipment as summarized in Figure 2.10-3.

Given they are industry-sponsored, consortium efforts tend to be applied research projects, and they are commonly short-term (typically around six months long) and combine simulation and measurement so students become proficient in both. A student typically works on one to three projects at the same time, and the projects can vary greatly from each other, providing a wide range of experience. Students learn by doing—which, Herrin noted, can include making, and ultimately correcting, mistakes. The program's graduate students have been "very successful" in finding employment in the United States, Herrin stated, at companies such as

Amazon, 3M, Ingersoll Rand Corp., Tesla, Cummins, W. L. Gore, Apple, Caterpillar, and Eaton Corp.

The consortium's meetings occur twice a year, Herrin explained. Each "mini conference" represents a valuable opportunity for international students to improve their skills in presenting and answering questions from NVH engineers. And, at these meetings and workshops in between, industry members can benefit from the opportunities to network with each other, as well.

In conclusion, Herrin summarized the benefits of the consortium as a mechanism for funding graduate students in a time of slashed NVH funding, and developing pilot projects that attract funding from government as well as industry—all while working to solve noise and vibration problems facing industry.

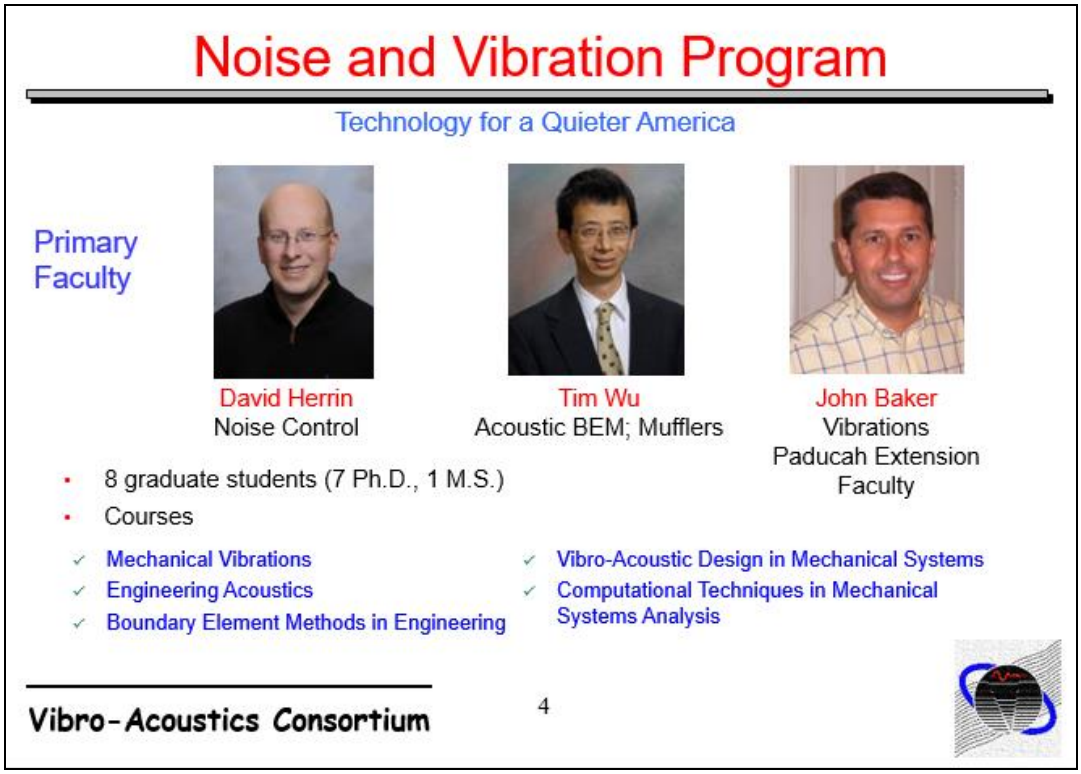


Figure 2.10-1 *Three primary professors teach mostly-PhD grad students*

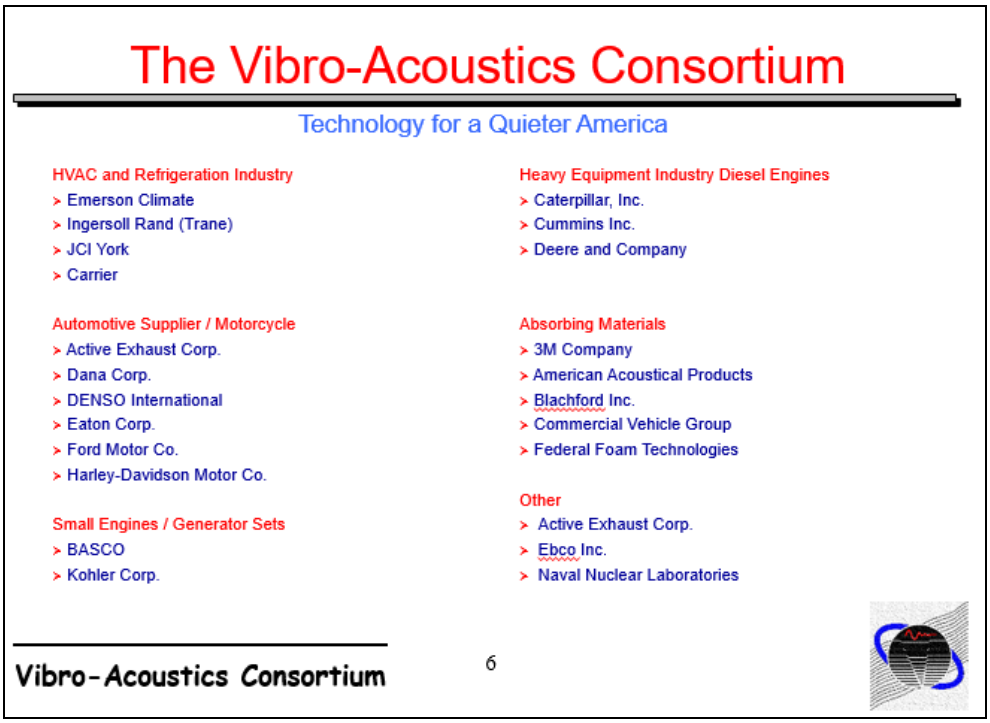


Figure 2.10-2 *20-plus consortium members present real-world challenges, provide funding*

Figure 2.10-3 *Consortium helps support acquisition of facilities, equipment*

2.11 Closing Discussion

Robert Hellweg—Moderator

A discussion period following the presentations on noise control education offered the opportunity for participants to make additional comments and raise remaining questions.

Session participants made points related to a range of issues. For example:

- One participant shared his experience of how he came to pursue his multidisciplinary engineering program as a Purdue undergraduate. His first-year advisor suggested the university's acoustical engineering program might be fitting given the student's interest in music and engineering. He began to gain knowledge about acoustics through hands-on learning in Purdue's theater department and learned acoustics theory during his junior- and senior-year coursework. He discovered the National Council of Acoustical Consultants and became employed at an acoustical consulting firm upon graduation and meanwhile earned his graduate degree through Penn State University's distance education program. "All the professors were wonderful and very knowledgeable," he said of his graduate school experience, "and that helped me grow in my profession as an acoustical consultant/noise control engineer."
- An attendee highlighted a point made by session presenters that graduate students land employment easily, raising the issue of how that demand could be driven home to university administrators and funding sources to address the supply side of this equation.
- Another participant mentioned that industry is seeking comprehensive expertise in noise control approaches and noise control engineering from one person who knows "everything there is to know about noise control." He raised the question of how to meet this challenge by developing talent that is best matched with the need.
- To a question posed by the moderator about whether compensation is increasing in keeping with the high demand mentioned, one attendee responded that yes, compensation for a fitting employee in the field is good, while another answered that some start-up companies and huge organizations provide generous compensation, but that industry consultants in noise control can be offered annual salaries as low as $30,000 or $40,000.
- A participant asked about industrial consortia and the issue of shielding research details from becoming public. Intellectual property is a common issue with research sponsors, another participant responded, and parties to research must discuss this topic. In her experience, the attendee continued, respectful collaboration can enable publication without disclosure of sensitive particulars.
- Replying to a question about the role of a dissertation for distance PhD students, a participant responded that the doctorate program does require a dissertation, and that, for its part, the University of Kentucky takes steps to accommodate students, including funding professors to travel to meet with students rather than requiring the students to come to campus.
- Finally, the point was made by an attendee that use of the once-common term "noise pollution" might serve to gain public support for noise control initiatives, and that

raising awareness of the serious effects of noise pollution could raise interest in projects in the field.

3

INCE-USA Outstanding Educator Award

The **INCE-USA Outstanding Educator Award for Excellence in the Teaching of Noise Control Engineering** is intended to honor a person who has significantly advanced the technology and practice of noise control engineering through unique contributions to the education of future noise control engineers, as demonstrated by one or more of the following qualifying accomplishments:

- Excellence in teaching, whether through the inspired dissemination of the principles of noise control engineering, or by inspiring students to attain high achievement in the field of noise control engineering.
- The notable improvement of tools such as textbooks, laboratory experiments, courses, and student projects for the teaching of noise control engineering in a university.
- Excellence in disseminating the principles of noise control engineering outside of a university setting through the teaching of short courses and seminars; by promoting cooperation among academic, industrial, or government sectors, or with other disciplines; or by advancing the public's understanding of the benefits of noise control technology.
- Enhancing and diffusing the knowledge of noise control engineering through seminal research, scholarly publications, or patents; or the development of noise control materials, products, techniques, or programs.
- Providing sustained and effective leadership for the educational programs and activities of the Institute of Noise Control Engineering.

3.1 Award Recipients

2019 David Herrin

For research of the highest quality and excellent mentoring of his graduate students .

2015 Marehalli G. Prasad

Who has significantly advanced the technology and practice of noise control engineering through unique contributions to the education of future noise control engineers.

2011 Mohan Rao

For teaching graduate and undergraduate courses in vibration, noise control engineering, and acoustics, advising dozens of Masters and PhD students, and exposing his students to real-world community, business, university, and industrial noise control problems. He has also taught short courses in noise control engineering to hundreds of professionals working in industry and

institutions in the US and overseas. He has authored more than 100 technical articles for our profession and his research, and research by his students, has been sponsored by numerous government agencies and major corporations.

2008 Laymon N. and Lucy Miller

Laymon Miller has developed and taught the longest-running and best-attended series of lecture courses on the principles and practical aspects of applied engineering noise control. Since 1969, the courses have been taught to thousands of professionals at dozens of cities and companies throughout North America. He has published extensive lecture notes expanding on and supporting his courses, which have served as a valuable reference for his students. He has also prepared outstanding handbooks and manuals on industrial noise control engineering in use by engineers nationwide. He has served as a trusted and respected mentor for many less-experienced younger associates, and has provided his students and clients a better understanding and awareness of the importance and benefits of acoustics and noise control engineering. Over a period of 60 years, he has prepared numerous scholarly publications, and has given presentations at professional societies. Laymon Miller's course is now taught by Reggie Keith.

1999 J. Stuart Bolton

For Excellence in Education of Noise Control Engineers

1995 Uno Ingard

This fourth INCE-USA Outstanding Educator Award honors the memory of Fritz Ingersley.

For Excellence in Education of Noise Control Engineers

1992 Malcolm J. Crocker

This third INCE/USA Education Award honors the memory of Theodore J. Schultz.

For Excellence in Education of Noise Control Engineers

1989 Rajendra Singh

This second INCE-USA Outstanding Educator Award honors the memory of founding INCE-USA member Ken S. Oliphant.

For Excellence in Education of Noise Control Engineers

1984 Robert F. Lambert

This first INCE-USA Outstanding Educator Award honors the memory of John C. Johnson.

For Excellence in Education of Noise Control Engineers

Hellweg Acoustics

NOISE CONTROL ENGINEERING EDUCATION DISCUSSION SESSION IN SAN DIEGO AT NOISE-CON 2019