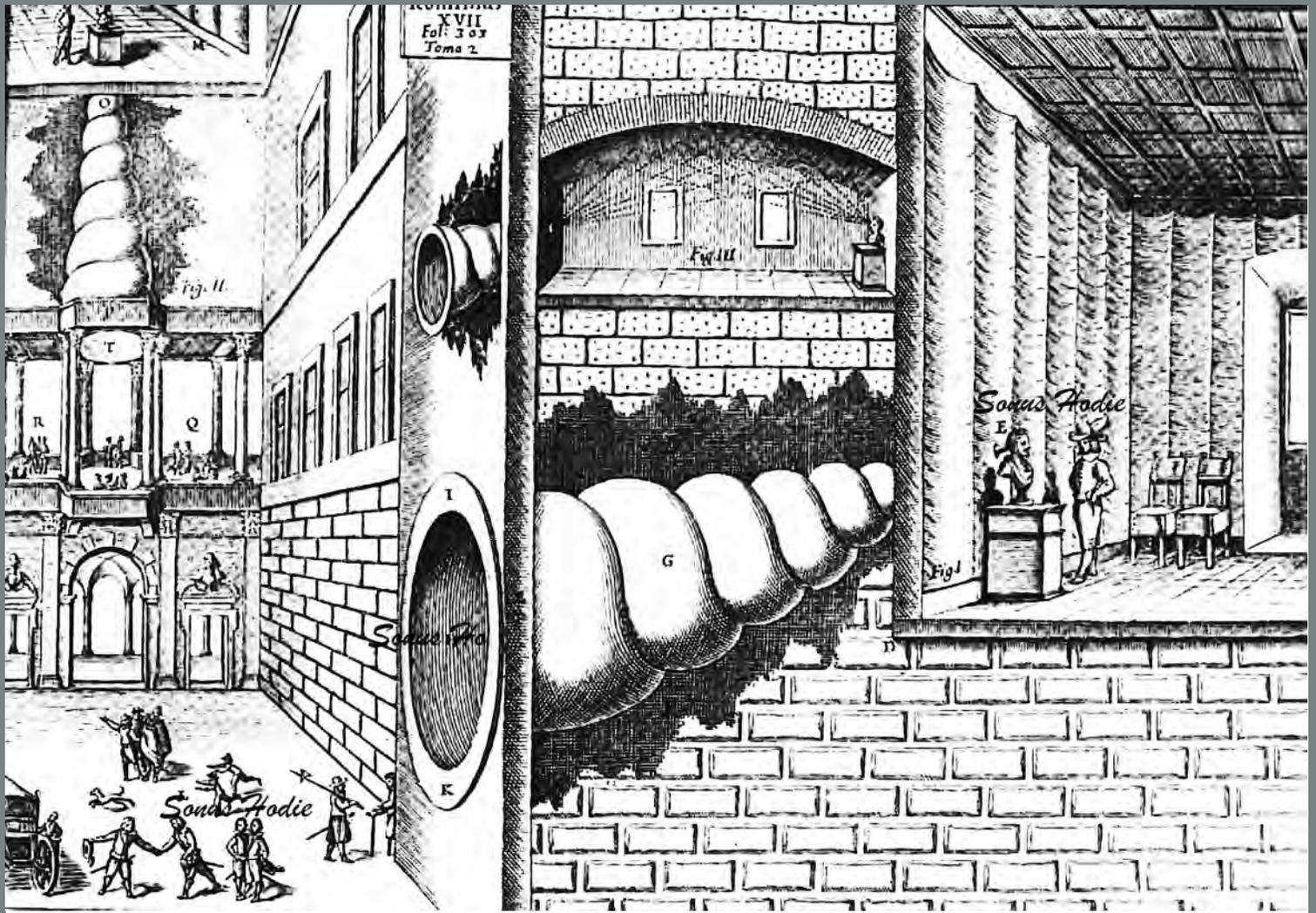


Acoustics Today



Phonurgia Nova
De Motu Soni
et Pluris

*A publication of
the Acoustical Society
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Acoustics in the Seventeenth Century



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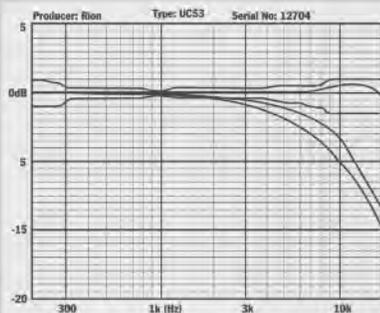
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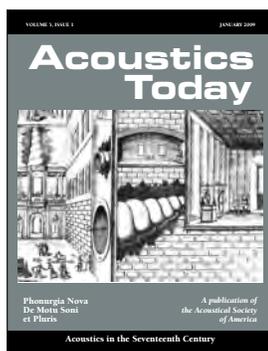
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Volume 5, Issue 1

January 2009



Cover: Athanasius Kircher's world of sound included statues that spoke, the aeolian harp, the megaphone, and reflection. He is credited with inventing (or at least improving) the magic lantern. He attributed the cause of diseases to micro-organisms (and thought that he actually had seen them using a microscope). He used astrology and trusted the existence of griffins and sirens. He was interested in Egyptology, hieroglyphics, anthropology, exploration, and archeology. He built a museum dedicated to his own inventions. He was a man who wanted to know about everything and perhaps most importantly, a showman who knew his audience.

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28 *De Motu Soni*—*William Derham (Translated by James C. Welling, Annotated by Thomas B. Gabrielson)*

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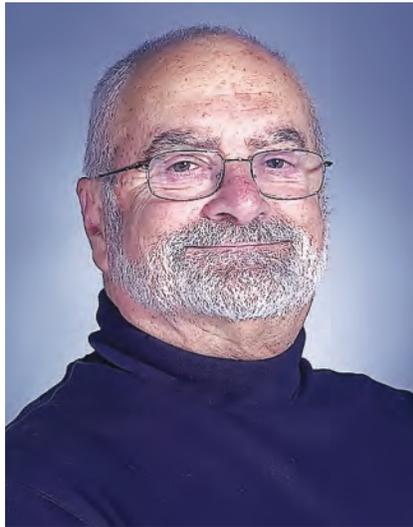
FROM THE EDITOR

Dick Stern

*Applied Research Laboratory, The Pennsylvania State University
State College, Pennsylvania*

This issue contains a new department—*Co-sponsored Meeting Reports*. These are reports of meetings for which the Acoustical Society of America (ASA) is a co-sponsor along with a university or another professional society but plays only a secondary, supporting role. This is contrasted with a joint meeting of two or more professional societies in which each society plays a major role (such as Acoustics '08 Paris). These reports have appeared in the Journal before now but usually have been buried in the seven hundred or so pages of an issue and are found only by those readers who are specifically looking for them. Remember, one of the missions of *Acoustics Today* is to let everyone know what everyone else is doing. We hope that most readers are interested in this issue's report. It is the first international meeting on Audible Acoustics in Medicine and Physiology.

You will notice from the cover and table of contents that this issue of *Acoustics Today* has an interesting theme, Acoustics in the Seventeenth Century. Perhaps the title of the issue should be *Yesterday's*



Acoustics Today. We thought that many of our readers might be interested in the forward thinking of two individuals, Athanasius Kircher and William Derham who lived in Italy and England, respectively, and who are virtually unknown and seldom mentioned in today's books about acoustics.

Finally, a word to the Chairs of ASA's Technical Committees. We hope that the concept of a theme issue of *Acoustics Today* might attract you to think about suggest-

ing one to your committee members. It is a great way to let the society know about your committee's current activities. It takes only three members that are each willing to write a magazine article about their work. Send their names and topics to AcousticsToday@aip.org and I'll do the rest. If you remember, the October 2007 was a theme issue about speech and hearing. This issue is about seventeenth century acoustics. One of the next issues could be yours.

See you in Portland.

Dick Stern

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PHONURGIA
NOVA

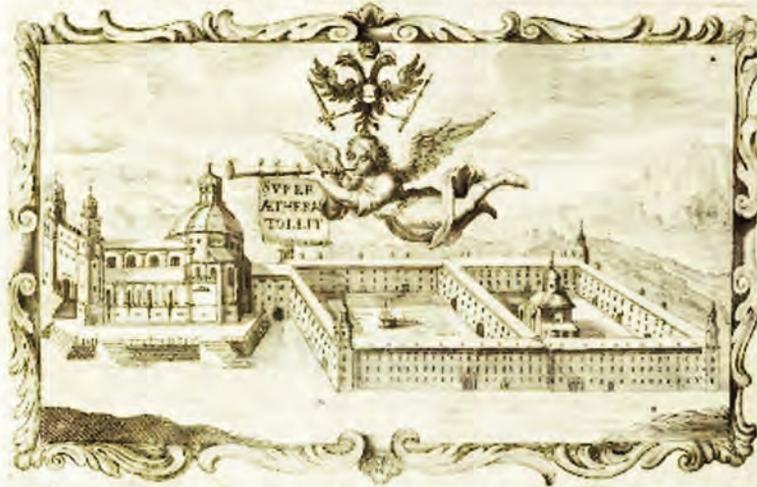
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effectuumq; prodigiosorum Cause, novã & multiplici experimentorum exhibitione enu-
cleantur; Instrumentorum Acusticorum, Machinarumq; ad Naturæ prototypum
adaptandarum, tum ad sonos ad remotissima spatia propagandos, tum in abditis domo-
rum recessibus per occultioris ingenii machinamenta clam palamve sermo-
cinandi modus & ratio traditur, tum denique in Bellorum tumul-
tibus singularis hujusmodi Organorum Usus, & praxis
per novam Phonologiam describitur.*



CAMPIDONÆ

ÆT RUDOLPHUM DREHERR. ANNO M. DC. LXXIII.

ATHANASIUS KIRCHER'S *PHONURGIA NOVA*: THE MARVELOUS WORLD OF SOUND DURING THE 17TH CENTURY

Lamberto Tronchin

Dipartimento di Ingegneria Energetica, Nucleare e del Controllo Ambientale (DIENCA)-Centro Interuniversitario di Acustica e di Ricerca Musicale (CIARM) University of Bologna, Bologna, Italy

Athanasius Kircher

Athanasius Kircher (Geisa, Germany; 2 May 1602– Rome, Italy; 27 November 1680) became a Jesuit in 1628 in Mainz, Germany (Fig. 1). He taught in Würzburg, Germany in 1629 and in Avignon, France in 1631. Afterwards, in 1633, he was invited to Vienna, Austria to take up Kepler's former post as Mathematician at the Court of Ferdinand II. However, during his journey across Northern Italy, Pope Urbano VIII (Barberini) called Kircher to Rome, where he moved and is known to have taught Mathematics and Hebrew at the Collegium Romanum (Fig. 2). After eight years, he was released from teaching, and he

“Kircher’s Phonurgia expresses a wish to enrich and widen the knowledge already existing in the field of architectural and musical acoustics. Written in Latin, the Phonurgia is an original mixture of Baroque aesthetics and sonic enquiry that could be called in Italian “meraviglia” or in English, “wonder,” and yet only a few studies of this fascinating work exist.”

focused exclusively on studying hieroglyphs. At this time he began to collect many items from all over the world, and in 1651 founded his Kircherian Museum.

At his time he was considered a *homo universalis*, since he studied many different topics starting from a single point of view. He studied geology (volcanoes), medicine (he understood that plague is caused by germs and he was the first to use the microscope), history (he invented a theory for translating the Egyptian hieroglyphs using Coptic manuscripts) anthro-

pology, astronomy, mathematics, magnetism, optics, mineralogy, exploration, archaeology and many other various topics.



Fig. 1. Athanasius Kircher in 1664, at the age of 62.



Fig. 2. The Roman College in the 17th Century.

As a typical Baroque academic, Kircher used astrology and trusted the existence of griffins and sirens while at the same time debating against the followers of Christian Rosenkreutz (1378–1484), the Rosicrucians. Kircher's intellectual contemporaries such as Boyle and Newton likewise trusted in alchemy, but whereas these names are celebrated in the history of science, Athanasius Kircher's name is not. His works were considered too much a patchwork of both fantastical and scientific worlds, and despite writing to more than 760 people, including two Emperors of the Holy Roman Empire and scientists such as Leibniz, Torricelli, and Gassendi. Kircher, *doctor centium atrium*, was completely ignored in



Fig. 3. The Kircherian Museum.

the *Dictionnaire historique et critique* of Pierre Bayle (1647–1706) and the *Encyclopédie* of Diderot and D’Alembert and in all the other encyclopedic works written during the Enlightenment.

Kircher’s *Phonurgia nova*

The literary production of Athanasius Kircher is vast, spanning almost every branch of knowledge, including the theory of music. The title of the literary work analyzed in this article contains the neologism, *Phonurgia*,¹ a compound of the Greek words *φωνή* (sound) and *ἔργον* (work, energy). The Latin word *nova* (the entire book was written in Latin) is added, and the title translates as *New Modality of Sound Production*. In the *Explicatio terminorum* (explanatory words) on the last page of the *Phonurgia nova*, Kircher himself defines “*Phonurgia* as *Facultas mirabilium per sonos operatrix*,” meaning “capability to provoke the marvelous by means of sounds.”

This treatise was written during the dispute with the contemporary English engineer Samuel Morland,² who claimed responsibility for the invention of the tuba stentoronica, a “trumpet with a strong sound.” This musical instrument aroused great interest among many contemporary scientists, due to its incredible sound emission potential. Kircher declared that he was the first to have invented it and provided the evidence for this claim in his *Musurgia*

Universalis,³ written twenty years previously. In this work he had already described the “tuba.” Besides, the polemical intention of Kircher’s *Phonurgia nova* expresses a wish to enrich and widen already existing knowledge in the field of room and musical acoustics. The *Phonurgia nova* is an original mixture of Baroque aesthetics and sonic enquiry that could be called in Italian, “meraviglia,” or in English, “wonder,” and yet only a few studies of this fascinating work exist.

After an initial humanistic subordination to classical sources, in the last decades of the 16th Century the growing scientific revolution imposed a radical turning point: the rediscovery of the conic section and the study of the burning glasses of Archimedes, the study of sound propagation advanced from a wave approach to that of ray-tracing, as related to light.

The Venetian Ettore Ausonio began the geometric approach to acoustics, soon followed by Giovanni Battista Della Porta (who wrote the *Magia naturalis*, Napoli, 1589) and by Giuseppe Biancani (author of a *Sphaera mundi*, Bologna, 1635), focusing on sound and modifying the musical scale. The first mathematic development along such lines was due to Bonaventura Cavalieri (*De speculo uestorio*, Bologna, 1632), who was the first to affirm that “...for the sound (instead of to rays of light) during the design, it is necessary to take into account a phenomenon called, in the optical field, *diffraction*.”

The study of the musical world, based on exact laws of physics, interested a large section of eighteenth-century science and culture. Kircher, for his part, revealed a logical, rational approach towards any occurrence of musical phenomenon.

In chapter one of the first book of *Phonurgia nova*, Kircher tackles the problem of the nature of sound. It is defined as a sensitive phenomenon that is perceived by hearing. It is a movement of bodies that are in contact with each other by means of a portion of air interposed among them. For the Jesuit, therefore, the movement of bodies was the fundamental presupposition of every acoustic manifestation.

Kircher’s definition of sound is based on Aristotle and Boethius. Aristotle defined sound as “a determined movement from two bodies that crash one against the other” (*Musurgia Universalis*); Boethius, similarly, believed that the sound was a movement that broke the air up and afterwards reached the ear.

For Kircher, however, sound was not simply a physical phenomenon, as it was for the two aforementioned authors, but also something that was deeply connected with human nature. Kircher’s conception of sound was not yet influenced by the modern theory of oscillations, which was formulated later thanks to the researches of Galilei and Newton, but it already considered the deep relationship between the number of the oscillations (frequency) and the pitch of the sound.

The *Phonurgia nova* is subdivided in two books. The *Phonosophia nova* is the more anthropological: in which Kircher analysed the influences of music on the human mind, inclined towards various types of “affections.” He also developed the concept that the art of sound making can be used effectively for therapeutic purposes. A remarkable example of this is the “tarantolati,” people who were bitten by

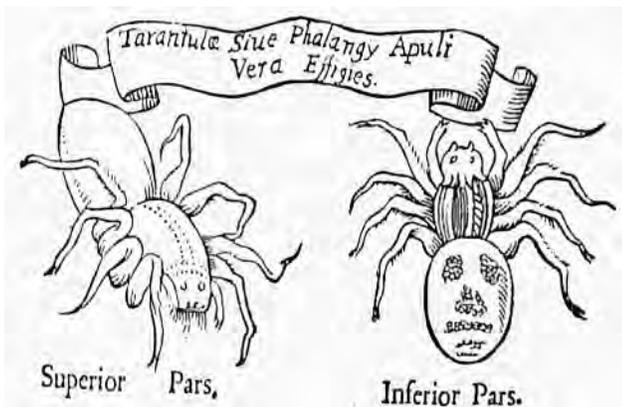


Fig. 4. The tarantula (*Lycosa tarentula*).

the tarantula (Fig. 4), a poisonous spider native to the Apulia Region in Italy (*Aranea Apula...arachneum animal nocentissimum*) that during 17th Century was considered very dangerous. The “tarantolati” (Fig. 5) were considered to be insane because they danced continuously without stopping, and looked like people dancing on a fire, jumping continuously, nervously. They could apparently be healed, thanks to the performance of a particular type of melody and rhythm (*antidotum tarantulae*).

In the *Phonosophia anacamptica*, Kircher was extensively interested in the prodigious phenomenon of echo. He considered echoes to be founded on sound waves that produced reverberation after hitting “obiecta phonocamptica,” or “obstacles,” propagated in air or water. In the same book he deals with sound propagation in tubes of various shapes and typologies, of sound strengthened in natural caves re-emerging at the surface with increased force, of how to listen to other people’s conversations with the aid of tubes and hidden devices while remaining in a concealed room, and how to exchange coded messages by the use of special trumpets.

Finally, Kircher accurately described cars and contraptions that he had himself often invented in order to astonish and amaze people: speaking statues, channels in which sounds and noises were spread, and musical instruments with internal mechanisms that generated unexpected harmonies, playing by themselves depending on the direction of the wind.

The mechanics of the magnificent

Kircher’s works express the typical Baroque vision of the “marvellous world.” All the machines that he invented reveal the strong alliance between science and magic. He wished to amaze, to convince people of improbable things and, finally, to explain the arcane that lies between hermeticism and exact science. From the point of view of the traditional history of science, the inventions of this German Jesuit remained a provocative source of perplexity. Such inventions could hardly be included into “experimental science.” Nevertheless, at that time, the Kircherian Museum (see Fig. 3) was renowned for its great splendour. The Kircherian inventions and other items collected in his museum reveal his audience to be specifically selected. The marvellous exhibits that he conserved and displayed belonged to a large variety of branches of learning, from mechanics to metallurgy, distillation to cosmetics, and magnetism to aerology.



Fig. 5. The “tarantolati.”

Sound entertainment for the aristocracy

The talking statue. Kircher’s talking statue caused a great amount of discussion: some people, following the principles of the occult sciences, believed the statue could have been constructed. They declared that Alberto Magnus built a man’s head that could perfectly pronounce articulate sounds. Moreover, Kircher declared that he had already fully demonstrated in his work, *Oedipus Aegyptiacus*, that the Egyptians had built some statues that were able to speak. Nevertheless, many people asserted this idea was in contrast with natural laws, and they argued that such a device had never been constructed. They declared that the machines of Alberto Magnus and the Egyptians were either fake or built with the help of evil spirits and divinities that gave responses through speaking oracles and statues. Others considered it feasible that a statue could be built with the capacity to pronounce some articulated sounds: following the examples in nature, it would be possible for the wind to animate a mechanical larynx, tongue, and other phonetic organs capable of producing the clear effect of an articulate voice.

However, Kircher did not wish to enter the argument over the famous head of Alberto Magnus or ancient Egyptian devices, because he thought they were impossible in themselves. Therefore he provided an alternative construction method for a similar statue, able not only to pronounce articulate sounds, but even to sing, reply to any solicitations, and to reproduce animal cries.

The text of *Phonurgia nova* relevant to Fig. 6 says:

“Inside a room ABCD, where a spiral-shaped tube (*cocleato*) was put and moved in E or in the vertical conduit S, lies a statue having moving mouth and eyes and having breathing life through the entire mass of the body. This statue must be located in a given place, in order to allow the end section of the spiral-shaped tube to precisely correspond to the opening of the mouth. In this manner it will be perfect, and capable of clearly emitting any kind of sound: in fact the statue will be able to speak continuously, uttering in either a human or animal voice: it will laugh or sneer; it will seem to really cry or moan; sometimes with great astonishment it will strongly blow. If the opening of the spiral-shaped tube is located in correspondence to an open public space, all human words pronounced, focused in the conduit, would be replayed

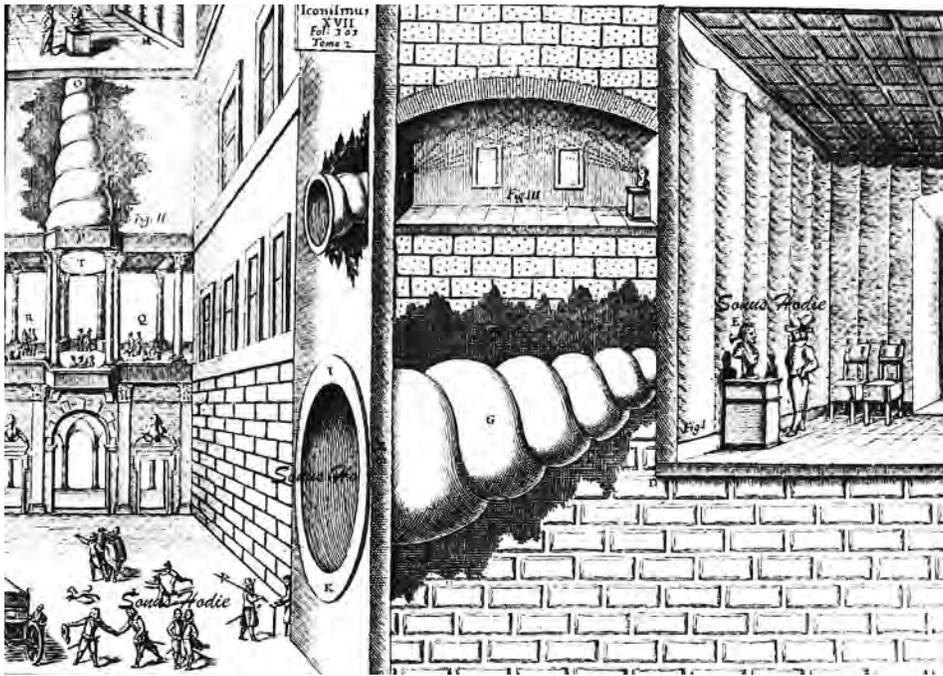


Fig. 6. The talking statues. They would be able to reproduce whispers from the square.

through the mouth of the statue: if it is a dog's bark, the statue will bark, if someone sings, the statue will answer with singing and so on. If the wind blows, this will be taken into the spiral-shaped tube and the statue will be forced to emit very strong breaths. Applying the breath to a pipe, it will play. Bringing a trumpet near to the mouth of the statue, the musical instrument will play and it will make innumerable fun effects of this kind, provided that the spiral-shaped tube is disposed with the greatest of attention."

Analyzing Fig. 6, the section of the conduit becomes narrower from the outside towards the interior, and therefore the air velocity increases to a considerable degree from left to right, inducing the talking effect in the statue. The acoustic mechanism which made the statue talk is substantially a microphone, which Kircher designed as a huge spiral-shaped tube, having the inner surface perfectly polished to reflect the waveforms. It was therefore able to convey the sound from outside into the room.

In the vertical version, (left side of Fig. 6 and in the back of the square) it seems to recall Borromini's lantern of St. Ivo to the Sapienza, even if the inspiration for Kircher was in the "Grotta di Dionigi" in Syracuse. Giorgio de Sepi,⁴ who wrote the first catalogue of Kircher's museum, described this talking statue: "Kircher, in the laboratory of his room, has constructed such a tube that the concierges can call him at the entrance, avoiding to go to his far apartment, but they can stop and call him with a usual voice from the garden."

Sonorous voyeurism. Kircher devoted an entire chapter of his *Phonurgia nova* to the description of many gorgeous architectonic devices developed for worthy nobles, many of whom would have read, or heard, of his work. All these devices are fully illustrated and provided with extensive technical information about their construction.

The *delectationes* were specifically developed to amplify the voice, to communicate at a distance, to send music to dif-

ferent rooms, and even to eavesdrop. Kircher's first described the invention regarding the singular location of certain palatial royal chambers, in which every spoken or whispered word could be heard distinctly, not only in the same space, but also in other rooms. Having explained that conduits suitable for directing sound and inserted into the walls should have a tubular or lengthened shape, Kircher indicated how to construct the building (Fig. 7).

Three receivers D, Z, S, have exactly the same common origin E, corresponding to the window on the floor above (see the drawing in section).

"Inside the room, where the tube (D) captured and channelled the conversation, (i.e., the "D room"), there was a low narrow door, which, in case of

necessity, could be hermetically sealed. In addition there was a window with glass of a crystalline thickness. The same characteristics had to be shared by the rooms Z and S. Sound emitted in one of the rooms, not able to exit by the sealed door nor by the window, was directed toward DE, ZE, SE and conducted through secret conduits, reaching the people on the floor above."

Following Kircher's detailed description, such a device could be feasibly installed and function in a large building.

The "science of the echo"

The first book of the *Phonurgia nova* is called *Phonosophia anacamptica*, i.e., "the science of sound from the perspective of the echo." Performing many experiments, Kircher studied the phenomenon of echo, beginning with its definition given by the Frenchman Marin Mersenne (1588-1648) in his *Harmonie Universelle*. Echo has two different meanings—in the first case *echo* is *imago vocis*—reflected (or repeated) voice. In the second meaning as expressed in Latin is resonance, from the Greek verb *ἤχέω*, (resound). This second meaning of echo is intended as the air in the cavities of a body, as within the Vitruvian vases, or in sound-chests.

The second section of the *Phonosophia anacamptica* is entitled *Architectura echonica*, and describes many experiments Kircher conducted with the phenomenon of echo (see Fig. 8). One of the more interesting experiments is regarding the *obiectum phonocampticum*, which refers to all the objects where the sound or the voice could be reflected, not only from walls and buildings, but also including trees, rivers, and metallic surfaces. During the explanation of his *Echosophia* (the "science of echoes"), Kircher found that air movement causes sound propagation, and wind propagation can influence echo effects as well as weather conditions. This could be considered as one of the most relevant results Kircher achieved in the field of acoustics.

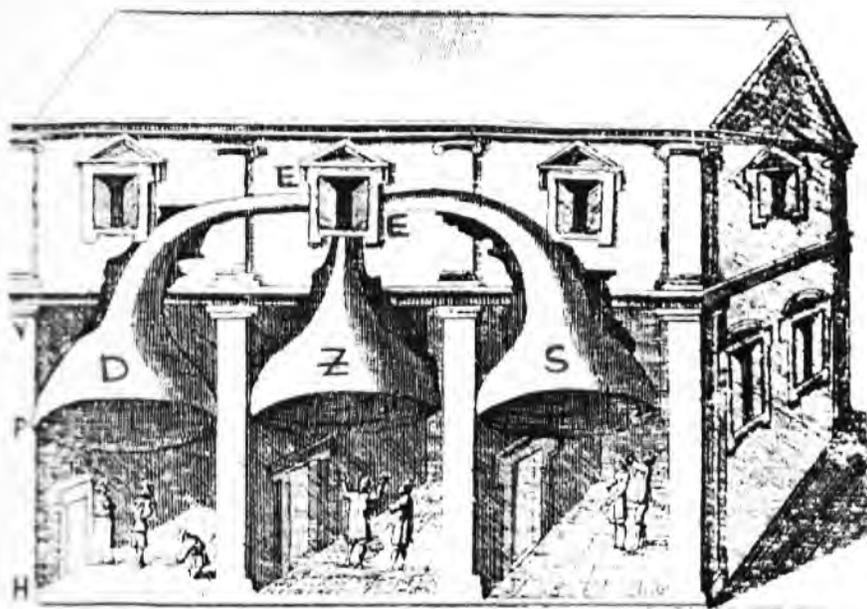


Fig. 7. Amplifiers and conductors of sound.

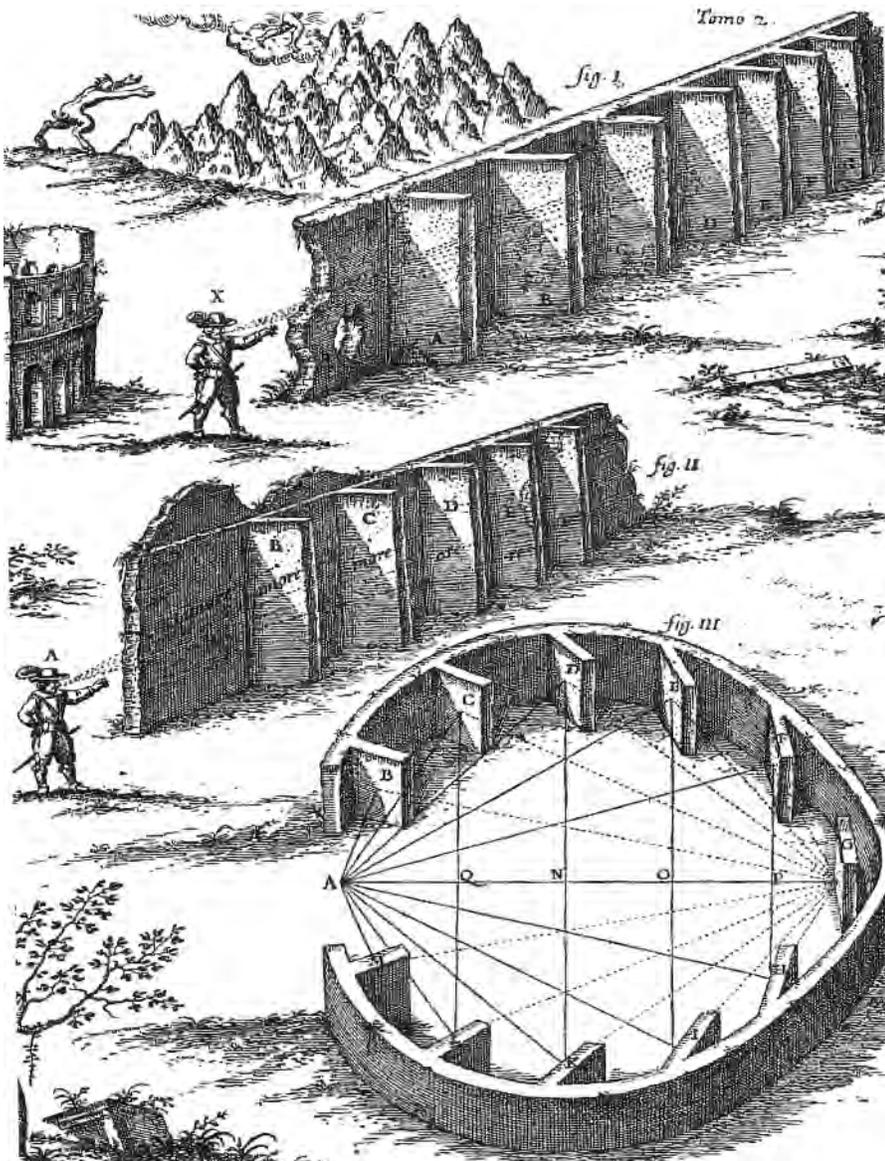


Fig. 8. Experiments with echoes.

Architectural acoustics. Section IV of the first Book of the *Phonurgia nova* also illustrates typologies and modalities of constructing buildings together with architectural acoustics, and the description of particularly interesting places, according to Kircher, from the point of view of their acoustic potentialities. Some of these places still exist today, and they have been famous since antiquity. In these cases, Kircher tried to comprehend the recondite modality of the production of particular sonorous effects or to explain their inner architecture. However, there are a few places he describes in detail which are actually pure Kircher inventions, intended to give entertainment, delight and provoke the curiosity of the contemporary wealthy nobility.

Heidelberg's echo. In Section IV of the first Book of the *Phonurgia nova*, Kircher described the interior structure of the Palace of the Powerful Elector of Heidelberg that he personally visited. Inside the palace, there was a particular room characterized by an extraordinary echo. Within the circumference CGEF (Fig. 9), words spoken in a soft voice at C could be perceived by another person at positions C, G, or F. The same phenomenon is present within the cupola of the Basilica of St. Peter in Rome (the whispering gallery). This room in the palace of Heidelberg possessed a remarkable capacity to amplify sounds, due especially to its circular shape and the vaulted ceiling, which contributed to a surprising acoustic effect. However, Kircher

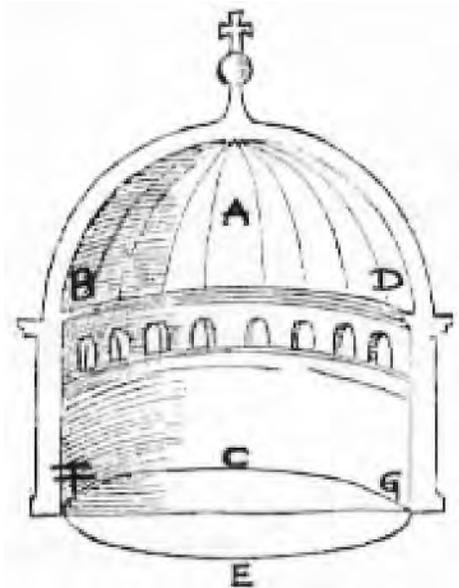


Fig. 9. Heidelberg's echo.

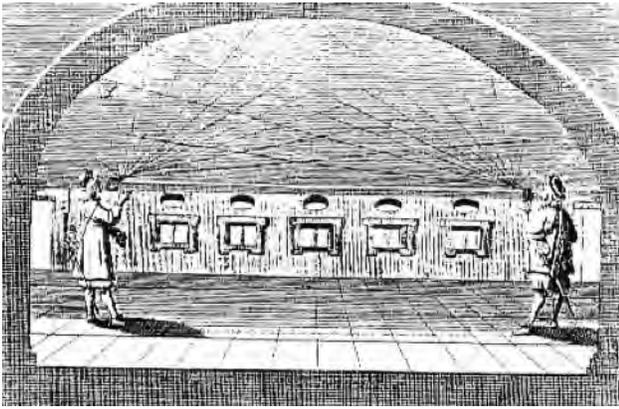


Fig. 10. The elliptical room. As with Heidelberg's echo, Kircher studied the effect of the ceiling shape.

analysed in particular the floor of the room, presuming the material used could contribute to the special acoustic effect. At that time, pavement in the so-called "Venetian style" became fashionable and extensively used in many palaces. This type of pavement, which still exists in several ancient palaces, is a mixture of mortar and stones; besides giving a pleasant aesthetic effect, once trampled, produces a singular sonorous effect Kircher emphatically compared to a thundering crowd rushing in threatening pursuit.

The elliptical room. Kircher demonstrated his knowledge that the geometric shape of rooms would influence acoustic behavior. One of his most interesting studies is regarding the capability of elliptically shaped ceilings to transmit and reinforce the voice better than any other shape. Kircher understood that the ellipse, which has two foci, could be used for the construction of a room. With an ellipsoidal vault it would be possible to use these two foci for two people to communicate easily with each other at a distance (Fig. 10). Kircher's intuition and consequent observations were of course correct. In the ellipse every outgoing straight line from a focus will be directed to the other focus. Moreover, the more reflective the surfaces, the more concentrated are the sounds. In such a case the property of restitution of the sound is effective and surprising. In order to strengthen his observation, Kircher also suggested the surfaces of the inner walls of the ellipsoidal vault should be cleaned with a mixture of water and Arabic rubber to optimise the acoustic effect.

Villa Simonetta. The description of the Villa Simonetta, "just outside the Door of the Gardeners" in Milan, was of particular interest. Ferdinando Gonzaga, the Governor of the city at that time, built the villa and, as Kircher relates, it became more famous for its echoes than for its extraordinary and admirable

architectural symmetry. On the first floor there is a window (Fig. 11) where every word that is uttered projects reinforced in intensity and echoed four-fold. Moreover, if the words are projected with a stentorian voice, they are multiplied so many times they can be heard almost infinitely. Kircher, having heard from many people about the singular acoustic phenomenon in the villa, decided to discover what caused it, and therefore satisfy his own curiosity. He declared that P. Matteo Storr, a faithful and erudite clergyman of the Company of Jesus, already observed and diligently annotated the dimensions of the building and its architectural details.

The Villa Simonetta complex consists of three parts around a great courtyard opening at the back towards a luxuriant garden. The façade is comprised of two porticoes with ten columns on each floor. The building has two floors separated by an ambulatory. On the ground floor, paving stones comprise the zone indicated by the letter K in Fig. 11. Laterally and parallel to this are the other two blocks, labeled XMVN and GFHL respectively. After having accurately described the measurements (height, length and width) of the three zones divided into dwellings, Kircher then moved his attention to the window where the famous echo is produced.

Some witnesses reported to Kircher that at this location the voice was multiplied 24 to 30 times according to its pitch. Kircher identified the cause of this as the proportional distance between the two parallel areas of the building, and in their perfect equality and absence of surface roughness. Furthermore, he demonstrated this thesis with the aid of a drawing (Fig. 12). Let us consider the walls AC and BD, which correspond to the two parallel zones of the Villa Simonetta; they are placed at a distance where it is possible to perceive, by means of the echo, words with two-syllables.

With the treatment of echo in the *Phonurgia nova*, Kircher made a remarkable contribution to feeding the

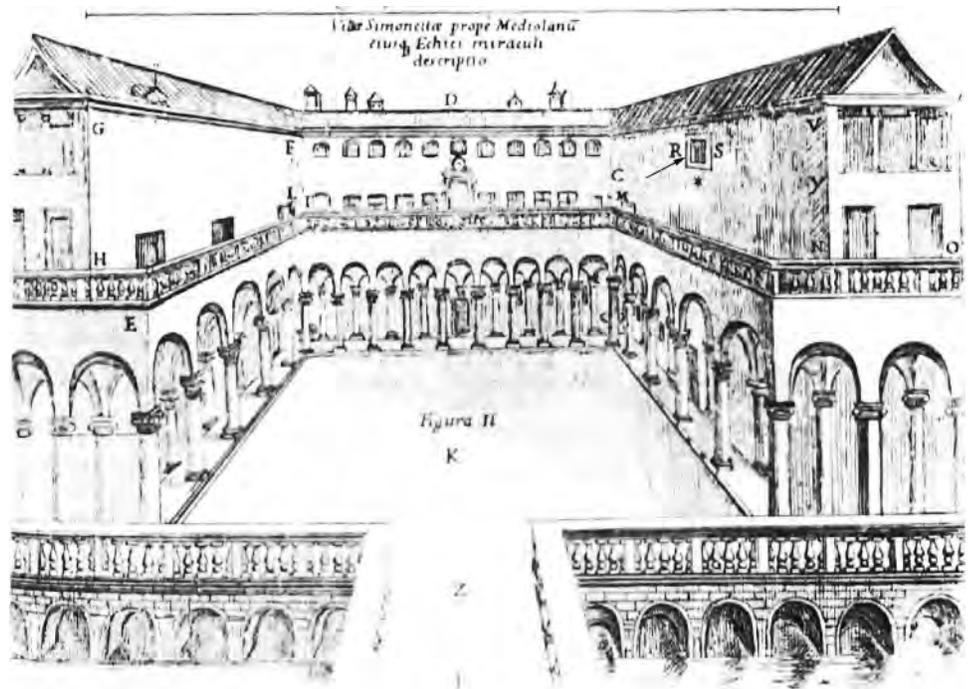


Fig. 11. Villa Simonetta.

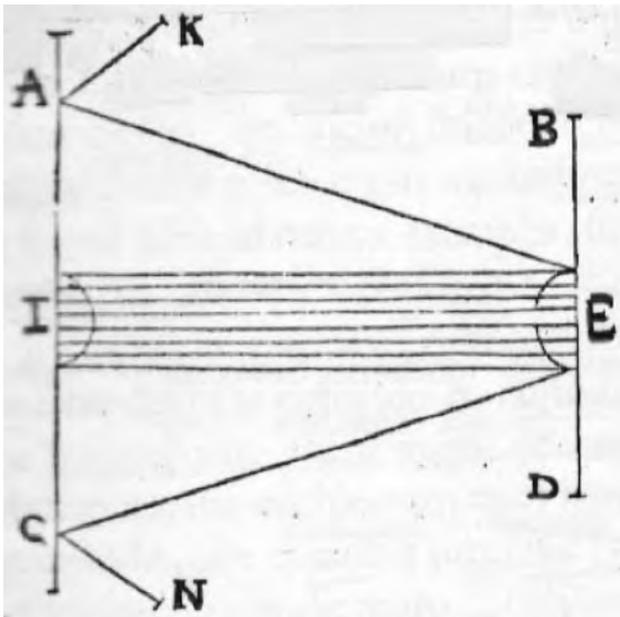


Fig. 12. Demonstration of echoes in the Villa Simonetta.

curiosity and interest surrounding the Villa Simonetta, the history of which is long and troubled. Some people prefer to call it evocatively the “Villa of the Echo,” following a popular tradition that Kircher helped establish. Today the Villa Simonetta is an important cultural centre that organizes concerts and courses.

Conclusions

Kircher’s complex symbolic universe is most expressly revealed in his machines. From appearance alone, they seem to be mere simple games, but by creating unexpected connections he surprises and invites the enquiring mind to question and investigate further.

The *Phonurgia nova* exhibits a rich and consistent playfulness that works on several levels—the religious, mystical, esoteric and scientific. Every theorem is described with the



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rigor of a geometric demonstration—hypothesis, corollary, explanatory images, solutions—but Kircher does not wish simply to extract data, but focuses on a particular element in order to formulate a law, transcribed with mathematical and geometric certainty that a particular phenomenon can be experimentally repeated.

The illusions induced by Kircherian devices are intended to provide evidence of the inadequacy of the human mind compared with the mysteries of Nature. Nevertheless, they do give us an intriguing vision of 17th century scientific concerns.

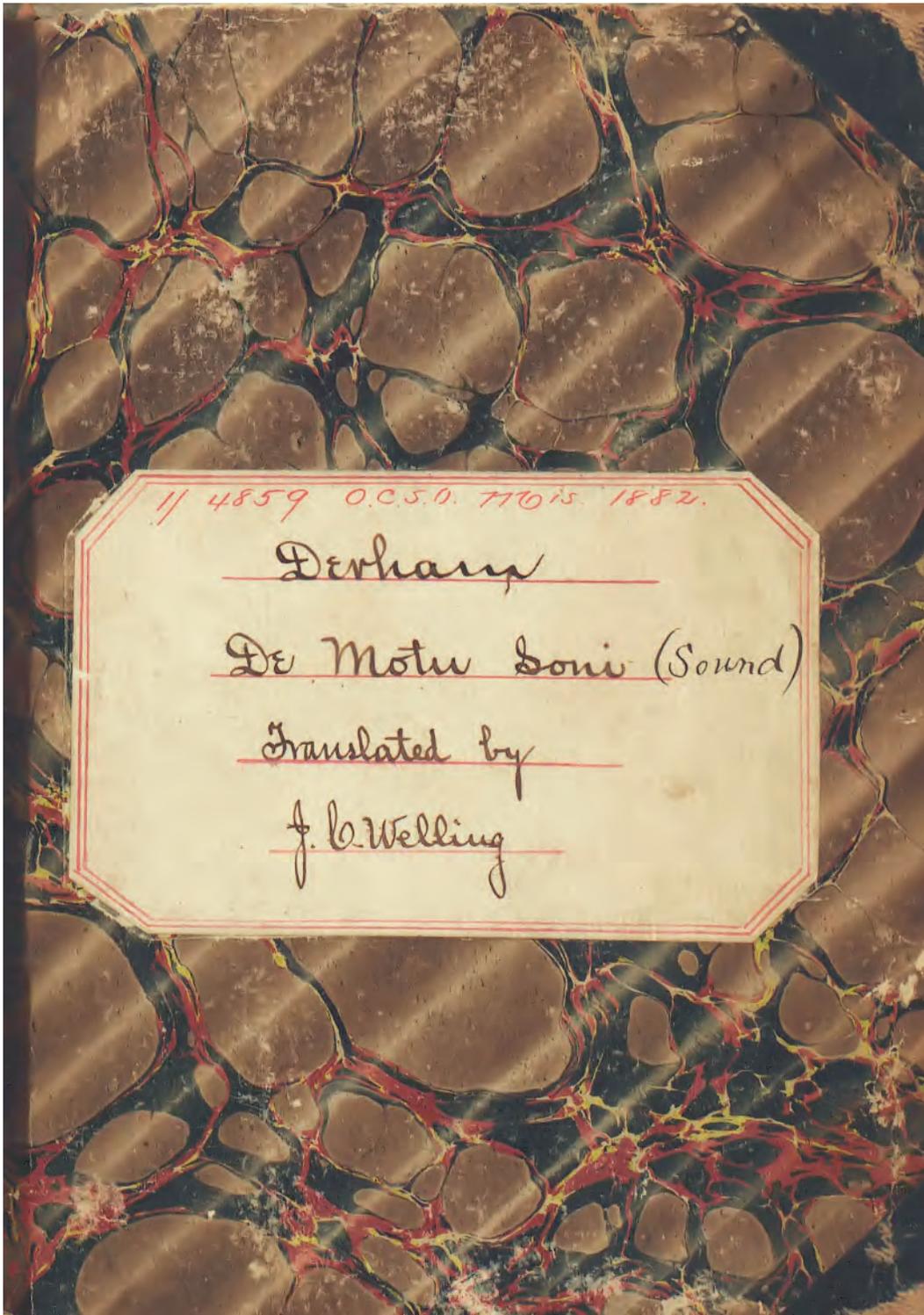
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The author expresses his acknowledgment to Galia Mastromatteo, who contributed considerably to the translation of the *Phonurgia nova* from the original Latin, to Paolo Gozza who gave precious suggestions about Kircher, and to David J. Knight, who proofread the English. [Note: This article was initially published in *Proceedings of Meetings on Acoustics* 4, 015002 (2008)].AT

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BACKGROUND AND PERSPECTIVE WILLIAM DERHAM'S *DE MOTU SONI* (ON THE MOTION OF SOUND)

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State College, Pennsylvania 16804

Author's note: To make this article consistent with the following article and easier to read, I have enclosed footnotes and comments in square brackets, printed them in blue, and placed them in the article where their reference numbers would have appeared.

Introduction

In 1706, the Rector of St. Laurence's Church in Upminster, William Derham, traveled to the eastern coast of England on a mission. [W. Derham, "De Motu Soni," *Philosophical Transactions*, Vol. 26, (1708 - 1709), pp. 2-35.]

"But that nothing might be wanting in confirmation of these facts, I made a journey to Foulness Sands on our Essex Coast. These Sands, washed and covered by the daily time of the sea, make a great and smooth plain for many miles. Upon this plain I measured off only six miles, because neither the time nor my leisure permitted that I should measure a greater distance. At the end of almost each mile I made experiments by the firing of muskets, not without great peril to my life from the influence of the sea and the darkness of night. From these experiments I found that all my former observations were most exact and true, to wit, that sound traverses one mile in $9 \frac{1}{4}$ half seconds..."

Measuring the speed of sound was a hobby for Derham. Though infrequently referenced in modern literature, Derham's measurements over a period of several years overshadowed previous efforts in quantity, quality, and supporting weather observations. He not only confirmed the inaccuracy of Newton's prediction for the speed of sound in air; his measurements also exposed the role of wind in the apparent speed of sound.

Nearly 170 years later, the American scientist Joseph Henry organized a series measurements along another coast, the southern coast of Block Island in Long Island Sound: [J. Henry, *Scientific Writings of Joseph Henry, Report of the US Light-house Board for 1875*]

"...on the 19th of August [1875] ...General Woodruff and Dr. Welling, starting from the bottom of the cliff below the light-house, went along the beach, one [to the east]...and the other [to the west]. General Woodruff found that the sound of the siren was distinctly heard all the way to the breakwater...Dr. Welling...entirely lost the sound within a quarter of a mile...the wind was in the direction traversed by

"Derham's extensive collection of sound speed measurements forced Newton's hand; Newton's prediction was well below the range of Derham's measurements."

General Woodruff and contrary to that of Dr. Welling..."

Although it was not obvious at the time, Henry's experiments, inspired by the work of Stokes and Reynolds, were part of a revolution in understanding the role of wind in the propagation of sound. The strange behavior of sound had evoked recurring comment for at

least two hundred years. At times, the smoke and flame of nearby gunfire could be seen clearly but the gun's report could not heard; at other times, cannon discharging far from sight could be heard distinctly. Some of these stories inspired Rev. Derham—a Fellow of the Royal Society of London—to conduct several years' worth of experiments; some of the same stories led Henry and Dr. James Welling to the beaches of Block Island.

Joseph Henry is well known, though mostly for his contributions to the study of magnetic fields (the unit of electrical inductance is the henry). In contrast, neither Welling nor Derham appear with any frequency in the literature of acoustics. Welling and Derham were both amateur physicists. Welling was the President of Columbian University—later renamed George Washington University— and an anthropologist by vocation; Derham was Rector of the Upminster parish of the Church of England. Both published on acoustics, Derham in the *Philosophical Transactions* of the Royal Society, Welling in the *Bulletin of the Washington Philosophical Society*.

Welling's interest in Henry's experiments on sound led him to Derham's paper; however, Derham's paper was published in Latin. Rather than relying on fragments of translated passages in other papers, Welling translated the entire paper into English. Welling presented his handwritten translation to the U.S. Weather Service in 1883 and the manuscript survives in the Rare Books Collection at the NOAA Central Library in Silver Spring, Maryland. [A high-quality scanned version of the handwritten manuscript is available on line. See http://docs.lib.noaa.gov/rescue/Rarebook_treasures/QC222D91708.pdf]

In the decades preceding Henry's experiments, there were two competing theories regarding the surprising behavior of sound in the atmosphere. Alexander von Humboldt, during his 1799-1800 expedition to the Orinoco River basin,

observed that the sounds of cascades on the river were louder and clearer at night even though the tropical forest was noisier at night. Humboldt reasoned that small, turbid irregularities in the atmosphere caused by solar heating of the ground during the day might scatter and attenuate sounds over relatively short distances. The British acoustician, John Tyndall, embraced Humboldt's explanation, named the turbid irregularities *flocculence*, and interpreted many observations as consequences of this flocculence.

In contrast, George Stokes had reasoned in 1857 that the normal increase in wind speed with height above the ground would bend or refract sound waves causing them to be lifted above the ears of observers upwind of the source and bent back down to observers downwind. Two decades later, Osborne Reynolds provided convincing proof of Stokes hypothesis over short ranges. At that time, Joseph Henry was head of the US Lighthouse Board and charged with evaluation of acoustic fog signals to supplement coastal lighthouses. Henry believed that refraction, not flocculence, produced the wide variation in audibility of these acoustic signals.

The experiments of Derham and Henry bookend a collection of adventures in understanding the transmission of sound through the air. Intervening events are chronicled elsewhere [For example, T. Gabrielson, "Refraction of sound in the atmosphere," *Acoustics Today*, 2006]; here we consider the contributions of the largely forgotten Rector of Upminster.

In 1708, Derham published what was, at the time, the seminal paper on the propagation of sound in the atmosphere. His decision to write this paper in Latin may have resulted in wider readership across the Continent in the 1700's, but, by the 1800's, researchers relied largely on a small collection of translated excerpts in contemporary publications. An abbreviated translation was published in the *Abridged Transactions of the Royal Society* in 1809 but it was not until James Welling took an interest in Henry's experiments that the complete paper was translated into English.

Derham's paper is important for several reasons. First, he addressed the question of the speed of sound in far greater depth than anyone else had. In 1697, Isaac Newton—a more senior member of the same Royal Society to which Derham belonged—published the first edition of *Principia*, his treatise on physics. In this work, Newton predicted what the speed of sound should be based on the density and static compressibility of air. Contemporary measurements of the speed of sound had sufficient variation that Newton found values both above and below his prediction; consequently, Newton was unaware how far his prediction was in error.

By 1708, however, more careful measurements suggested that Newton's value was about 20 percent low. By far, the largest set of these measurements was assembled by Derham. Derham and others had reduced the measurement uncertainty sufficiently far that Newton's prediction was no longer tenable. In subsequent editions of *Principia*, Newton wove several creative and ultimately unsupportable arguments as to why his values, if properly corrected, did in fact agree with measurement. [See R. S. Westfall, "Newton and the fudge factor," *Science* 179, 751-758, 1973. For example, Westfall writes "...[Newton's] use of the 'crassitude' of the air particles to

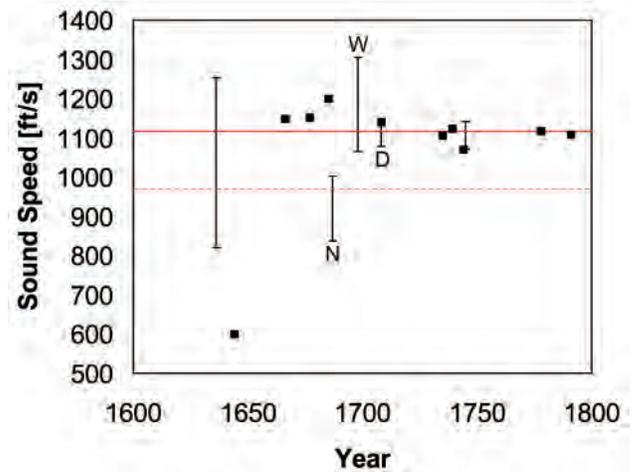


Fig. 1. Early measurements of sound speed. Insofar as is possible, the measurements are referred to 15°C and ranges are shown where there is sufficient information to present them. Three of the ranges shown are: (N) Newton's, (W) Walker's, and (D) Derham's measurements. The solid red line is at the value for the sound speed at 15°C; the dashed red line is Newton's prediction for sound speed. The spread in published values dropped dramatically with Derham's 1708 paper. (Values from Lenihan (1952), Walker (1698), and Derham (1708).)

raise the calculated velocity by more than 10 percent was nothing short of deliberate fraud.”]

Newton should have quit while he was ahead. His calculation was flawed but neither he nor anyone else of that era understood the consequences of the miniscule temperature changes experienced by air under normal acoustic compression and expansion. Another century and a half would pass before the consequences of coupled temperature and pressure oscillations during the passage of an acoustic wave were understood clearly. [See B. S. Finn, "Laplace and the speed of sound," *Isis* 55(1), 7-19, 1964.]

Derham's extensive collection of sound speed measurements forced Newton's hand; Newton's prediction was well below the range of Derham's measurements. (See Fig. 1.)

However Derham's work was much more than a simple table of sound speed measurements. He investigated the effects of atmospheric conditions on the propagation of sound—both as regards speed and intensity. He established definitively that sound propagation was faster with the wind and slower against the wind.

Naturally, Derham's work was also naïve: he dutifully recorded barometric pressure that has little effect on sound speed or propagation, and did not record temperature that does influence sound speed and propagation. At the beginning of the 18th century, however, these errors are understandable—wind has a far larger effect on sound speed than temperature and it would have been difficult to arrange an experiment to isolate the smaller temperature effect; even Newton failed to emphasize the connection between temperature and sound speed in his theory. [Newton's prediction for sound speed was wrong because he used the static compressibility of air instead of the dynamic ("adiabatic") compressibility. But he still would have known that density of air is a function of temperature and that would have made his isothermal sound speed a function of ambient air temperature. Had Newton suggested explicitly that there should be a dependence of sound speed on ambient temperature, the

other members of the Royal Society—including Derham—would have looked for it.]

Measurement of the speed of sound

How was sound speed measured at the turn of the 18th Century? Often by the obvious method of observing both the flash of a gun or cannon and the subsequent report. Timing was accomplished by observing the oscillations of a simple pendulum. The natural decay of the pendulum amplitude limited the usable propagation time.

Derham opens his paper on sound with an analysis of the work of previous investigators. When confronted with the wide range of values for sound speed presented by others, he isolates two critical issues: (1) the difficulty of watching the oscillations of a simple pendulum while at the same time watching for the flash of the gun to start the timing, and (2) the uncertainty inherent in using a short distance from gun to observer for a speed measurement.

Derham understood that using a clockwork pendulum would yield better results than a simple pendulum for two reasons: each half-cycle produces an audible “tick” so the observer can concentrate on watching for the flash of the gun; and the oscillations do not decay so longer measurement times and distances can be used. With his background in clock mechanics, Derham equips himself with a state-of-the-art pendulum clock that he himself tuned. Realizing that the error associated with a short baseline contributed to the wide variation in sound speed values in the past, Derham made the measurements over as long a distance as he could.

The location and elevation of his church tower at Upminster allowed a clear line of sight to the artillery training ground at Blackheath 12.5 miles distant and Blackheath provided a ready source of cannon discharge.

But there were other clever methods of sound-speed measurement. Joshua Walker (1698) gives fascinating insight into echo methods:

“...and standing over against a high Wall I clapt Two small pieces of Boards together, and observed how long it was e’re the Echo returned, and I removed my Station till I found the Place whither the Echo return’d in about half a Second. But that I might distinguish the time more nicely, I clapt every Second of Time Ten or Fifteen times together; so that by this Means I could the better discover whether the Distances betwixt the Claps and the Echoes, and the following Claps were Equal. And though it be very difficult to be exact, yet I could come within some few Yards of the Place I sought for, thus: I observed the Two Places where I could but just discover that I was too near, and where I was too far off...”

In Walker’s account, clapping pieces of wood together gave a sharp sound with a distinct echo. By adjusting the distance to a wall, the experimenter can find a point of coincidence between the clap-and-echo time and the period of a simple pendulum. Rather than timing the echo over an arbitrary distance, the difference between the echo-return time and the pendulum oscillation time is adjusted to be as close to zero as possible.

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Walker makes a further refinement of the echo method. He discovered that it is quite natural to develop an alternating rhythm: clap-echo-clap-echo, with equal intervals between echo and clap. Instead of attempting to match a single clap-echo against a single swing of the pendulum, he establishes this rhythmic clapping and compares it to multiple swings of the pendulum.

This rhythmic clapping is brilliant. Human ability to establish such a rhythm is remarkable—a series of claps can be evenly interspersed between the series of echoes with a remarkable uniformity of interval. [It is, however, all too easy to get bad results. Care must be taken to select a wall without overhangs, steps, or inside corners. All other reflectors must be sufficiently distant to have no influence. And changes in ambient noise can distract sufficiently to upset the rhythm.]

Had this technique been pursued more seriously, it may have been capable of the precision required to determine the temperature dependence of sound speed 50 years before it was actually measured. Matching the periodicity of the clap-echo pattern with the periodicity of the pendulum is an early variety of synchronous averaging. Over a long period of observation, the clapping rate and the pendulum rate could have been matched closely by either increasing or decreasing the distance to the wall. Walker used a simple pendulum—a lead bullet on a wire—and this limited the period of observation as the pendulum's oscillation decayed. [In addition trying to keep the required rhythm while both listening for echoes and watching the pendulum would very likely have created problems. It would have been difficult to avoid unintentional phase locking between the clapping rate and the pendulum unless a second observer was used. If Walker had concentrated only on clapping the boards and a second observer watched the pendulum, this could be avoided.]

Walker suggested the use of an “automatic” clock but apparently did not try it himself. If Walker had Derham's automatic clock and if Walker had chosen to perform the echo experiment on the coldest and hottest days available to them in England, he may have uncovered the temperature dependence of sound speed.

What would have been required to see the temperature dependence of sound speed and could such an experiment have succeeded in 1700? In air, the speed of sound (in m/s) is equal to 20.05 times the square-root of the absolute temperature in kelvin (the temperature in celsius plus 273.1). Consequently, the variation in sound speed with temperature in the vicinity of 15 °C is 0.59 m/s per degree celsius. From winter to summer in England, it would not have been difficult to find temperatures from at least 0 to 25 °C. This temperature range would produce a seasonal sound speed difference of almost 15 m/s—slightly more than 4 percent. Derham claimed a timing resolution of 0.25 seconds. With this timing resolution a total travel time of at least 6.25 seconds would be just sufficient to resolve a 4 percent difference in sound speed. A measurement of ten times that duration would resolve easily the 4 percent variation in sound speed. So the question reduces to this: can we design an experiment to give a one-minute period of coherent observation? Derham's timing measurements from Blackheath to Upminster had a travel time of about 60 seconds but the

dependence on wind is so strong that it would have been challenging to uncover the temperature dependence. [Furthermore, refraction—unknown to anyone at that time—would have confounded the interpretation. It would have been natural to select the coldest conditions and compare those results to the hottest conditions but these two extremes would most typically be accompanied by significantly different actual path lengths because of differences in refraction.]

If, however, rhythmic clapping in the echo method could be maintained for 60 seconds, there would be a chance of success. In the echo method, the effects of wind are second order and a short baseline would avoid the effects of refraction. A careful, rhythmic echo measurement may have uncovered the temperature dependence of sound speed using the clocks available in 1700.

Of course, echo methods are not suitable for assessing the effects of wind. A round-trip measurement has a much weaker dependence on wind speed than the one-way measurement. [It is sometimes naively stated that the echo method cancels any effects of wind but that is not true. The round-trip measurement cancels the *first-order* influence of the wind but the measured speed still depends on the square of the ratio of the wind speed to the sound speed. In addition, the error introduced by the wind biases the round-trip measurement—the measured speed is always less than the thermodynamic sound speed regardless of the direction of the wind.]

In retrospect, what is surprising is that the echo methods did not produce particularly good results in the late 1600's and early 1700's. Even Walker who seemed to have an exceptional grasp of the structure of a good measurement did not produce a particularly good value for sound speed. For the eleven measurements he reports, the average (with one standard deviation) is 1305 ± 120 ft/s. By and large, the credible measurements were long-baseline, one-way measurements by flash-and-report timing of guns or cannons. Furthermore, long one-way measurements were necessary to identify the effects of wind.

Like Walker, Derham believed that an “automatic” clock was a far better measurement tool for sound speed measurement than a simple pendulum. Walker describes the typical timing pendulum as a length of cord or wire with a lead bullet crimped onto the end. This is, in fact, the apparatus described by Newton in his measurement of sound speed. Newton's approach was a modification of the simple echo method but not as elegant as Walker's. Newton located himself 208 feet from a reflecting wall and compared the echo transit time to two pendulums. [This is the experiment described in the first edition of *Principia*.]

He noted that the echo returned before one half-cycle of an 8-inch pendulum but after one-half cycle of a 5.5-inch pendulum. From these observations, Newton concluded that the speed of sound must be greater than 920 ft/s but less than 1085 ft/s. These values bracketed his flawed prediction of 968 ft/s so he had little incentive to refine the measurement. [Convincing experimental evidence that the value of 968 ft/s was far too low came after the first edition of *Principia*. Newton did try again later with revised results published in the second and third editions.]

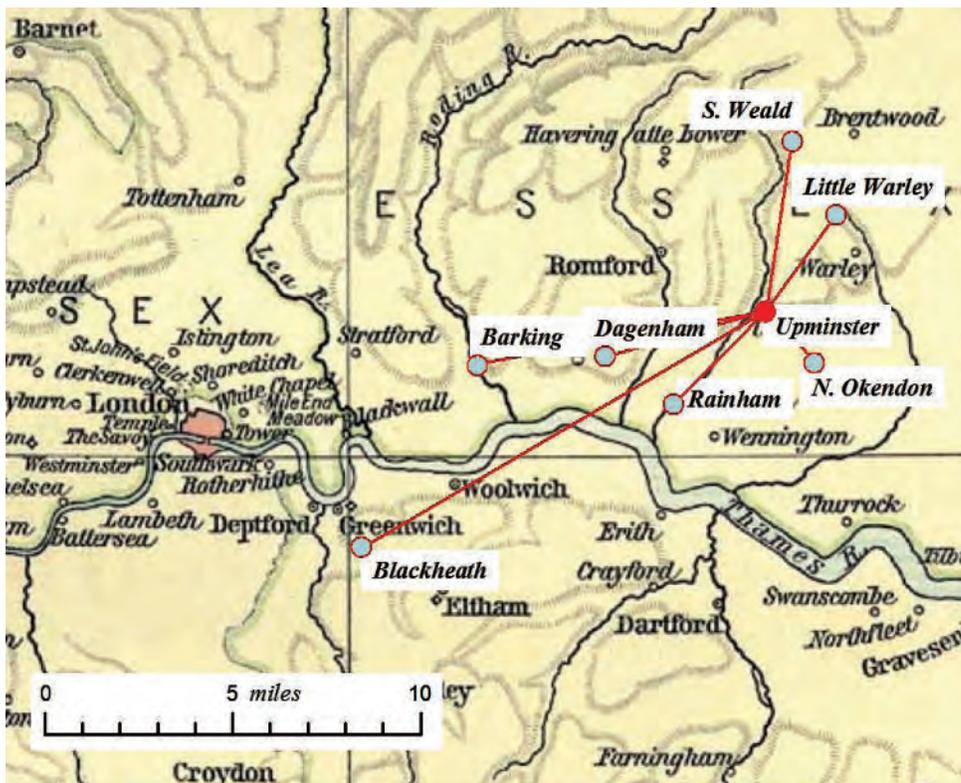


Fig. 2. Derham made an extensive set of measurements over a two-year period between the artillery training range at Blackheath and his church at Upminster. He also made other measurements, often between his church and other churches in Essex—the elevation of the church towers being useful. (Base map, Vicinity of London, reproduced by permission from *The Historical Atlas* by William R. Shepherd, Henry Holt and Company, NY, 1911.)

A fundamentally different technique was introduced by Joseph Sauveur. Sauveur compared the pitches of organ pipes with their length and concluded that the speed of sound could be determined from this relationship. He was approximately correct but knew nothing of the significance of acoustical end corrections for open-ended pipes; it would be 150 years before these corrections were known well enough for the resonance in an open-ended pipe to be useful for estimating sound speed. [This century-and-a-half period appears more than once. It would be about 150 years before Laplace’s proper calculation of sound speed from the physical properties of air was accepted widely and it would be about 150 years before refraction of sound by wind (as opposed to simply increasing or decreasing the apparent sound speed) was understood.]

Analysis of Derham’s measurements

Derham compiled what appears to be the largest set of sound speed measurements of his time but he did little quantitative analysis of his own data. Although he was a capable surveyor, none of Derham’s many published works shows an aptitude for mathematical analysis. Considering all of his published measurements (without attempting to correct for wind or temperature), the average value is 1138 ± 25 ft/s where one standard deviation is given for the uncertainty. If, instead, we average all of his measurements over his favorite path—Blackheath to Upminster—we obtain virtually the same result: 1135 ± 28 ft/s. Instead of citing 1135 ft/s as the value for sound speed, Derham shows his deference to others and merely claims that his measurements support the value of $9\frac{1}{4}$ half-sec-

onds per mile (1142 ft/s) obtained by Flamsteed and Halley. There is little significant difference between Derham’s value and the Flamsteed/Halley value but Derham reports many measurements with their baseline distances and supporting meteorological observations. (See Fig. 2.). [Derham also cites the speed of sound as $9\frac{1}{4}$ half-second vibrations per mile of travel. This works out to 1142 ft/s. Apparently, there is no extant reference to the Flamsteed/Halley measurements other than Derham’s paper so it is possible that Flamsteed and Halley reported the same $9\frac{1}{4}$ half-seconds rather than 1142 ft/s.]

A one-way measurement is influenced by wind. Not all of Derham’s contemporaries agreed that wind was important but Derham left the question open and addressed it specifically in his measurements. His table of values from two years of observations from Blackheath to Upminster includes notation regarding wind direction and speed. His wind

speed notation was simply a number related to his perception of the wind force. If we use his wind direction to determine the component of his wind-force index that aligns with the direction of the path from Blackheath to Upminster, we can calculate a wind-speed index that relates to the degree to which the wind would aid or hinder sound. Plotting that wind-speed index against the measured travel time, there is a clear relationship between the two. Derham saw this relationship from his numbers and, unless evidence is found to

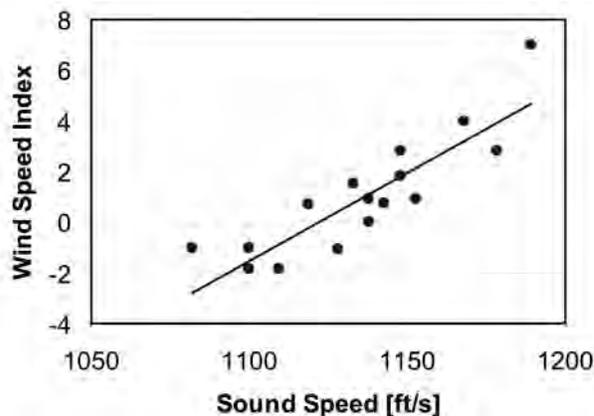


Fig. 3. Derham recorded wind direction and a speed number for each of the measurements he tabulates from Blackheath to Upminster. The vertical scale for this plot is derived from his values for wind direction and speed by projecting his index number onto the direction from Blackheath to Upminster. This gives a quantitative approximation to the aiding or retarding influence of the wind. Derham claims to have established a relationship between wind speed and sound speed and this plot substantiates that claim clearly in spite of the spread in his individual measurements. The black line is a linear-regression fit.

the contrary, his work appears to be the first, clear demonstration of the effect of wind on sound speed. (See Fig. 3.)

This plot reveals another facet of these measurements. Wind aided the propagation in more instances than it hindered the propagation. This may have been a climatological bias—if the prevailing winds were from the west, there may simply have been more opportunities to observe in conditions of wind-aided propagation. However, this could also have been the result of refraction. Once the influence of winds was suspected, experimenters realized that they might be able to reduce the effects of the wind on their one-way measurements by repeating the measurement in the opposite direction. On the surface, this seems a good idea but many who attempted the reciprocal measurement were frustrated. Gerrit Moll (1824) writes of his measurements [G. Moll, A. Van Beek, “An account of experiments on the velocity of sound, made in Holland,” *Phil. Trans. Roy. Soc. London* 114, 424-456, 1824. Zevenboompjes and Kooltjesberg are low hills about 11 miles apart near Amersfoort and Blaricum respectively.]:

“The first night of our experiments, the 23d, 24th, and 25th of January, 1823, we experienced the same annoyance of which the French philosophers had to complain the first night of theirs. The report of the shots of Zevenboompjes was not heard at all at the station of Kooltjesberg. But at Zevenboompjes all the shots of Kooltjesberg were distinctly heard.”

Until the effects of wind-induced refraction were understood, this was a mystery, but sounds are often far weaker upwind of a source than downwind. Derham’s data set may have been biased by the difficulty in making an observation with propagation against the wind.

It is unfortunate that Derham did not record temperature but the uncertainty in his measurements would have obscured any relationship. Criticism in hindsight is wasted effort; it is more useful to examine what he did record. In addition to recording the local wind speed and direction, he also recorded (when possible) the direction of movement of clouds. Cloud motion indicates wind direction at altitude that can be different than the direction at the ground; a difference in wind direction with altitude solved an intriguing mystery a century and a half later. Based on observations, Joseph Henry suspected that, near coastal areas, the surface winds might be directed so as to hinder propagation but that an opposite wind direction at higher altitudes could produce good acoustic transmission. Joseph Henry advocated launching small balloons during acoustical measurements to identify conditions that changed sig-

nificantly with altitude. [Even today, atmospheric acoustic measurements are often made without sufficient supporting meteorological data. Unless the propagation ranges are extremely short, measurements of wind speed vertical gradients and temperature gradients are often necessary (and how many experimenters have neglected to measure humidity in spite of its marked effect on absorption of sound?).]

Where Derham was mistaken

As careful as many parts of Derham’s work were, there are several unfortunate statements in his paper. The first relates to the work of the German Jesuit scholar, Athanasius Kircher:

“Kircher says that he always found the velocity of sound to be different at different times, at morning, at midday, at evening and at night. But I, relying on a better chronometer and using a more suitable distance, never have found that the celerity of sound is different at these times, but in all weather, whether the atmosphere be clear and serene, or cloudy and turbid; whether snow is falling or fog, (which both powerfully blunt the audibility of sound); whether it thunders or it lightnings, whether heat or cold dries the air; whether it be day or night, summer or winter; whether the mercury is rising or falling in the barometer—in a word I may say that in all changes of atmosphere whatsoever (winds only being excepted) the velocity of sound is neither greater nor less. The sound is only more or less clear from this variation of the medium, and perhaps this fact deceives the sagacious Kircher.

In considering this statement, it is important to recognize that Derham was disputing more than just Kircher’s

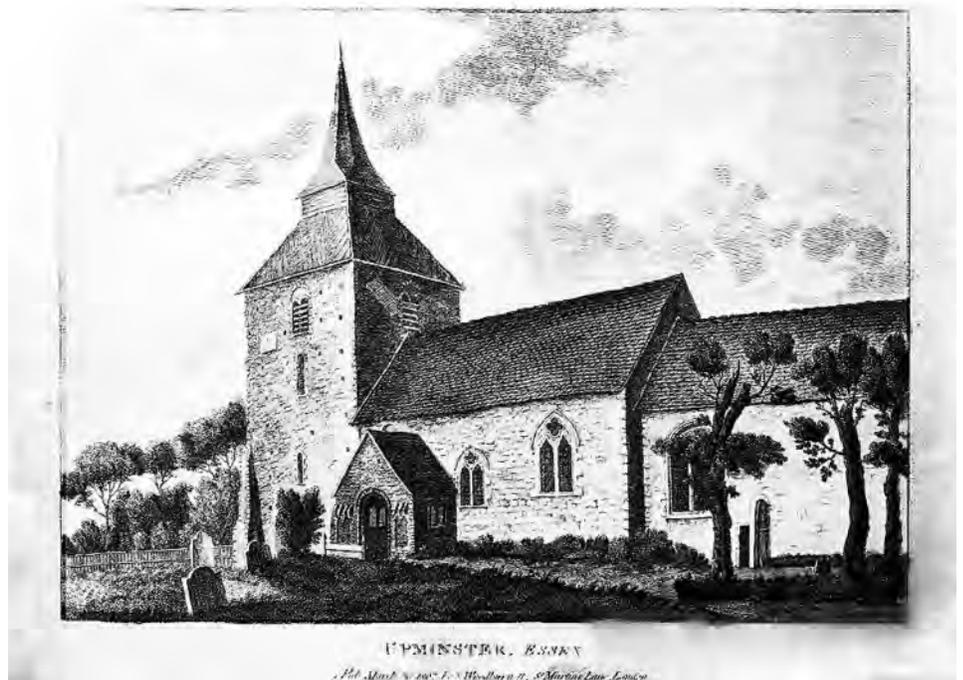


Fig. 4. St. Laurence Church at Upminster. William Derham was Vicar, then Rector of the Upminster parish for much of his adult life. In Derham’s time, there was a door and a platform on the south side of the tower from which he made many of his speed-of-sound, astronomical, and meteorological observations. (Image supplied by Fr. Michael Hore, current Rector of the Upminster Parish.)

ideas regarding the speed of sound. In 1700, there were many strange ideas. Some workers thought that wind had no effect on the speed of sound; others thought that any wind, no matter what the direction, retarded sound; still others believed that sound was affected strongly by barometric pressure. Most of these ideas were ill-considered and supported only by observations made in ambiguous circumstances. For example, Kircher did not demonstrate the proper dependence of sound speed on temperature. Derham countered sloppiness with careful, repeated observations but his techniques could not resolve the small temperature dependence of sound speed. Derham said that "...whether heat or cold dries the air,...whether summer or winter,...the velocity of sound is neither greater nor less..." In hindsight, he was clearly wrong. He would have been safe to say that such changes must be smaller than his ability to resolve. He would also have been safe to say that others in writing about apparent variations in sound speed were not making careful enough measurements to support their claims. But he didn't.

Later, Derham writes, "But as regards thick fogs, it is certain that they are dampers of sound in the highest degree." The fact that this statement follows a lengthy discussion of the variability of observations in clear and foggy air is uniformly ignored by those who lifted this quote to support their opposition to acoustic fog signals in the mid 1800's. Derham is wrong but the lack of discussion makes one wonder whether he is simply repeating the opinion of others. In any event, this remark is a mystery: contrary evidence is easy to find. Derham did not describe any personal observations in heavy fog; his sound-speed measurement could not be made if the source could not be seen and this lack of personal observation may excuse his naïve acceptance of current belief. Regarding other questions, Derham constructs measurements to support or refute the question; here, he does not.

Finally, Derham speculates on the connection between wind and sound and the discussion reveals a peculiar (to us today) view:

"...only will I observe as to sounds, to wit, that while their motion is accelerated by wind it is plain that those parts of the atmosphere by which sounds are impressed or propagated are not the same as those from which winds are blown, but certain other more ethereal and volatile parts, as one may suppose. For the fleetest winds do not pass through more than 60 miles in an hour, but sounds travel more than ...778 miles in the same time."

Derham assumes that, because the speeds of wind and sound are so much different, that they must be carried by distinctly different parts of the air, one more ethereal than the other. It is quite possible that Derham didn't understand the basis of Newton's expression for the speed of sound since Newton based his calculation on the ordinary properties of air.

Where Derham was correct

Notwithstanding Derham's detractors, he was right more often than he was wrong. His measurements were sound and showed remarkably little variance considering the equipment that was available to him. The care with which he made his measurements served as a model for those to follow:

"I have selected these observations from very many others, all of them being cautiously made and each one repeated two or three times or oftener..."

Derham was the first to establish clearly the dependence of sound speed on wind speed and direction.

He understood the psychology of measurement and


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tried to avoid the pitfalls. He understood that it was difficult to depend on vision both to watch the timing pendulum and to watch for the flash of a distant gun; he replaced the simple pendulum with an automatic pendulum that he could hear while watching, often through a telescope, for the muzzle flash. He attributed Kircher's faulty conclusions to confusion between clarity of sound and the apparent speed.

He also understood uncertainty in measurement and he realized that the longer the measurement baseline, the less the impact of an uncertainty in timing.

He did not ascribe to the then popular (and incorrect) belief that optical transparency implied acoustical transparency and the optical opacity implied acoustical opacity.

Summary

When considered in the context of the times, Derham's work was exceptional. He first analyzed the weaknesses with other investigators' techniques and then he designed his own measurements to avoid these problems. He was rarely dogmatic; he would often point out inconsistencies in his own observations. [And the few times that he made unsubstantiated statements, he was more often wrong than right. There's a lesson here.] Unfortunately, several of his less-well-considered statements were quoted then re-quoted well into the 1800's – even then, the “sound bite” was more attractive than dogged pursuit of truth.

Derham's work had a substantial impact on research and literature for about 150 years after which it faded into obscurity. The impact was not always positive—quotes often propagated from paper to paper bereft of their context. [Certainly this would “never” happen today.] Derham wrote that freshly fallen snow seemed to deaden sounds dramatically until the snow became compacted. This statement is true but it was twisted by subsequent authors into a statement that *falling* snow hindered the transmission of sound.

More often than not, Derham bases his conclusions (or lack of conclusion) on multiple observations and, if those observations are inconsistent, he says so. Before his brief statement about heavy fog, Derham shares contradictory observations regarding the effects of light rain and fog. One has to wonder, given Derham's openness about contrary observations and his deference to “experts,” whether the dogmatic statement regarding heavy fog is anything but an echo of the expert opinion of the day.

In the cultural climate of England at Derham's time, there was no great divide between the pursuit of religion and the pursuit of science. Derham was twice invited (1711 and 1712) to give the prestigious Boyle Lectures—lectures for the purpose of communicating to the public the connection between science and religious thought. Derham's most widely distributed book—*Physico-Theology*—expounded this connection. His earliest book was technical rather than philosophic: *The Automatic Clockmaker* is a summary of the state of the art of

timekeeping instruments. This background positioned him well for timing his sound speed measurements.

He published 44 papers for the Proceedings of the Royal Society of London on topics ranging from meteorology to astronomy and entomology. He edited and published the scientific memoirs of Robert Hooke and the naturalist, John Ray. Derham was Rector of Upminster and his access to the church was particularly useful. A doorway and platform were installed in the tower of St. Laurence's Church in Upminster. Derham used this platform as an observation point for many of his sound speed measurements and his astronomical and meteorological investigations. (See Fig. 4.)

William Derham and James Welling, who translated *De Motu Soni*, each stood at crossroads: Derham's paper at the start of the 18th century on the motion of sound marked the beginning of high-quality measurements of the speed of sound; the connection he drew between wind and sound opened new avenues. Welling—another amateur scientist—contributed to one of the many experiments near the end of the 19th century that established refraction as critical to the understanding of sound propagation in the atmosphere.

Prior to Derham's paper, confusion reigned in the realm of meteorological effects on sound. While other investigators believed that wind had some effect, Derham demonstrated an effect and got the magnitude and direction about right with respect to sound speed. But it wasn't until the latter half of the 19th century that refraction or bending of sound by gradients in wind and temperature was demonstrated. Whereas John Tyndall, with his curious idea of flocculence is better known in the community of acousticians, it was left to George Stokes, Osborne Reynolds, and Joseph Henry to elucidate refraction of sound.

A. D. Atkinson provides a fitting conclusion [A. D. Atkinson, “William Derham, F.R.S. (1657-1735),” *Annals of Science* 8(4), 368-392, 1952.]:

“If not an outstanding character, Derham yet emerges from his half-forgotten books and letters with surprising clarity...His busy, rather self-important, investigations, now being rowed round the marshes, now climbing the Chapel at Windsor or the Observatory at Greenwich, discussing the wheel-work of the Hampton Court clock with the Fenchurch Street watch-maker, listening from his church-tower for the echoes of gun-fire from half a dozen neighbouring parishes...all these ...go to make the portrait of a far from unworthy man. If the ...zeal which persuaded him to taste ear-wax and beetles, raise a smile, such trifles add humanity to the picture. If his genius was limited, his curiosity and devotion seem unquestionable, his career an admirable example of a way of life which, now impossible, has often in the past contributed to the progress of thought and literature in England.”

Appendix 1: Timeline

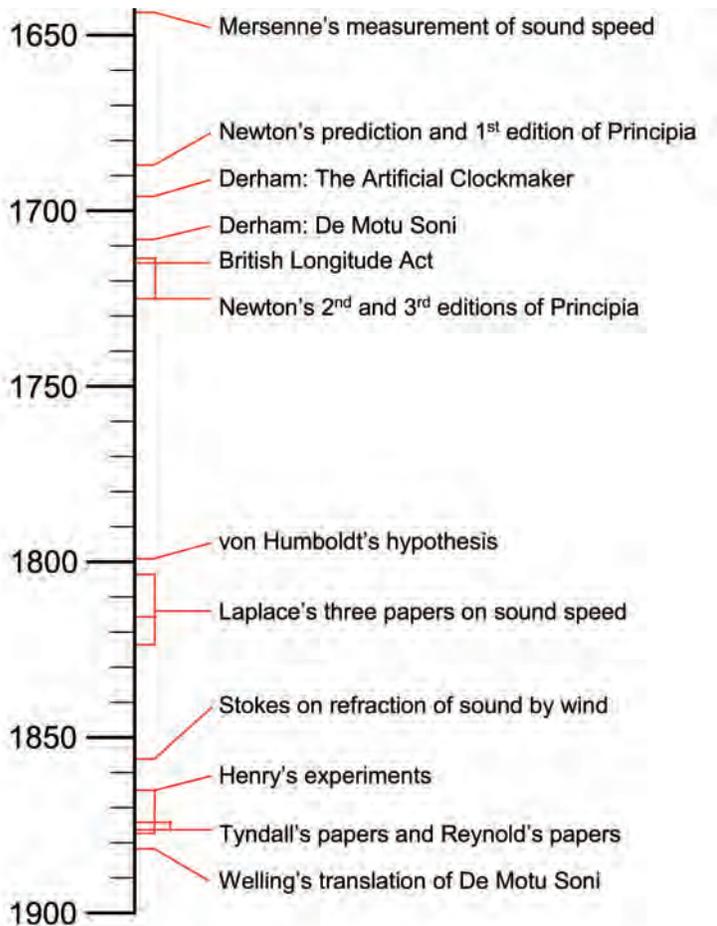


Fig. A1. Time line of significant events with relevance to Derham's paper on sound. Newton's prediction of what we know call the isothermal speed of sound was given in the 1st edition of Principia; it was not until Laplace's third paper that theory for the proper "adiabatic" sound speed was published. Tyndall relied on von Humboldt's hypothesis, which Tyndall called flocculence, in his interpretation of sound transmission; whereas, Henry advocated Stokes' hypothesis of sound refraction. Derham's earlier work on clocks positioned him well for accurate measurement of sound speed but, when the prize for a ship-board chronometer was announced through the Longitude Act of 1714, he and many others shifted their focus to astronomical observations.

Appendix 2: Other publications by Derham

Books and Lectures

The artificial clock-maker: A treatise of watch and clock-work, London, 1696.

Physic-theology: or, a demonstration of the being and attributes of God, from his works of creation, London, 1713. This book went through several editions. Boyle Lectures, 1711 and 1712.

The philosophical experiments of Robert Hooke, London, 1726.

Miscellanea Curiosa, containing a collection of some of the principal phaenomena in nature, London, 1726.

Titles of papers published by Derham in *Philosophical Transactions of the Royal Society of London*

These papers were published in the *Philosophical Transactions of the Royal Society of London* from 1698 through 1735. I include only the titles (abbreviated in some

cases) and the year of the volume in which it was published.

- An account of some experiments about the height of the mercury in the barometer at top and bottom of the Monument. (1698)
- A contrivance to measure the height of the mercury in the barometer. (1698)
- Observations of the height of the mercury in the barometer, rains, wind, etc for the Year 1698. (1699)
- An account of observations of the weather for the Year 1699. (1700)
- Concerning an insect that is commonly called the Death-Watch. (1700)
- Concerning observations on the weather for some years past. (1702)
- Some observations on the spots of the sun. (1702)
- Observations concerning the Late Storm. (1704)
- An instrument for seeing the sun, moon, or stars, pass the meridian. Useful for setting watches in all parts of the world with great exactness; to assist in the discovery of longitudes. (1704)
- A supplement to the account of the pediculus pulsatorius, or Death-Watch, serving to the more perfect natural history of that insect. (1704)
- Experiments about the motion of pendulums in vacuo. (1704)
- An account of some magnetical experiments and observations. (1704)
- Prospect of the weather, winds, and height of the mercury in the barometer, on the first day of the month; and of the

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- whole rain in every month in the Year 1703. (1704)
- Concerning a glade of light observed in the heavens. (1706)
- An account of a pyramidal appearance in the heavens observed near Upminster in Essex. (1706)
- Concerning the migration of birds. (1708)
- An account of some inundations; monstrous births, appearances in the heavens, and other observables received from Ireland. With observations of the eclipse of the sun, Sept. 3, and of the moon, Sept. 18, 1708. (1708)
- The history of the great frost in the last Winter 1703 and 1708/9. (1708)
- An account of a child's crying in the womb. (1708)
- A short dissertation concerning the child's crying in the womb. (1708)
- Experimenta et observationes de soni motu...(in Latin). (1708)
- Tables of the barometrical altitudes at Zurich in Switzerland in the Year 1708. Also on the winds, heat and cold occurring in three different parts of Europe. (1708)
- Observations concerning the subterraneous trees in Dagenham and other marshes bordering upon the River of Thames in the County of Essex. (1710)
- Observations of the eclipse of the moon on Jan. 12, 1711-12. (1710)
- Observations upon the spots that have been upon the sun from the Year 1703 to 1711. (1710)
- The case of a woman big with child, who recovered from small pox, and was afterwards delivered of a dead child. (1713)
- An account of the mischiefs ensuing the swallowing of the stones of bullace and sloes. (1714)
- An account of the rain which fell every year at Upminster in Essex, the last eighteen years. (1714)
- Extracts from Mr. Gascoigne's and Mr. Crabtree's letters, proving Mr. Gascoigne to have been the inventor of the telescopic sights of mathematical instruments. (1717)
- An account of a large quantity of alcalious salt produced by burning rotten wood. (1720)
- Observations about wasps and the difference of their sexes. (1724)
- Observations on the lumen boreale or streaming on Oct. 8, 1726. (1726)
- Observations of the eclipses of Jupiter's satellites from 1700 to the Year 1727. (1727)
- The difference in time of the meridians of diverse places computed from observations of the eclipses of Jupiter's satellites. (1729)
- A description of some uncommon appearances observed in an aurora borealis. (1729)
- Of the meteor called the ignis fatuus from observations made in England. (1729)
- Concerning the frost in January, 1730/31. (1731)
- An abstract of the meteorological diaries communicated to the Royal Society with remarks upon them. (Five parts from 1731 to 1733)
- Observations of the appearances among the fixed stars called nebulous stars. (1733)
- Experiments concerning the vibrations of pendulums. (1735)

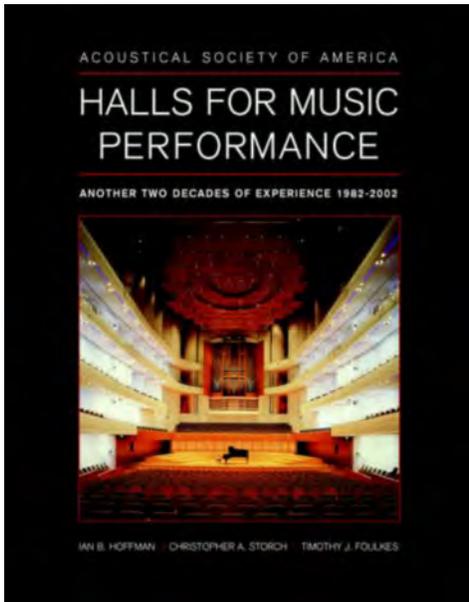
Appendix 3: Background references

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- J. C. Welling, "Anomalies of sound signals," *Bulletin Phil. Soc. Washington* **5**, 39-46 (1883) (delivered at the 205th meeting, Nov. 5, 1881).
- Bernard S. Finn, "Laplace and the speed of sound," *Isis* **55**(1), 7-19 (Mar. 1964).
- J. M. A. Lenihan, "The velocity of sound in air," *Acustica* **2**(5), 205-212 (1952).
- Essayes of Natural Experiments made in the Academie del Cimento, translated by Richard Waller, London (1634).
- Joseph Henry, *Scientific Writings*, 1886. See the various Reports of the US Light-House Board for 1875.
- R. S. Westfall, "Newton and the fudge factor," *Science* **179**(4075), 751-758 (1973).
- Harry Bateman, "The influence of metrological conditions on the propagation of sound," *Monthly Weather Report* **42**, 258-265 (May 1914). [In Bateman's end-note 1, "A copy of an English translation by Rev. Dr. J. C. Welling is in the library of the U. S. Weather Bureau."]
- Walker, "Some experiments and observations concerning sounds," *Phil. Trans.* **20**, 433-438, (1698).AT



Tom Gabrielson is a Senior Scientist and Professor of Acoustics at Penn State. Tom received a Ph.D. in Acoustics with research in the effects of turbulence on the refractive focusing of infrasound in the atmosphere. His current research concerns the design and development of high-performance transducers, the development of precision calibration techniques, and the development of techniques for measuring high-amplitude sound.

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§. I. *Celeberrimorum Authorum dissensus de Soni Progressu, & Cæpti mei Ratio.*

Philosophi celeberrimi operæ pretium existimârunt, in jucundum & mysticum de *Sono* argumentum inquirere; speciatim de ejus *Motu & Progressu*.

Et quoniam magna inter eorum *Observationes* discrepantia est, ideo partim ut scrupulos meos eximerem; partim ut memet horis meis subsecivis recrearem, conatus sum, quantum in me fuit, rem totam exponere & decernere.

Et quandoquidem *Instrumenta* mihi sunt aptissima, occasioneque non contemnendæ rem experiendi, ideo hoc faciendo, arbitror me tantum proprium munus obire, sive debitum solvere *Mundo Philosophico*, præcipuè insigniffimæ *Societati nostræ Regali*, quæ me in suum numerum cooptare dignata est.

Dissensus inter *Authores celeberrimos* de *Soni Velocitate* facili intuitu in sequente *Tabellâ* conspici potest: in quâ (*Pedibus Anglicanis*) *Spatium* exhibetur quod *Sonorum Progressui* in uno *Minuto Secundo Temporis* ascribunt.

D. If.



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DE MOTU SONI

by

Rev. William Derham

Philosophical Transactions, London 1708 – Vol. XXVI

Translated by

Dr. J. C. Welling

1882

Annotated by

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Annotator's note: Unless specifically attributed to either Derham or Welling, all of the annotations and footnotes are mine, are enclosed in brackets, and are printed in blue. Relevant references have been added wherever possible. I have taken small liberties with punctuation and, rarely, changed words (for example, changing *interjacent* to *intervening*), to avoid excessively awkward constructions. Proper names have occasionally been changed to correspond to modern spelling to facilitate map and web searches for further information.

An abridged translation appeared as “Experiments and observations on the motion of sound,” *Phil. Trans. Royal Soc. Abridged* 5, 380-395, 1809, by Hutton, Shaw, and Pearson. This abridgement is a rather dry condensation of the facts of Derham's paper. Welling attempts to preserve Derham's style and Welling's translation is complete. Welling's translation is handwritten and the original manuscript resides at the NOAA Central Library, Rare Books Division, in Silver Spring, Maryland. A high-quality scanned version is available on the web through the Central Library:

http://docs.lib.noaa.gov/rescue/Rarebook_treasures/QC222D91708.pdf

J. C. Welling was, at the time of this translation, the President of Columbian College (later named George Washington University) in Washington, DC. Welling also participated in several acoustics experiments performed by Joseph Henry as part of the US Lighthouse Board's study of the feasibility of fog horns.]

**Experiments and Observations on the *Motion of Sound*,
and Other Things Pertaining Thereto,
Made by the
Reverend Mr. W. Derham,
Rector of Upminster Church and
Fellow of the Royal Society of London.**

1. Disagreement of the most celebrated authors about the progress of sound and the reason of my undertaking.

The most celebrated philosophers have thought it worth while to inquire into the delightful and mysterious reasoning about sound, and especially about its motion and rate of progress; and since the discrepancy among their observations is great, partly that I might remove my own doubts, partly that I might find amusement in my leisure hours I have

endeavored, as far as I am able; to unfold and decide the whole matter.

And since my instruments are most suitable, and my opportunities for testing the matter were not to be despised, I suppose myself, in doing so, to be merely performing an appropriate duty, as to pay a debt to the philosophical word, especially to our most famous Royal Society which has deigned to admit me into its number.

The dissent among the most celebrated authors about the velocity of sound [See also, J. M. A. Lenihan, “The velocity of sound in air,” *Acustica* 2(5), 205-212, 1952.] can be seen by a slight glance at the following table, in which is exhibited, (in English feet) the space they ascribe to the progress of sound in a single second of time:

Between the last and the next to the last of these estimates, the disagreement is not considerable, and the estimate of the French authorities is not much greater than these two. But among the rest the disagreement is great; and the reason of the discord manifestly is that it arises either from a defect in the instruments used or from the inadequate distance at which the observations were made, or from the effect of wind. [These observations regarding sources of error in measurement represent one of the most significant contributions of Derham's paper. Derham did not go so far as to assign specific uncertainties to measurements—few investigators of this time did—but his identification of sources of error and his conscious design of experiments to minimize these problems sets his work apart from his predecessors.]

A. The apparatus by which some of these distinguished men made their measurement was not automatic, but was a ball suspended by a cord, which vibrates seconds. [The expression, “vibrates seconds,” means that the pendulum period for a full cycle of its motion is two seconds. In other words, the pendulum reached an extreme point in its swing every second—once to the right, then to the left. A pendulum that “vibrates half-seconds” would have a full-cycle period of one second.]

Now to all who are versed in such matters it is obvious that the ball is much less convenient than an automatic instrument, and is not so accurate; since it is necessary that the eye should first be engaged in observing the flash and then should glance towards the ball or pendulum – a process which consumes time and produces confusion. This fact then

Sound speed in feet per second from various investigators

Sir Isaac Newton ^a	968	Princ. Ph. Nat. Math. Lib. 2 prop. 50
Hon. Mr. Roberts ^b	1300	Philosophical Transactions, N. 209
Hon. Mr. Boyle ^c	1200	Essay of Languid Motion, p. 24
Mr. Walker ^d	1338	Philosophical Transactions, N. 247
Mersenne ^e	1474	Balistic Prop. 39
Messrs Flamsteed and Halley	1142
Distinguished citizens of Florence ^f	1148	Exp. per Acad. del Cimento, p. 141
... Frenchmen	1172	Du Hamel Hist. Acad. Royale

[a Newton, *The Mathematical Principles of Natural Philosophy* (Principia), Book II (Of the motion of bodies), Section VIII (Of motion propagated through fluids), Proposition 50. Derham would have had the first edition published in 1687. There were two subsequent editions (1713, 1726). The third edition gives two values for sound speed: 979 ft/s and 1142 ft/s. In the first edition and for the lower value in the third edition, Newton based his calculation on the static compressibility of air and its density; the higher value in the third edition was based on an imaginative and specious correction for the (then unknown) size of air molecules. The higher value was an attempt to reconcile theory with the overwhelming experimental evidence for a speed considerably higher than 968 ft/s. Another century passed before the calculation was done correctly (by Laplace).

b Francis Roberts, "Concerning the distance of the fixed stars," *Phil. Trans.* 17, 101–103, 1694.

c Robert Boyle, *An Essay of the Great Effects of Even Languid and Unheeded Motion*, London, 1685, p. 24.

d Walker, "Some experiments and observations concerning sounds," *Phil. Trans.* 20, 433–438, 1698. Well worth reading to illustrate the nature of the pendulum timing devices but also contains an excellent description of two variations of the echo method for determining sound speed. In the simpler echo method, the observer adjusts his position with respect to a flat wall until the echo from a clap (Walker used two small boards) returned just as the pendulum completed a swing. A refinement consisted of repeated clapping – clapping each time an echo was heard – and dividing the total time by the number of claps to get the single round-trip time. A further refinement of the repeated echo technique was developed later: rather than trying to react instantly to a received echo, if the claps are interspersed evenly with the echoes, the achieved timing precision is much greater. Perception of rhythm is much more accurate than instantaneous reaction to an event.

e M. Mersenne, *Cogitata Physico-Mathematica*, Paris, 1644, *Ballistica*, proposition XXXIX, p. 138.

f *Essays of Natural Experiments*, *Accademi del Cimento*, 1634, translated by Richard Waller, FRS, 1667, pp. 140–142.]

considered in connection with the slowness of our senses, and of our perception or attention, may produce a great error, as is well known to those who have made experiments concerning these matters. This is especially the case if

B. The interval between the sounding body and the observer may have been small. It is manifest, however, that the most of these distinguished men made their experiments at the distance of only a few feet, and made their measurements by the return, or echo of the sound. For some of these observers scarcely extended their measurement beyond six or seven hundred feet, and others not beyond a mile. But I have always observed that an ambiguity arises in a distance so small, though the best apparatus may be used. Because the slightest error in distances so very small is to be considered comparatively great for the pendulum, perhaps has passed through the half of its sweep or arc, from the last vibration when the sound may have been first emitted; but we count that beat as if it had been a full and complete vibration; or perhaps we may anticipate the vibration. And after the sound reaches us, we may perhaps count more or less than is right.

Or, if the distance shall have been long enough, still an error may arise from that very circumstance, if

C. Account is not taken of winds—about which more hereafter. These are the certain, inevitable and perpetual inconveniences which accompany the measurement of the

progress of sounds – inconveniences which in small intervals, as I have said, especially if the instruments be bad, are able to produce great errors; and without doubt they have been the greatest cause of the disagreement among authors so eminent. But one can see how very near is the agreement among the distances assigned by the last three observers in our table—a fact which doubtless arises from the circumstance that they were furnished with good automatic instruments, in the use of which the ear is simply occupied with catching the vibrations of the pendulum, while the eye marks the flash or some other indication of the sound. These observations, besides, were made at long distances, in which a petty error will not be of great account. For the observations of the very celebrated Messrs. Flamsteed and Halley were made at a distance of almost three miles, (a few perches [The perch is a surveyor's rod 16 ½ feet in length.] more or less being excepted), from the Royal Observatory on Shooter's Hill, and the sound came to them in 13 ½ seconds. The gentlemen of Florence, who were also celebrated members of the *Accademie del Cimento*, made their experiments at about the same distances and some experiments at the distance of only a mile. And finally, the very celebrated Messrs Cassini, Picard, and Roemer made their experiments at a distance of 1280 French toises, which is more than one English mile and a half.

That the truth might be brought to light in the midst of the aforesaid disagreements, I have made very many exper-

iments at various distances, to wit, from one mile to twelve miles or more—And for the purpose of measuring the time, I have a very accurate portable instrument which is automatic and furnished with a pendulum vibrating half seconds.

That I might proceed the more safely I proposed to myself the following questions to be discussed:

1. How great is the space which sound traverses in a second or other interval of time.
2. Whether a gun fired towards an observer sends the sound in the same interval of time as when it is fired in the opposite direction.
3. Whether in every state of the atmosphere when the mercury is rising or falling in the barometer sounds traverse the same space in the same interval of time.
4. Whether sounds are propagated with greater velocity by day than by night.
5. Whether a favoring wind accelerates sound and an opposing wind retards it – that is, whether winds affect sound at all, and if so, in what manner.
6. Whether sound is propagated with a greater velocity in a tranquil atmosphere than when the wind is blowing.
7. Whether a strong wind blowing crosswise accelerates or retards the velocity of sound.
8. Whether sounds have the same velocity in summer and winter by day and by night.
9. Whether sounds have the same velocity in snowy and in clear weather.
10. Whether a great and a small sound have the same velocity.
11. Whether at all [angular] elevations, viz: horizontal, ten degrees, 25 degrees, and so on to 90 degrees, the sound of a gunshot strikes the ear of an observer at the same interval of time.
12. Whether sounds of all kinds, i.e., of guns, bells, hammers etc., have the same velocity.
13. Whether charges of powder varying in strength produce a variation in the velocity of sound.
14. Whether on the tops of high mountains and in valleys, that is, whether in the highest and lowest parts of the atmosphere, sounds travel the same space in the same interval of time.
15. Whether an upward and a downward sound have the same velocity, that is, whether it descends from the top of a mountain to its base at the same rate as it ascends from the base to the top.
16. Whether sound is propagated in the beginning with greater velocity and in the end with less, as occurs in many other violent motions.
17. Or whether, on the contrary, it is uniform—that is, whether or not it is propagated half the space in half the time, one fourth of the space in one fourth of the time, *etc.*
18. Whether in all regions northern or southern—in England, France, Italy, Germany, etc.—sounds have the same velocity. [This question seems particularly strange but Derham's discussion in Section 9 gives the background.]
19. Whether sound passes from place to place in a straight line, (i.e., by the shortest path), or according to the [irregular] superficies of the intervening land.

For the settlement of these questions I asked some kind friends of mine, (whose favors I here most gratefully acknowledge) to fire muskets from towers and other high places at a distance of one, two, three and even as far as eight miles, (which I have found to be the greatest distance at which I could hear the sound of a gun in these parts, covered as they are with woods, etc.). These musket shots were of great use to me. But what especially answered my purpose were the cannon (Sakers [[Welling's note: The saker is a species of small ordnance.](#)]) which are used at Blackheath in training the raw recruits who are to serve the artillery of our most illustrious queen. I could see the flash and hear the report of these cannons from the tower of my church; sometimes also I made use of a telescope. And hence I have devoted myself with all care and diligence to the observations of these cannons since February, 1704.

After a few observations made in the midst of their discharges, I took measures for making a certain particular experiment through the courtesy of the late Baron Granville then the Governor of London Tower and of other eminent men who on that Tower serve the interests of the royal artillery, (and whose favors I here most gratefully recognize). Two cannon (Sakers) were placed side by side one with its mouth towards me the other with its mouth reversed. These two cannon on the 13th February 1704 were fired every half hour from 6 o'clock P.M. to midnight, while a gentle breeze was blowing directly against the sound. The interval between the flash of each gun (which flash I could see with the naked eye) and the arrival of the sound was always about 120 or 122 half seconds – I have said 120 or 122, since the sound came to me duplicated – that is the first sound came within 120 half seconds (which was a weaker sound) and the second within 122 half seconds (which was a stronger sound) and in the same manner, through the whole time of the observation, the crash of each cannon came in a duplicated form.

This reduplication of sound seems to me an echo, reverberated, as I think, from the watermill at Blackheath, or from the houses situated in its vicinity. [[London Tower is just slightly south of west from Derham's church at Upminster; Blackheath is west southwest from Upminster and about 3/4 as far as London. The azimuth angle to Blackheath is more southerly than to London but not by more than 30 degrees.](#)] I have no reason for doubting about this point except the contrary opinion of a learned friend and sagacious philosopher who believes that there is no echo to be heard save that produced by objects reflecting sound near the observer, instead of its being produced by those near the sounding body—or other distant objects.

The next disquisition, therefore, will be,

2. Concerning sounds reverberated from a distance, or the distant echo.

Perhaps this disquisition will be considered a digression but since it pertains to the subject of sound I hope that a few observations on this subject will not be ungrateful to ingenious minds.

And in the first place I believe that this [the fact that the

my many experiments. And what I have just now suggested respecting the sound of the artillery on Blackheath, I have found in all other cases, viz. that the motion of sound is neither swifter nor slower whether the cannon be fired towards the observer or in the opposite direction.

Likewise, in all positions of a musket, whether horizontal or perpendicular, and at all elevations, ten degrees, twenty degrees, etc., there is no variation in the sound of its discharge. So true in this matter is the observation of those famous gentlemen connected with the Accademi del Cimento in Florence.

The force also of the powder, whether it be strong or weak, and the greater or less the quantity of the charge, though serving to increase or diminish the sound, have no effect in accelerating or retarding its motion.

5. Concerning the velocity of sound in any state of the atmosphere and any time of the year.

Kircher [[Athanasius Kircher \(1602-1680\), a German Jesuit scholar](#)] says, that he always found the velocity of sound to be different at different times, at morning, at midday, at evening and at night. But I, relying on a better chronometer and using a more suitable distance, never have found that the celerity of sound is different at these times, but in all weather, whether the atmosphere be clear and serene, or cloudy and turbid; whether snow is falling or fog, (which both powerfully blunt the audibility of sound) [[This generalization is, unfortunately, one of Derham's remarks that influenced thought for about 150 years. Subsequent descriptions by Derham in Section 10 indicate that he was really not unequivocal in this opinion and he may have succumbed to repeating popular lore here.](#)]; whether it thunders or it lightnings, whether heat or cold dries the air; whether it be day or night, summer or winter; whether the mercury is rising or falling in the barometer—in a word I may say that in all changes of atmosphere whatsoever (winds only being excepted) the velocity of sound is neither greater nor less. [[The one important factor that Derham missed was the dependence of sound speed on temperature. Given the chronometers available to Derham at the time and the fact that the effects of wind are normally considerably larger than the effects of temperature, it is not at all surprising that Derham did not see the change in sound speed with temperature. It would be almost half a century before Bianconi provided convincing experimental evidence of the temperature dependence of sound speed.](#)] The sound is only more or less clear from this variation of the medium, and perhaps this fact deceives the sagacious Kircher.

Hence it follows that the conclusions drawn by Mr. Walker from his ingenious observations and from those of Dr. Plot (Derham note: Philos. Trans. N. 247.) and of Kircher were erroneous. [[The more complete reference is "Some Experiments and Observations concerning Sounds," By Mr. Walker, Late of Brazen-Nose-College, Oxon. Philosophical Transactions \(1683-1775\), Vol. 20. \(1698\), pp. 433-438.](#)]

6. Concerning the velocity of a strong and of a weak sound, and of the sound of different sounding bodies.

Though Kircher thinks otherwise I do not doubt that the sounds of all bodies—of muskets, bells, hammers, etc., have

the same velocity. In the year 1704, I compared the beatings of a hammer and the crack of a musket at the interval of a mile (the greatest distance at which I could hear the sound of a hammer), and I found that the sound of both reached me in the same time, as also that they traversed $3/4$, $1/2$ and $1/4$ of the same space in $3/4$, $1/2$ and $1/4$ of the same time.

As regards strong and weak sounds I do not doubt that they traverse the same space in the same interval of time. This fact will be in a measure apparent from the following experiments:

January 13, 1704: The master gunner of Tilbury Fort at my request fired two gun shots in succession, and a heavy cannon in which he had well measured a charge of powder. The report of all these reached me at the distance of about three miles in the same time.

The master gunner of England [[Translator's note: "The Master Gunner of England" was the title of the Senior Master Gunner in the ordinance service of England at this period.](#)] also on the 11th Sept. 1705, after sunset, as a matter of favor to me fired on Blackheath some muskets, some heavy cannon, (Sakers) and some mortars. I could not hear the muskets on account of the great distance, or because the air was not sufficiently serene. But I heard the sounds of the cannon and of the mortars in the same interval of time, though the crash of the mortar was much more torpid and weak than that of the cannon.

Notwithstanding the fact that I used the greatest care in

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Place where the guns were fired	Number of vibrations of pendulum	Distance of Places		Direction of the wind
		by trigonometry miles	by sound miles	
Hornchurch	9	0.9875		crosswise
N. Okendon Ch.	18 ½	2.004	2.0	crosswise
Upminster Mill	22 ½	2.4	2.4	favoring
	23		2.48	snow, crosswise
Lower Warley Ch.	27 ½	3.0	2.97	strongly favoring
Rainham Church	33 ¼	3.58	3.59	crosswise
Alvely Mill	33	3.58	3.57	crosswise
Dagenham Church	35	3.85	3.78	favoring
South Weal Ch.	45	4.59	4.86	crosswise
East Thorndon Ch.	46 ½	5.09	5.03	rather favoring
Barking Church	70 ¼	7.7	7.62	favoring
Blackheath	116	12.5	12.55	crosswise

these experiments, I nevertheless wished afterwards to try them over again at greater distances, but the opportunity was wanting. I leave this matter therefore to be better tested by others.

7. Concerning the uniformity of the velocity of sound.

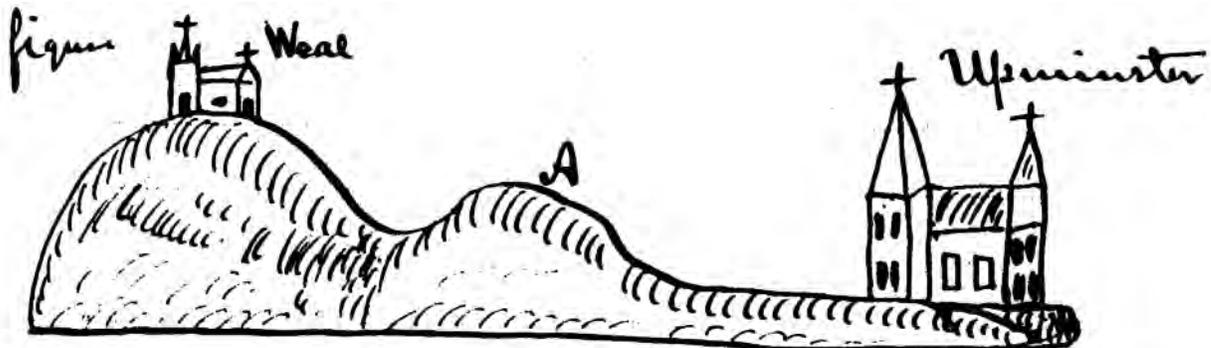
The next observation was concerning the uniformity of the velocity of sound. I have found this to be the same as the illustrious Accademia del Cimento has already defined. That is, sounds traverse half the space in half the interval of time; one fourth the space in one fourth the interval of time and so on. This fact will be plain from the examples in the following table:

The distances of the places marked in the table from Upminster (where I made my observations) I measured with as much accuracy as I could either by the surveyor's rod or by trigonometrical art. [There are two small errors in this table. The actual distance from the Lower Church to the Church at Upminster is 3.10 miles, not 3.0 miles and the distance from the South Weal Church is 4.64 miles.] And from the great consonance between the distances measured in this way and by the velocity of sound, the excellence of my instruments, the truthfulness of my calculations and observations is set in a clear light. For the difference between the distances ascertained by measurement, and taken from sound, either disappears entirely, or is that of only a very few hundredths of

parts, unless where there may have been a favoring wind (the case of south Weal Church being excepted, concerning which hereafter). So, too, in the observations made from the churches at Dagenham, Warley, Thorndon, and Barking, the distances marked by sound seemed a little shorter because the wind accelerated the sound. But in working up this column of distances by sound, I have allowed nothing on account of the acceleration of the winds, but have simply divided the number of the vibrations, or half seconds, by 9 1/4 or 9.25 (the number of half seconds in which sound traverses a mile.)

The equible rate of the motion of sound is also manifest from this table, as will appear from a comparison of the vibrations and the distances, or from the column of the distances alone as derives from sound.

But that nothing might be wanting in confirmation of these facts I made a journey to Foulness Sands on our Essex Coast. These Sands, washed and covered by the daily tide of the sea, make a great and smooth plain for many miles. Upon this plain I measured off only six miles, because neither the tide nor my leisure permitted that I should measure a greater distance. At the end of almost each mile I made experiments by the firing of muskets, not without great peril to my life from the influence of the sea and the darkness of the night. From these experiments I found that all my former observa-



tions were most exact and true, to wit, that sound traverses one mile in 9 1/4 half seconds; two miles in 18 1/2 seconds, three miles in 27 3/4 half seconds, and so on.

8. Concerning the upward and downward motion of sounds, or concerning the ascent and descent of sounds. Likewise whether they pass from place to place in a straight line or according to the superficies of the intervening land.

As regards questions 15 and 19, I frankly confess that I have never satisfied myself on these points by any of the experiments which I have hitherto made. In the first place let us treat the progress of sound by the shortest path, under the head of question 19. The reason for doubt about this was the discrepancy between the distance from Weal to Upminster by trigonometrical measurement and by sound, as is exhibited in the preceding table. The trigonometrical measurement was taken in so many ways and with such good angles, that I can have no doubt about it. But since the distance as measured by the motion of sound seems to be greater, and since the superficies of the intervening ground takes on a form like that exhibited in this figure,

I have in consequence, somewhat doubted whether sound may or may not move a little crookedly, that is, whether or not that intervening elevation at "A", by the resistance which it offers to the mass of sound beats them back and retards them.

That I might in some way solve this problem I took care that experiments should be made with the sound of a musket from the top of Langdon hill to the valley below at a distance of 3.79 miles. The distance was well measured trigonometrically, from angles and from a base line sufficiently large; and the experiment was made while a gentle breeze was slightly opposing the sound. Between the flash and the report I counted 35 1/2 half seconds. This number squares so exactly with the distance, and so nearly agrees with other experiments that it cannot be doubted that the sound descended from the top into the valley by a straight line (through the air), and not according to the curved superficies of the intervening ground.

I believe therefore that there was some error in the aforesaid observations at Weal since neither in the last experiment at Langdon, nor in any others, have I observed anything like it.

As regards the upward and downward motion of sound, that is, whether sounds are borne with equal tenor and at the same rate from the top of a mountain to the bottom, I scarcely hope that I shall ever satisfy myself or any body else. For neither in Essex nor in the conterminous parts are any hills found high enough from which one may make sufficient experiments to this end. In fact the highest of all which it has yet been my lot to see, (such as those which they call the Langdon hills), do not much exceed 300 ft. For I measured the highest of these hills both by trigonometry and by a portable barometer, and I found it to be by the former mode 363 ft high by the latter mode, ... [\[ellipsis in Latin manuscript.\]](#)

On a former summer, however, when I was making a journey in the western parts of the kingdom, I determined to try an experiment on a certain hill whose altitude I ascertained by measurement a few years previously to be (unless

my memory deceives me) about 1875 feet. At a time when the wind was blowing across the path of the sound, but so gently that it would not extinguish a lighted candle, I ordered some muskets to be discharged at the base and at the top of the mountains, and I perceived that the sound reached me from each in almost the same interval of time. If I observed any slight discrepancy at all it seemed to consist in this that the sound may have ascended somewhat more swiftly towards the mountain than it descended from the mountain. But to speak according to the fact, I was scarcely able to measure the time with the accuracy which is due, since unluckily, it had turned out that the chronometer which I used had been somewhat disturbed by a concussion received on the journey.

Hence I leave this experiment to be tried more successfully and certainly by others. And I would that the votaries of higher culture and philosophy among the Italians, (in whom has been implanted a curious felicity of genius) might be willing to try this same experiment on the Alps.

9. Concerning the translation or motion of sound in Italy.

Inasmuch as I have made mention of the Italians, it seems not irrelevant to recite certain observations and experiments made in Italy on my account by that very acute, learned and accomplished friend of mine Dr. Newton, the envoy of her Britannic Majesty at Florence. [\[This Dr. Newton is Henry Newton, not Isaac Newton. Both Newtons were Fellows of the Royal Society.\]](#) The occasion of these was as follows:

The late ingenious and excellent Richard Towneley, Esq., (a name familiar and grateful to our renowned society) had signified to me by a letter written in the year 1704, that "Sounds are rarely heard as far at Rome as in England and in our northern regions." He said particularly that while he was staying at Rome, on an occasion when some cannon of the castle of St. Angelo were fired on account of joyous intelligence, and when he was standing on Mount Trinita, he has observed that the sound was much more languid in that situation than in any other location at the same distance. And after the death of Towneley [\[The name does not appear in the Latin manuscript. Welling inserts Newton's name here by mistake. The reference is to the late Richard Towneley. Henry Newton is still alive when Derham writes this paper \(see the next paragraph\)\]](#), his brother reported to me, in writing, that in the year 1688, "when on leaving Rome, he repaired, for a season of recreation to Castel Gandolfo (a certain higher location near Lake Albano, about 13 Italian miles from Rome), he had observed that the sound of the heavy cannon booming from the aforesaid Castle of St. Angelo seemed to him reduced in volume and weak. Also at another time when he was passing around the walls of this same castle in a carriage, and when the great guns were bellowing from it, they seemed to send forth a sound which, as there observed, was neither in quality nor volume like that observed elsewhere."

Since these things had been noticed by two men of no common intellect, and since the phenomenon itself seemed entirely new and unusual, the desire entered my mind of enquiring what might be the cause of it. I therefore wrote to

the very distinguished Dr. Newton, whose praises I have already celebrated, and he in the month of October, 1706 was good enough to report to me what he and also what his friends have observed respecting this matter.

He recites that on a journey from Bologna towards Florence he heard at the city of San Michele in Bosco, near Bologna the sound of the firing of Cannon. These cannon were forty miles off, being fired at Mirandula, which a French army then held in siege. And on the following night he heard the same sound while he was resting over night in the Apennines, (twenty miles further off.)

But the observations and experiments which the same very eminent man through his politeness and benevolence caused to be made by others, justly claim for themselves a particular specification as well as my best thanks for these honors which his excellency has conferred upon me. When he received my letter at Florence he disclosed what I wanted to a certain nobleman who was at the same time an eminent philosopher; and he in turn communicated these wishes of mine to the Grand Duke. “The Grand Duke, as he says, in accordance with his singular love of the arts and of learned pursuits, as also in accordance with that gracious indulgence towards the votaries which he has received by inheritance from his ancestors along with his scepter, immediately gave orders that experiments should be made for the sake of fully satisfying me on this point; and he set Joseph Averrani a renowned philosopher of Pisa, and a man skilled in every one of the more liberal arts, over the inspection and direction of these experiments. The memoirs of this most honorable gentleman our most honorable envoy has deigned to write out at length for me. But the gist of the matter amounts to this: After having premised with equal caution and ingenuity very many things which might produce a great difference in the progress of sounds he at length proceeds as follows:

“In the lower fortress of Florence a culverin [[a long-barreled cannon](#)] was fired frequently between the first and the third hour of the night. Certain men at the same time were kept at Leghorn and were ordered diligently to observe whether they could hear its report. Of these men, some who had been stationed at the Lanterna and at Mazzoco heard no sound; (perhaps because the roar of the sea obscured the sound); but others who were standing on the bastions of the old fortress (which they call Donjon) and those who had been sent to Mount Rotondo (which is about five miles from Leghorn in the direction of Mount Nero) caught up the sound in their ears. And as often as the gun was fired its report was clearly heard in the same places. Now the distance of this Fortress of Florence from Mount Rotondo in a straight line is reckoned at not less than fifty five miles. And it is worthy of note that the intervening country was studded with many hills, which must needs have somewhat obstructed the path of the sound. To these considerations should be added that on the same evening a west wind was gently blowing which, (since Leghorn is situated to the south southwest with respect to Florence) may justly be supposed to have slightly impeded a freer expansion of the sound. In order however that an open place and one lying level in all directions might be obtained, that tract of the sea was selected which lies

between Leghorn and Port Ferraio, the distance of which, according to the calculation of the most skillful sailors, is set down, at sixty miles. The report, however, of artillery not infrequently reaches from Leghorn to this Port, and the places in its vicinage. Nor is there need of favoring winds to promote this passage of sound, in order that it may be surely heard. Indeed any wind whatsoever, whether it be favorable or adverse, is equally an impediment, and renders the sound less audible; it may be because the roar of the sea, agitated by this cause, is more a disadvantage than the current of the air blowing in the same direction is an advantage.

“Hence it is that the sound is heard only when the wind is entirely still or is only murmuring very gently—when the air is serene and the sea tranquil. Nor then, indeed, is it heard indiscriminately from all points, but only from those which are a little more elevated, such as the two bulwarks which are called Stella and Falcona and the place called Mulini. Moreover it is required that the observer should be as attentive as possible, and should not be hindered and troubled by the voice or clamor of persons making a din around him. But then equally by day and by night he may hear the sound provided the atmosphere be clear and still—the only difference being that the sound seems somewhat stronger and clearer in the night time, when no noises occur such as are often wont to disturb the ears by day.

“Moreover, it has been reported to us by most credible witnesses that many years ago when an insurrection was raging at Messina and the city was closely besieged, the sound of the guns startled the ears of the inhabitants of Augusta and of Syracuse [[about 80 miles over water](#)].

“Likewise when the French were shaking Genoa with heavy siege guns it is certain that the sound of the cannon reached as far as Mount Nero which overhangs Leghorn [[about 90 miles over water](#)].

“From these observations I am inclined to believe that there is no difference in this regard between Italy and the northern regions.

“But as regards the other question—whether a wind blowing directly or adversely accelerates or retards sound—it is not in my power as yet to give a certain reply. For the experiments which I have instituted and by which I had hoped that the truth would be explored, do not suffice for settling the question. In fact during the summer time (when for the most part the winds by day blow from the sea and from the west, while when evening comes on they are generally still), the most suitable occasions for frequently and certainly testing the matter were wanting to me. I hope, however, that towards the close of the year, after weather of another kind shall have supervened, I may obtain more favorable opportunities for instituting and testing experiments of this kind with greater success and frequency, as also with greater accuracy. But for the present it must suffice to report what happened to me on the 10th of August last past, when I was permitted to try the following experiments:

“A culverin of a certain kind [*culverina quaedani*] was placed on the curtain of the lower fortress of Florence, and was so planted there that its mouth pointed towards Artemino, which is the country palace of the Grand Duke of

Tuscany, [Welling renders the Latin, *Hetruria*, as *Esterinæ*; Hutton, et al., translate as *Tuscany*] situated on a rather high hill, and opposite to the west side of the aforesaid fortress, from which also it is distant about 12 miles. I selected a particular day when the west wind was blowing rather briskly, so that the velocity of sound might be resisted by a contrary wind. But this helped the matter only a little, for towards evening the air was entirely still, or at least was agitated with such a slight breeze as would not have put out the flame of a candle. Having left at this spot certain observers skilled in these inquires to whom I had previously given in charge what they should most particularly attend to, I proceeded to the aforesaid palace of Artermino, where the very Honorable Envoy had preferred to be stationed. According to my orders the culverin was frequently fired between the first and third hour of the night, and I plainly counted 49 seconds between its flash and its report. We also fired some cannons at Artermino, and the aforesaid observers, whom I had left in the fortress, counted between the flash and the report of these only 48 seconds. Hence it appeared that the sound was borne from Artermino to Florence only a second more rapidly than it was borne contrariwise.

“I do not so fully confide in this observation of mine that I would venture to refer this very small difference of velocity to the force of a favorable or of an opposing wind. In fact a mistake of the observer himself, as he counted the vibrations of the pendulum, might perchance have given occasion to it. This at least might readily occur. For it must needs often happen that he should not see the flash until after the vibration of the pendulum has begun, and that he should hear the

report of the sound before the vibration has been completed; so that in this way he may make his calculation too large by one vibration, whilst in point of fact the interval of time is precisely the same both ways.

“I was hoping however that on the next morning a contrary wind would perchance arise, (for often at this point, at least with the first dawn of day break, a wind is accustomed to blow from the east) which would better serve for the experiments I had begun. I had ordered therefore the culverin to be fired again as soon as day should have dawned, but the wind was propitious neither to my wishes nor my undertaking. In fact it had shifted only a very little towards the north quarter, in so much that the variation of the time and of the velocity of the sound could scarcely be perceived with such a slight change of the wind. I counted, therefore, the usual 49 vibrations of the pendulum, as before. In the mean time I hope thoroughly to try these same experiments as soon as a more suitable weather shall occur, and as more frequent changes of the winds shall afford more convenient opportunities for trying them to better advantage, until at length I shall satisfy myself perfectly.

“As regards the space which sounds traverse in any given time my informants are not yet agreed among themselves, but from certain experiments they conjectured that the matter is as the experiments of the *Accademia del Cimento* signified.” [This is the end of *Averrari's* contribution.]

So much from this acute and skillful man, whose praises I need not repeat. From his observations together with those which the very honorable and distinguished Envoy [Dr. Henry Newton, that is] has communicated to me it is abun-



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dantly clear that sounds can be heard much further in Italy than my before named ingenious friend informed me. For the Excellent Envoy himself has heard the report of heavy guns at the distance of sixty miles. The guns likewise which at his request were fired at Florence and were heard 55 miles. The cannon fired at Leghorn were audible at a distance of 60 miles. Those which were discharged at Messina, as appears from the geographical tables surprised the ears of men who were distant nearly 100 Italian miles. The report of those which were fired in the siege of Genoa traversed (as appears from the maps) more than 90 Italian miles [one Italian mile = 1.0277 English miles].

When all these facts are recalled to the mind and seriously weighed, I can scarcely avoid the belief that sounds are propagated no less widely in all quarters of the south than in the northern parts of the world. Although the examples of a greater progress of sound are not wanting in certain northern quarters of the globe, a Danish nobleman, a servant of our illustrious Prince of Denmark, has told me, in a conversation, that while he was living in Denmark he had clearly heard the report of cannon fired at Carlsroon, a distance, unless my memory deceives me, of 80 English miles. Likewise that very skilful man Dr. Hearn, the physician of the most illustrious King of Sweden has communicated a special memoir to our Royal Society respecting the guns fired at Stockholm when the obsequies [\[a ceremony to honor the recently departed\]](#) of one of the Royal Princes were celebrated in the year 1685, the report of which traversed an interval of 30 Swedish miles, which are equal to about 180 English miles. At that naval battle likewise which was fought between England and Holland in 1672, the sound of the cannon struck the astonished ears of men through an intervening space of more than 200 miles, reaching as it did, across our island even as far as Salisbury and Wales.

What therefore both the Towneley brothers observed is wholly special and peculiar to the aforesaid Castle of St. Angelo or at least to Rome. For it is not permitted to suspect either the perspicacity of their intellects or their conscientious carefulness.

The diminution of sound which they observed (unless I surmise amiss) must be ascribed either to the situation of this aforesaid castle, or to the intervening houses (rising everywhere and on all sides in that very crowded city) or to the din of the city resounding from all quarters, or to adverse winds, or, in fine, some other like cause, which I leave to be attained by happier conjecture on the part of those whose lot it is to live there, or perhaps these men made their aforesaid observations in that state of the atmosphere in which sounds, although they have the most favorable winds, are nevertheless much more languid than at other times when the winds are entirely adverse. And at one time I had persuaded myself that an atmospheric condition of this kind always obtains at Rome, and not in other parts of Italy, until I fell upon the contrary opinion of Kircher, who says: "Here at Rome, wonderful to relate, when the north wind blows, echo or sound acquires the greatest vigor; when the south wind blows it is weak; when the southeast and east winds blow, it is of a medium character."

But this condition of the air, since it affects sounds so greatly, will not be foreign from our purpose to consider in detail. It is my purpose, therefore, in the next place to treat it more fully, and to set forth the observations which I have made in the premises.

10. Concerning the various weakening and intensity (or audibility) of sound according to the different state of the atmosphere.

I have often observed in summer time, when the air has grown hot, that sounds appeared more languid than usual and were exceedingly weak in their impression on the ear; while in weather of another sort, especially in winter, if it happens to be freezing cold, the same sounds were much more piercing and shrill, and struck the ear more forcibly. Also, when the north or south east wind was blowing, however adversely, I have observed the sounds to be clearer and shriller than if the wind was blowing from contrary quarters, as Kircher also observed at Rome. But this is not uniformly and always the case.

Nor could I form any more certain conclusions from the inspection of a rising or falling barometer as I had too confidently expected to do. For I discovered that sounds were sometimes very clear and shrill, sometimes very faint and languid when the mercury was rising to the top; and on the contrary, sometimes very strong, sometimes very weak, when the mercury was sinking to the bottom.

A like uncertainty obtains with regard to clear and foggy air. In rainy and damp weather I have often observed that sounds are blunted and that after torrential rains they acquire the greatest strength, as Kircher observed at Rome. But the contrary also often happens. For instance, on May 31, 1705, the air on this occasion was more clear and free of vapor than I remember ever before to have seen it. For such was the purity and liquid serenity of the atmosphere that I could clearly and readily perceive exceedingly remote objects. But nevertheless, I was not able to hear the cannon that were fired at that time on the grounds of Blackheath (if I except a single one whose thud reduced to a faint sound, I may have caught in my ears), although I could clearly perceive the flash of them all in the distance. And at the same time the current of the clouds and of the wind was setting in the same direction with the sound. Moreover, the breeze which was then blowing was a very gently one, such as could scarcely ruffle the hair; and, in fine, all things necessary to promote the force and velocity of sound seemed to concur. But on the other hand, when the state of the air and weather has been wholly changed—when everything seemed turbid and the atmosphere full of vapor—I have often heard strong sounds, and not less often have I heard them blunt and weak.

The causes of these variations I leave to be inquired by others, since I confess that it equally exceeds the grasp of my mind to discover them and to assign what may be the proper medium or vehicle of sound – whether the ethereal and more subtle part of the atmosphere, or the vaporous and denser part of the atmosphere, or both combined.

But as regards thick fogs, it is certain that they are dampers of sound in the highest degree. [\[This statement is](#)

unfortunate. It is certainly not true but it was used through the eighteenth century and the first half of the nineteenth century to support the argument that acoustic fog warning signals would be useless. The degree of certainty in Derham's words is surprising particularly in contrast to the uncertainty throughout this section with regard to other effects. When Derham includes detailed observations, he does not shrink from pointing out inconsistencies. In this section alone, he uses the phrases, "...but this is not uniformly and always the case..."; "...but the contrary often happens..." In contrast, he gives no observational evidence regarding propagation in thick fogs, just the unequivocal statement. One wonders whether he is simply repeating "what everyone knows." For sounds then seem to be for the most part very weak and blunted—a fact which very certainly proceeds from the interposed vapors and thick particles which compose fog. I have likewise observed the same concerning snowy weather. [Some authors assert that Derham believes that falling snow damps sound but the next paragraph makes it clear that Derham is talking about the effects of snow on the ground. Freshly fallen snow is a poor reflector of sound.]

For when fresh snow has fallen on the ground sounds straightway grow dull; but when its surface has been covered with ice, the sounds suddenly become more acute, and I then have heard bells ringing and cannon booming just the same as if there was no snow on the ground. My friend Towneley was telling me not very long ago that he had observed (the like of which I have myself experienced) that when he was riding on horseback ringing not far from him was barely able to reach his ears whenever a house covered with snow lay between him and the sound, so that he on entering the little town, was very much surprised that the bells should so suddenly be stilled while he was passing along the first houses that intervened, and that they should suddenly sound again when he was passing along the next vacant space. Indeed during the whole of his course in this town he observed that the sound of bells reached his ears or not according as building covered with snow were intervening or not.

But concerning these things more than enough has been said. We proceed to other matters of greater moment.

11. Concerning the force of winds or their influence on the velocity of sound.

The illustrious Accademi del Cimento at Florence found from experiments that the velocity of sound was neither retarded by adverse winds nor accelerated by favorable ones, but that, however the winds might blow, sounds always traversed the same space in the same time. Gassendi was of this opinion, and almost all the rest who have philosophised before or since.

Since, however, the contrary of this is plain from mere experience, these authorities must be corrected of error, into which they seem to have fallen for this reason, that their experiments were tried within a too short space. For it is very probable that these philosophers made their observations at a distance of only one or, at the most, of two or three miles. Hence I do not wonder that their observations are faulty; but if they had tested the matter, as I have often done, at ten or twelve thousand paces, using accurate instruments, they

would have easily recognized their error.

This common error, I myself, relying on the authority of these men, admitted for a long time, until at length, by more than three years of observation of cannons on the Blackheath grounds, I luckily detected it. When, however, at first I perceived the sounds to come to my ears sometimes quicker, sometimes slower, the suspicions entered my mind that I had committed some error, either because I had less accurately counted the vibrations of the clock, or had badly observed the flash of the cannon, or from want of attention, had fallen into some other such like error. But after the cannons were continuously fired, at my request, every half hour, from six o'clock in the evening till midnight, and after I constantly perceived that the sound reached me, without any perceivable variation, in the space of a hundred and twenty or of a hundred and twenty-two half seconds, however much wind may have been directly adverse; while at other times, when the wind was blowing favorably, either directly or crosswise or obliquely, I found that the sound of the same cannon reached me in the space of 111, 112, 113, 114, 115, 116 or, at the most, of 117 half seconds, then at last I became thoroughly persuaded that there was a certain real difference that produced this variety in the observations.

Nor is it only true that favorable or adverse winds accelerate or retard the velocity of sounds but it is also true that, in accordance with the variety of the degrees with which they blow more strongly or more gently, so much the more or less do they promote or impede this velocity. For greater certain-

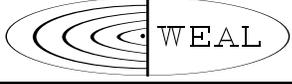


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Table of the sounds of cannons on the grounds of Blackheath according to the variation of the winds and the force with which they were blowing.

Year, month, and day	Time of Day	# of ½ second vibrations	Direction of the wind ^a and rate of velocity ^b	Direction of the clouds	Height of the barometer	Remarks
1704^c						
Feb. 11	11 ½ AM	119	E, 2	E	30.22	
Feb. 13	From 6 PM 'til midnight	120	NE by E, 1	NE by E	29.99	
		122				
1705						
Mar. 30	10 AM	119	SW, 7	SW	29.30	
Apr. 2	8 ½ AM	114 ½	S by W, 1			
Apr. 3	10 AM	116 ½	S, 4	lower S, upper W by N	29.80	
Apr. 5	1 PM	111	SW by W, 7	SW by W	29.20	
Apr. 13	8 ½ AM	120	N by E, 2		29.26	
Apr. 24	5 PM	116	SW by W, 0	NW	29.59	
Sept. 11	6 ½ PM	115	W, 2	W by N		saker
	7 PM	115 ½	W by N, 2			mortar
Sept. 29	10 ½ AM	112	SSW, 4	SSW	29.38	
Oct. 6	10 AM	117	ESE, 1&2	SE	29.34	
Nov. 30	12 m	115	SSW, 4	SSW	29.10	
Feb. 15	11 AM	116	S by W, 1	SW	29.60	
1706						
Nov. 29	11 ½ AM	116	SW, 0	SW by W	30.06	
	12 m	118	SW by S, 1			
Feb. 7	12 m	113	SW by W, 4	W	29.83	
Welling's note: [N.B. The distance of the guns from the observer seems to have been about 12 miles. $1142 \times 58 \text{ sec} = 66236 \text{ ft} \div 5280 = 12 \frac{1}{2} \text{ miles.}$]						

[a SW by W would indicate a wind directly from Blackheath to Derham's observation point.

b The wind velocity is indicated by the number given after the direction. See text, Sections 11 and 12.

c Customary usage of the year included January and February following. For example, Feb. 13 is listed above under the heading, 1704. The next entry is Mar. 30 under the heading, 1705, but these two observations are most likely only a few weeks apart rather than a full year apart (and both would be in 1705 by modern accounting).]

ty respecting all these things I will subjoin in the following table certain special observations, which were made after I had before noted that the cannon on the Blackheath grounds ranges from the sound, that is, that they inclined to the quarter of the compass a little beyond S.W. by W.

I have selected these observations from very many others, all of them being cautiously made and each one repeated two or three times or oftener, so that what I have said above respecting their truth is abundantly and indubitably manifest. For, from the experiments made on April 5 and Sept. 29 it is plain that the stronger winds push forward and hasten the velocity of sounds. For on the fifth of April, when the

motion of the wind and of the sound was nearly coincident, and when the same wind was a little stronger (as is denoted by the number 7 annexed, just as the number 0 denotes tranquil weather, and as the numbers 1, 2, 3, 4, signify different powers of the wind) then, I say, the sound finished its passage in the space of 111 half seconds. But on the 24th, when the wind was blowing from the same quarter, and the air was still, the sound made the same passage in an interval of 116 half seconds. So likewise on the 7th of February, 1706 when the wind was blowing from the same quarter of the compass and was carrying the sound with it, but now with only half the strength, 113 half seconds elapsed before the sound made its

usual passage. So, in fine, on Sept. 29, 1705, when a stronger and less favorable wind was blowing, the sound completed its progress within 112 half seconds. From which examples, and from others in the table, it plainly appears that stronger winds assist the propagation of sound, but that lighter winds are less effective in promoting its propagation.

The same likewise is plain respecting those winds or currents of air which directly favor or obstruct the progress of sound—that they make its velocity quicker or slower—and where intermediate currents (streams) of air are blown, that they produce in like manner an intermediate progress of sound, as measured by the vibrations of the pendulum.

The greatest difference which I have yet observed in the passage of sound through a space of about 13 miles amounts to about nine or ten half seconds, that is, when strong winds are aiding and only gentle ones are obstructing the sound.

But when only gentle winds, or almost none at all, are either obstructing or aiding the sound, then the difference does not exceed two or three half seconds.

After, in this way, I had perceived what influence the winds have, both for accelerating and retarding the course of sounds, curiosity led me to inquire into the velocity of the winds themselves. And though the inquiry may be foreign to my subject, it will not be wholly ungrateful, as I hope, to curious minds, if I publish in this connection certain observations on this point.

12. Concerning the velocity of winds.

In order to ascertain how large a space winds may traverse in any given time, I have used, in prosecuting my experiments, certain bodies of the somewhat lighter sort, such as thistle down, light feathers, etc., which seemed better to serve my purpose than the instrument which is described for us in the *Philosophical Transactions*, No. 24; or even that other more available one, recalling the figure of a mill with wings attached, invented, unless I mistake, by our most acute friend, the late Dr. Hook. [Derham often references the *Philosophical Transactions* by number rather than by volume. The reference here is to Moray and Hook, “Directions for observations and experiments to be made by Masters of ships, Pilots, and other fit persons in their sea-voyages,” *Phil. Trans. Royal Soc. London*, 2, 433-448, 1667.]

From very many experiments which I have made, with the aid of the lighter sort of bodies, when the winds were blowing with different degrees of force, I have found that the most violent wind traverses scarcely 60 miles an hour. For example, on the 11th of August, 1705, the violence of the wind excited such a tempest that it almost overturned the windmill itself near the spot where I made my observations. [The different degrees of the force of the winds, as has just been seen, I have for the most part noted by these numbers: 0, 1, 2, 3, 4, 5, 6, up to 10, 15, or still higher degrees.] Now I have estimated that the force of the above indicated wind answers to about 12 or 14 on this scale. And from very many reiterated experiments I have concluded that that violent wind traversed about 33 feet in a half second, or 45 miles in an hour; hence I gather that the fleetest and most tempestuous winds (that violent wind which raged in the month of

November, 1703, not being excepted) do not traverse more than 50 or 60 miles an hour.

After we have measured the velocity of the rapid winds, it is not difficult to conjecture what may be the velocity of less rapid ones; for I have also marked the course of these, and from various experiments I have convinced myself that some of them accomplished 15, some 13, others many less miles per hour; while some are propagated with such a slow motion that they move scarcely a single mile an hour. Moreover, other winds are so sluggish that one may easily outstrip them while making a journey on horseback or on foot. This fact is apparent to our senses, for when we arrest our steps we perceive a soft breeze gently fanning us, but if we advance with it we feel none at all; while if we quicken our pace instead of a breeze accompanying us and blowing in the same direction with our movement, we plainly feel the air resisting us, and blowing full in our faces. Likewise when the atmosphere is entirely quiescent and stagnant, if we chance to be walking or riding on horseback, we then perceive a gentle breeze pressing against us, with such degrees of force, in fact, as correspond to the rates of our own motion. And a breeze of wind or current of air is borne with the same rate of motion or velocity when it presses against us with an equal impetus as we stand still, or linger in our track.

From these observations about the velocity of winds very many things, not without utility, might be noted, but especially might we assign in view of them, one reason why the mercury rises and falls for such a long time before clear weather or rain sets in.

But I will omit these considerations as being foreign to my purpose, and this only will I observe as to sounds, to wit, that while their motion is accelerated by wind it is plain that those parts of the atmosphere by which sounds are impressed or propagated are not the same as those from which winds are blown, but certain other more ethereal and volatile parts, as one may suppose. For the fleetest winds do not pass through more than 60 miles in an hour, but sounds travel more than seven hundred thousand paces, or 778 miles in the same time.

But if it be objected that winds do accelerate or retard sounds it is to be answered that this does not only proceed from the current or tendency of the windy particles alone, but rather from the conjoint and cooperating motion of all the particles of the atmosphere, both the thicker and the ethereal. If the direction of this course of motion favors the waves of sound it is altogether in accordance with probability that the impulse of sounds should be accelerated by this cause, but if the direction is adverse that, the impulse should be retarded.

13. Concerning the velocity of sounds.

After having in this way set forth the operation and effects of wind on the progress of sound and having spoken thus generally respecting the velocity of sounds, it remains at last that I should report the more special observations which I have made on this point. From what has been said, therefore, and from many other things which we have noted before I conclude most decisively that sounds are propagated with

the following degree of velocity, to wit, that they traverse the space of a mile or 5280 English feet in $9\frac{1}{4}$ half seconds. Or which amounts to the same thing, 571 ft in $\frac{1}{2}$ second and 1142 ft in a whole second.

This, however, is the defined space traversed by sounds, if a current of the atmosphere blows across their path, and is their mean progress or velocity.

But if the wind increases the rapidity of the sound, it is possible that it may traverse more than 600 ft in the space of a $\frac{1}{2}$ second; or on the other hand if the wind retard its motion it may not proceed more than 560 ft in the same interval of time.

So, at length, I have brought to an end this memoir of mine, in which I have summarily embraced the principal observations I have made about the progress of sound, and certain other things pertaining thereto.

Practiced and ingenious men will not have much difficulty in applying this exposition to very many uses which are not to be despised. But especially would the aforesaid observations and experiments seem to pertain not a little to

1. The Philosopher, who, even because of them, will be in some respects better equipped for the investigation of the secret nature of sounds and for explaining their very numerous abstruse phenomena;

2. To the Sailor, who hence may learn how far off are the ships which he sees floating in the distance, or lying at anchor; how remote likewise may be the desired land or beach which he sees in the distance—facts which, from shots designedly fired on a given signal, may be easily and certainly known;

3. To the Soldier for the purpose of finding how far an enemy has placed his camp; at what distance an arsenal, a fort, or a besieged city is situated, for the purpose of planting against them siege cannon, and aiming mortars and bomb shells;

4. To the Geographer, for more readily and certainly measuring the distances of places, because any body who is furnished with a small quantity of powder can, in this way, within an hour or two exhibit almost the whole of any region with a table most accurately outlined seeing that gunshots, as I have said, serve to mark distances by their firing, and any mathematical instrument by which angles are measured, either that common instrument which surveyors use, called the Plain Table or a single rule, furnished with graduated scales, will indicate the situations of the various places, which afterwards can be easily delineated. [The Plane Table or Plain Table was normally used in surveying as follows: two or more level tables would be set up at surveyed locations. A sighting device—an alidade—was used on each table to draw direction lines to objects sighted from both locations. From the sighting lines from both tables, and the locations of the tables, a map could be constructed locating any object sighted.] In this way, too one can readily inquire into the correctness and truth of maps, and if they have any errors he can correct them.

In fine, this method of observing sound, would be of great use in measuring distances of inaccessible places, especially of very wide rivers and places of that kind not other-

wise easy to be measured. For a specimen of this work, I resolved with the aid of friends to compare the distances of certain among the more celebrated bays and straits, especially of the Strait of Gades, between Tangier and Gibraltar, and the British Channel between Dover in England and Calais in France, where the breadth of the channel according to the measurement of ingenious Frenchmen, is 22.07 English miles. But the lamentable season of war through which we are now passing has interposed an obstacle to these undertakings and to others having for their object the promotion of learning;

5. For the measurement of echoes. Although many learned men have anxiously inquired both anciently and in subsequent times concerning this amusing and pleasant phenomenon of sound, still there is not a good degree of harmony among them respecting many things which relate to it, especially respecting the extent of space necessary for the repetition of one, two, three or more, syllables, or, what amounts to the same thing, respecting the space traversed by an echo in a certain interval of time. Mersenne allows... [ellipsis in Latin manuscript] yards for the repetition of a monosyllabic sound. Blancanus allows 24 yards, to which our very celebrated countryman Dr. Plot gives his assent, but Athanasius Kircher asserts that nothing at all can be defined with certainty respecting it, because, the variation of the winds, the intensification and the relaxation in the force of sound and many other things produce an immense variation.

It is not difficult, however, to offer an explanation of this disagreement among these distinguished men, for it can arise from many causes—certainly from the slowness and from the different disposition of our senses, or from the various audibility of sounds; from the grave or acute sound of the syllables themselves, or from their protracted or prolonged pronunciation, or from any other cause which may protract the interval of time. I can have no doubt for instance, that if any sound reflecting object, should be able to reverberate all the syllables of this verse

vocalis nymphe quae nec reticere loquenti

[Welling's note pertaining to this line of Latin and the next: Quoted from Ovid's *Met.*, iii, lines 357 and 359.]

it would not be able to reverberate all the syllables of the following verse, since its pronunciation is much more prolonged:

corpus adhuc echo, non vox erat, et tamen resume

And still less would it be able to repeat all the harsh and prolonged syllables of the following verse:

Arx tridues rostris sphinx, praester, torrida, seps, strix.

But from the foregoing observations concerning the velocity of sound it may be concluded that echoes, like sounds, traverse certain and determinate spaces in a certain definite time. What I have myself frequently learned from

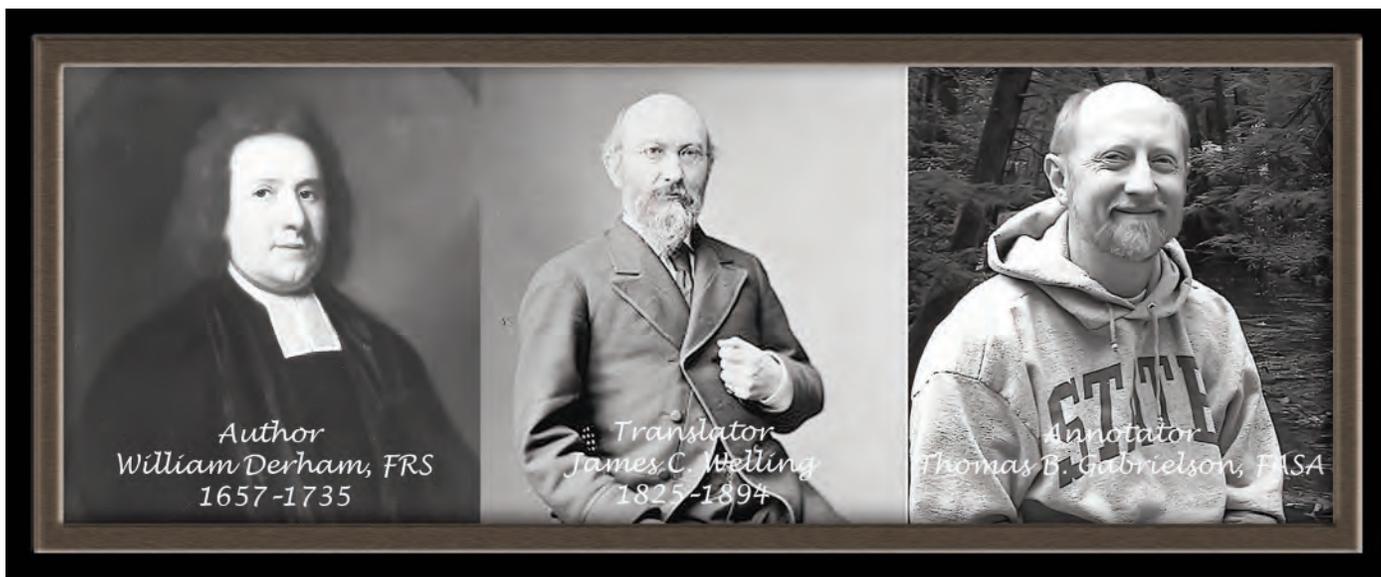
experience is this: that an echo returns in double the interval of time in which the primary sound reached the sound-reflecting object. For example, if the sound-reflecting object was distant 600 ft., the return of the echo would take place within the same interval of time in which the primary sound would have traversed 1200 ft. if it had not been reverberated.

And this fact has often been of great use to me in measuring the distance of places. For example, when I was standing on the bank of the river Thames opposite the town of Woolwich, the echo of a monosyllabic sound has been reverberated from the opposite houses in six half seconds from which I infer that the width of the River Thames at the at point, from the margin of one bank to the margin of the other

is 1712 English feet, or over a quarter of a mile. For, as 9.25 half-seconds are to 5280 feet (a mile), so are six half-seconds to 3423.8 feet – the half of which is 1711.9 feet.

Finally, in this way the height of thunderclouds and the distance of the thunder and lightning itself may be easily ascertained. [The idea of determining the distance to a thunderstorm by counting seconds from the lightning flash to the report of thunder is not original with Derham. This idea was expressed by members of the Accademie del Cimento in Florence prior to Derham's paper. See the English translation by Waller of these writings (reference given in the first Table above).]

Finis.



The portrait of William Derham is printed with the kind permission of The Royal Society ©. The picture of James C. Welling is printed with the kind permission of the Library of Congress and is from the Brady-Hardy Collection. The picture of Thomas B. Gabrielson is printed with the kind permission of the Annotator.



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ANSI STANDARDS: ALIVE AND WELL IN THE GRADUATE AUDIOLOGY CLASSROOM

Sandra Gordon-Salant

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Audiology graduate curricula are infused with the basic science foundations of the profession of audiology. Virtually all of the work that audiologists do involves presentation of acoustic stimuli to clinical patients, whether during hearing assessment, hearing aid evaluation and fitting, or aural rehabilitation. One fundamental tenet of this work is to ensure that the signal being delivered through the instrumentation (including audiometers, aural acoustic immittance units, and hearing aids) is accurate. A secondary tenet is that the acoustic environment in which tests are conducted, and/or services are delivered to patients (including educational services to students) conforms to minimum requirements for noise and reverberation. Additionally, audiologists may be involved in hearing conservation programs that include noise surveys conducted in the work environment. These surveys must conform to rigorous standards of measurement. Fortunately, the American National Standards Institute (ANSI) provides a range of standards for measuring sound pressure levels, force levels, and reverberation to verify signal accuracy and environmental sound quality. For the most part, standards that are relevant to the work of audiologists are developed by Accredited Standards Committee S3, Bioacoustics that is sponsored by the Acoustical Society of America (ASA).

There are dozens of ANSI standards that are relevant to the practice of audiology, and they are covered in a variety of courses in the typical audiology curriculum. For example, the standards that describe acoustical measurement of hearing aids (e.g., ANSI S3.22-2003: American National Standard Specification of Hearing Aid Characteristics; ANSI S3.46 – 1997, (R 2007): American National Standard Methods of Measurement of Real-Ear Performance Characteristics of Hearing Aids) are usually taught in the sequence of hearing aids courses. The standard on classroom acoustics (ANSI S12.60-2002: American National Standard Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools) is taught in an educational audiology course. Courses on industrial audiology generally present the standards on measurement of noise in the workplace, as well as the effectiveness of hearing protection. Instrumentation courses and/or courses on hearing assessment include material from ANSI S3.6-2004: American National Standard for Audiometers and ANSI S3.39-1987 (R 2007): American National Standard Specifications for Instruments to Measure Acoustic Impedance and Admittance. How is the material taught and

“ANSI standards are alive and well in the audiology curriculum because they teach students to conform to the highest principles of professional practice.”

how do students gain access to the ANSI standards? The balance of this report describes my own experience teaching the American National Standard for Audiometers in the course, Basic Hearing Measurement, that is the gateway course for the graduate curriculum in audiology at the University of Maryland at College Park.

Course material about the development of audiometers and physical features of contemporary audiometers segues into the types of audiometers that are currently in use, including standard markings denoting these types. Subsequently, the importance of calibrating audiometers on a regular basis is discussed. Students are introduced to the ANSI organization and the role it has played in establishing national standards. Definitions of technical terminology such as Reference Equivalent Threshold Sound Pressure Levels (RET SPLs) are provided, as well as procedures for calibrating the output levels, linearity, and harmonic distortion of audiometers. Students learn about the tolerances associated with each measurement, and how to determine whether or not an audiometer is in calibration. Tables specifying the standard audiometer types, RET SPLs, Reference Equivalent Threshold Force Levels (RET FLs), Equivalent Threshold Sound Pressure Levels (ET SPLs), harmonic distortion levels, and ambient permissible noise levels from the ANSI S3.6, 2004 standard (American National Standard for Audiometers) are discussed in detail. Classroom demonstrations of these measurements with instrumentation needed to perform the calibration are followed by assignment of a calibration lab.

One prevailing issue over the years that I have taught this course has been how to provide the information from the ANSI standard to students while conforming to fair use of this copyrighted material. In previous years, I have relied on secondary sources (e.g., textbooks and journal articles) that reproduced the relevant tables. Unfortunately, the textbooks and articles rapidly became outdated with frequent revisions of this particular standard. An alternative was to distribute selected tables from the standard to provide the essential information required by students to perform the calibration. Both of these methods of delivery were inadequate for conveying to students the rationale for each of the measurements and the detail of many aspects of the standard. Requiring students to purchase the entire standard (current cost of \$150) was an excessive financial burden for students, who were also required to purchase a textbook for the course.

In November, 2005, the ASA issued a press release (<http://www.acosoc.org/standards/Educational%20use%20of>



Clockwise from upper left: Hallie Plevinsky checks the sound level meter with the pistonphone. Ting Wei attaches earphone to NBS 9A coupler and places 400 g weight on top of earphone. Will Bologna and Julia Rainsford check the sound level meter reading with the ANSI reference equivalent threshold SPLs. Julie Cohen and Danielle Zion note sound level meter readings on calibration worksheet. Center: Sandra Gordon-Salant with Barbara Libbin, who was awarded her AuD diploma at the University of Maryland 2008 graduation ceremony.

%20stds%2011-1-05.pdf) describing a new policy for distribution of ANSI standards for educational purposes. The policy, initiated by then-President William A. Yost, was intended to encourage classroom use of standards by making the standards readily available at a nominal fee. Instructors who are members of the ASA can request a watermarked, downloaded copy of an ANSI standard at a cost of \$5/student enrolled in the class.

This new distribution program is the perfect mechanism for providing one or more entire ANSI standards to students at a minimal cost. I have been using this program since fall, 2006, with a high level of success. Arrangements for obtaining educational use of the standard are made through e-mail contact with Susan Blaeser, ASA Standards Manager, (sblaeser@aip.org). The instructor or academic department completes a site license agreement and pays the fee for a specified number of students enrolled in the course. Within 24 hours, a watermarked version of the standard is sent to the instructor as an e-mail attachment in pdf format. I have distributed the standard to students by uploading it onto my course website maintained by Blackboard. Hence, the material on this website is available exclusively to students enrolled in the course.

Student access to the entire standard has short-term and long-term advantages. In the short-term, students can learn more about the development of the standard and all of the detailed information included in the standard, to supplement information covered during class lectures. They have ready access to all of the definitions in the standard and cross-referencing of other standards that are pertinent to ANSI S3.6. More importantly, they develop an appreciation for the comprehensive nature of the standard and its use in clinical procedures. In the long-term, students have a resource that will be used in their professional practice. Whether they conduct calibration on their own or hire a contractor to perform this function, audiologists must know the essential elements of calibration and how to determine if an audiometer fails calibration requirements. They also must be cognizant of the need to update the standard as new versions are published,

and how to determine changes in the standard over time. All of these objectives are met by placing the standards in the hands of students early in their educational career.

Another, less tangible, advantage of using the ASA educational distribution program is to model an ethical standard for professionalism. Faculty members are required to follow fair use agreements regarding distribution of copyrighted material for classroom use. This includes reproducing book chapters, journal articles, and other published material in course packets. One function of faculty members is to serve as role models for students to emulate. By informing students of the ASA program to distribute legitimate copies of the ASA standard, the faculty member demonstrates that he or she is conforming to ethical and legal standards in academia.

Students appreciate the opportunity to obtain the ANSI standard during their professional training. They recognize that they will be using ANSI standards throughout their career to ensure precision in stimulus presentation, hearing measurement, and hearing aids. One first-year student commented, "I now understand the importance of having these standards and how calibration can affect daily practice and research" (H. Plevinsky), while a second-year student (K. James) noted that having access to the ANSI standards has been useful because she can consult them whenever she has a question or concern regarding calibration and/or tolerances.

In summary, the ASA educational distribution program for ANSI standards is an invaluable resource in audiology graduate programs. It provides students with the primary source in its entirety, which serves as a reference for the student during individual courses as well as throughout the student's educational career. Ready access to the standards familiarizes students with their importance and promotes their use of essential standards during their professional practice. Use of legitimate copies of the standards in the classroom encourages students to follow ethical principles by obtaining legal copies when they are practicing audiologists. Yes, ANSI standards are alive and well in the audiology curriculum because they teach students to conform to the highest principles of professional practice.**AT**



Sandra Gordon-Salant is a Professor and Director of the Doctoral Program in Clinical Audiology in the Department of Hearing and Speech Sciences at the University of Maryland, College Park. She has taught a course entitled, Basic Hearing Measurement, for over two decades to first-year graduate students in Audiology. She is a member of the Acoustical Society of America and has served as a member of the National Research Council Committee on Disability Determination for Individuals with Hearing Impairments. She directs an NIH-supported research program on the effects of aging and hearing loss on auditory processes and speech perception.

Elaine Moran

Acoustical Society of America
Melville, New York 11747



Floyd Dunn

Floyd Dunn receives William J. and Francis J. Fry Award

Floyd Dunn was awarded the William J. and Francis J. Fry Award by the International Society for Therapeutic Ultrasound for his lifelong contributions to the general area of biophysics and bio-effects of ultrasound.

Floyd Dunn received the B.S., M.S., and Ph.D. degrees in 1949, 1951, and 1956, respectively, from the University of Illinois, Urbana, all in Electrical Engineering. He joined the faculty of the University of Illinois in 1955, became Professor in 1965, and retired in 1995 with emeritus status. During his tenure, he held joint appointments as Professor of Electrical Engineering, of Bioengineering, and of Biophysics, was Director of the Bioacoustics Research Laboratory from 1977 to 1995, and Chairman of the Bioengineering Faculty 1978 to 1982. His main research interests including all aspects of the interaction of ultrasound and biological media, about which he has published more than 200 journal articles, book chapters, and books.

Floyd Dunn is a Fellow of the Acoustical Society of America (ASA), the Institute of Electrical and Electronics Engineers (IEEE), the

American Institute of Ultrasound in Medicine (AIUM), the American Association for the Advancement of Science, the Institute of Acoustics (UK), and the American Institute of Engineering in Medicine and Biology. He is a member of the National Academy of Sciences and the National Academy of Engineering.

Professor Dunn has received numerous awards, including the Medal of Special Merit of the Acoustical Society of Japan (1988); the ASA Silver Medal in Bioresponse to Vibration (1989); the Career Achievement Award of the IEEE Engineering in Medicine and Biology Society (1995); the 1996 IEEE Edison Medal, and the ASA's Gold Medal (1998) "for creative contributions to fundamental knowledge of ultrasonic propagation in, and interactions with, biological media."

Floyd Dunn is an Associate Editor of the *Journal of the Acoustical Society of America*. He has served ASA in numerous positions including President (1985-86), President-Elect (1984-85), Vice President (1981-82), Vice President-Elect (1980-81), Member of the Executive Council (1977-80), and as member and Chair of numerous committees.

Carol Espy-Wilson named Radcliffe Fellow

Carol Espy-Wilson, professor in the electrical and computer engineering department at the University of Maryland at College Park and Director of the Speech Communication Laboratory, was named a 2008-09 Radcliffe Fellow. Radcliffe Institute fellowships are designed to support scholars, scientists, artists, and writers of exceptional promise and demonstrated accomplishments who wish to pursue work in academic and professional fields and in the creative arts.

During the fellowship year, Espy-Wilson will focus on the noise robustness of a probabilistic landmark-based speech-recognition system. The devel-



Carol Espy-Wilson

opment of this technology is a collaborative effort between researchers in engineering, linguistics, computer science, and rehabilitation science.

Professor Espy-Wilson received a B.S. in Electrical Engineering from Stanford University, and M.S., E.E., and Ph.D. degrees in Electrical Engineering from the Massachusetts Institute of Technology. She was a faculty member at Boston University prior to joining the University of Maryland faculty. She received a National Science Foundation Minority Initiation Award, the Clare Boothe Luce Professorship, a National Institutes of Health (NIH) Independent Scientist Award, and a Honda Initiation Grant. She has received considerable research funding over the years from the National Science Foundation, The National Institutes of Health and from partnerships with various companies.

Professor Espy-Wilson is a fellow of the Acoustical Society of America (ASA), where she currently serves as chair of the Technical Committee on Speech Communication and a member of the Editorial Board of *Acoustics Today*. She is a senior member of the Institute of Electrical and Electronics Engineers; and a past member of the NIH Language and Communication Study Section.



Purnima Ratilal (c)

Purnima Ratilal receives President's Early Career Award

Purnima Ratilal, Assistant Professor in the Department of Electrical and Computer Engineering at Northeastern University, has been named one of the sixty-seven recipients of the 2007 Presidential Early Career Awards for Scientists and Engineers, the United States highest honor for professionals at the outset of their independent scientific research careers. The awards ceremony took place on 19 December 2008 at the White House, presided over by John H. Marburger III, Science Advisor to the President and Director of the White House Office of Science and Technology Policy.

The Presidential Early Career Awards for Scientists and Engineers honors the most promising researchers in the U.S. within their fields. Nine federal departments and agencies annually nominate scientists and engineers whose work shows exceptional promise for leadership at the frontiers of scientific knowledge. Recipients receive up to five years of funding to further their research in support of critical government missions. Purnima Ratilal, was chosen after being nominated by the U.S. Navy for her work on acoustics and remote sensing. She will receive \$200,000 a year for five years.

Purnima Ratilal received a B.Sc.(Hons.) in Physics from the National

University of Singapore, 1994 and a Ph.D. in Ocean Engineering from the Massachusetts Institute of Technology (MIT), 2002. She was a Postdoctoral Associate at the MIT Department of Ocean Engineering (2002-2004) and a Research Engineer at DSO National Laboratories, Singapore (1994-1998).

Dr. Ratilal has also won the Office of Naval Research Young Investigator Award in 2007 and the Office of Naval Research Postdoctoral Award in Ocean Acoustics from 2002 to 2004. She was awarded the R. Bruce Lindsay Award of the Acoustical Society of America in 2006 "for contributions to the theory of wave propagation and scattering

through a waveguide, and to the acoustic remote sensing of marine life."

She is a member of the ASA Technical Committee on Underwater Acoustics and was also one of the nine young investigators selected to present Young Investigator Keynote addresses at the 75th Anniversary Celebration of the Acoustical Society of America in 2004.

Portland State University engineering student awarded a graduate traineeship

Jorge Quijano, a Ph.D. candidate in the Department of Electrical and Computer Engineering (ECE) in the Maseeh College of Engineering and Computer Science at Portland State University (PSU), has been awarded a Graduate Traineeship Award by the Office of Naval Research (ONR). The award is competitively given to students who "have demonstrated a special aptitude and desire for advanced training in ocean acoustics." Quijano's award will provide financial support for up to three years of his Ph.D. studies, including stipend, tuition, and travel expenses.

Jorge Quijano joined PSU in 2004 as a Fulbright scholar to pursue a masters degree in Electrical and Computer Engineering. In 2005 he joined the Northwest Electromagnetics and Acoustics Research Laboratory and in 2006, Quijano was invited to participate in the Navy sponsored Shallow Water 2006 Experiment as part of the



Jorge Quijano

team aboard the Research Vessel Knorr operated by MIT Woods Hole Oceanographic Institution. The experiment was conducted off the eastern coast of the United States and it provided high quality data on ocean bottom acoustic scattering.

Jorge Quijano is a student member of the Acoustical Society of America (ASA) and a member of the Organizing Committee for the Portland ASA meeting to be held in May 2009. He was recently selected Outstanding ECE Ph.D. student for 2008.



Erica Ryherd



Oleg Godin



Martin Pollack

Martin Pollack presents ASME Invited Lecture

Martin Pollack, Corporate Scientist at Applied Physical Sciences Corp. in Groton, Connecticut, presented the American Society of Mechanical Engineers (ASME) 2008 Rayleigh Lecture at the NoiseCon 2008/ASME Noise Control and Acoustic Division Conference in Dearborn, MI in July 2008. The Raleigh Lecturers are selected from among those who have made pioneering contributions to the sciences and applications of noise control and acoustics.

At Applied Physical Sciences Corp., Dr. Pollack has been responsible for developing advanced methods for predicting the acoustic performance of motors and actuators. He is also a member of the Participating Faculty at Union Graduate College, a member of the Acoustical Society of America, and a fellow of the ASME.

Erica Ryherd receives ASHRAE award

Erica E. Ryherd, Assistant Professor, Georgia Institute of Technology, received a 2008 New Faces of Engineering Award from the National Engineer Week Foundation. She was one of five engineers nominated by the American Society for Heating, Refrigerating and Air Conditioning Engineers. The New Faces of Engineering program highlights the interesting and unique work of young engineers and the resulting impact on society. Young engineers two to five years out of school are the focus of this recognition program.

Erica Ryherd received a Ph.D. from the University of Nebraska. She was a postdoctoral researcher at the Sahlgrenska Academy of Medicine in Gothenburg, Sweden and joined the Georgia Tech faculty in 2007. She received the ASA F. V. Hunt Postdoctoral Research Fellowship in Acoustics (2006-07), the Robert Bradford Newman Medal (2002), and the Institute of Noise Control Engineering Martin Hirschorn IAC Prize (2001).

Dr. Ryherd is a member of the ASA and has served on the ASA Student Council. She is faculty advisor, with Karim Sabra, to the ASA's Georgia Tech Student Chapter. Most recently, she was the Technical Committee on Noise representative to the Technical Program Organizing Meeting for ASA's Fall 2008 meeting.

Oleg Godin receives award from the Cooperative Institute for Research in Environmental Sciences

Oleg Godin, a CIRES Senior Research Scientist with ASAP (Advanced

Sensor Application Program) Group at the Physical Science Division of the Earth System

Research Laboratory (NOAA/ESRL) was named recipient of an Outstanding Performance Award by the Cooperative Institute for Research in Environmental Sciences (CIRES). CIRES' Outstanding Performance Awards program was established to recognize exceptional contributions by its members.

Dr. Godin is an authority on the theory of wave propagation in inhomogeneous and moving media. In recent years, he achieved a number of scientific accomplishments, which demonstrate his initiative, resourcefulness and creativity. He developed a theory of the so called "tsunami shadows," i.e., changes in ocean surface roughness induced by tsunami waves, and proposed to use this phenomenon for tsunami detection from space. In 2006-2007, the theory has been confirmed by analyses of satellite imagery. He also discovered the phenomenon of anomalous transparency of water-air interface. The phenomenon completely changes the outlook on the possibility of acoustic communication through the water-air interface and has important geophysical, biological, and national security implications.

With Dr. David R. Palmer of NOAA/AOML, Dr. Godin compiled and edited a 1200-page multi-author book, History of Russian Underwater Acoustics. This book brings to the Western reader a wealth of information, which remained classified or otherwise unavailable. In order to commemorate his late mentor and out-

standing Russian scientist Acad. Prof. L. M. Brekhovskikh, Godin prepared for publication in Russian a fundamental, 1000-page treatise of sound propagation (L. M. Brekhovskikh and O. A. Godin, *Acoustics of Inhomogeneous Media*. Vol. 1, *Fundamentals of Sound Reflection and Propagation Theory*, Nauka, Moscow, 2007; Vol. 2, *Sound Fields in Layered and 3-D Inhomogeneous Environments*, Nauka, Moscow, in press). This book is an extended and updated version of *Acoustics of Layered Media* by the same authors published in English in 1990-1999.



Betty Tuller

Betty Tuller elected fellow of AAAS

Betty Tuller, a member of the Acoustical Society of America, was elected a Fellow of the American Association for the Advancement of Science in November 2008. New AAAS fellows will be recognized at the Fellows Forum during the AAAS Annual Meeting in February. Dr. Tuller earned her doctorate in Psychology from the University of Connecticut in 1980. She is Professor of Psychology at Florida Atlantic University Center for Complex Systems and Brain Sciences and is currently a Program Director for Perception, Action, and Cognition at the National Science Foundation.

ASA members receive Audio Engineering Society Awards in 2008

The Audio Engineering Society (AES) presented its Fellowship award to four

members of the Acoustical Society of America (ASA) at its 125th Convention in October 2008. The Fellowship Award is given to a member who had rendered conspicuous service or is recognized to have made a valuable contribution to the advancement



Robert Maher

in or dissemination of knowledge of audio engineering or in the promotion of its application in practice.

Robert C. Maher is Department Head and Professor in the Department of Electrical and Computer Engineering at Montana State University. He holds a BS from Washington University in St. Louis, an MS from the University of Wisconsin-Madison, and a Ph.D. from the University of Illinois-Urbana, all in Electrical Engineering. His research and teaching interests are in the area of digital signal processing, with particular emphasis on applications in digital audio, digital music synthesis, and acoustics. Professor Maher was cited “for research contributions in, teaching



Neil Shaw

of, and service relating to digital audio signal processing.”

Neil A. Shaw, of Menlo Scientific Acoustics, Inc., in Topanga, California, and the University of Southern California Thornton School of Music faculty, is a Fellow of ASA and serves as a Patent Reviewer for the *Journal of the Acoustical Society of America*. He studied at the Cooper Union in New York and received BS Engineering and MS Engineering degrees from the University of California, Los Angeles and has been a design consultant for more than 32 years. Neil Shaw was recognized “for contributions to engineering acoustics, sound reinforcement, and service to the Society.” He is a member of the ASA Technical Committees on Architectural



Julius Smith (r)

Acoustics, Engineering Acoustics, and Physical Acoustics and the Committees on Books+, Education in Acoustics, and Regional Chapters.

Julius O. Smith is Professor of Music and Associate Professor (by courtesy) of Electrical Engineering at Stanford University, based at the Center for Computer Research in Music and Acoustics (CCRMA). He received MS and Ph.D. degrees from Stanford University. Activities include teaching courses in signal processing and music technology, graduate student advising, and research in signal processing techniques applied to music and audio. Professor Smith, a Fellow of ASA and a member of the ASA Technical Committee on Musical Acoustics, was cited “for applications of digital signal processing to musical acoustics.”



Victor Zue

ASA member named Fellow of the ISCA

ASA Fellow Victor Zue was among the first group of fellows named by the International Speech Communication Association (ISCA) which begin its Fellow Program to recognize and honor outstanding members who have made significant contributions to the field of speech communication science and technology.

Professor Zue, who is a Fellow of the Acoustical Society of America, is Professor of Electrical Engineering and Computer Science at the Massachusetts Institute of Technology and Co-Director of the Institute's Computer Science and Artificial Intelligence Laboratory (CSAIL). He was cited by ISCA “in recognition of his pioneering work in spoken dialogue systems and in spectrogram analysis.



Laymon Miller (r)

INCE Outstanding Educator Award

Laymon N. Miller has been selected to receive the Outstanding Educator Award of the Institute of Noise Control Engineering of the USA (INCE/USA). The award was given for developing and teaching to thousands of professionals the longest-running and best-attended series of lecture courses on the principles and practical aspects of applied engineering noise control. Since 1969, the course has been taught at dozens of cities and companies throughout North America. He has also prepared outstanding published handbooks and manuals on industrial noise control engineering in use by engineers nationwide. Laymon Miller 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.

ASA paints for Miami Habitat for Humanity

For the second year in a row, on the final day of the ASA meeting, ASA members have donned their work clothes and devoted a day to the Habitat for Humanity. Last year it was for the New Orleans Area Habitat for Humanity. This year it was for the Miami Habitat for Humanity. This effort was again coordinated by ASA member Brandon Tinianov. Thanks Brandon. The Habitat for Humanity organization is an ecumenical, Christian ministry dedicated to building homes and communities in partnership with low-income families. This organization provides ownership opportunities to low-income families in communities of need by building and renovating modest homes with family partners and providing them with interest-free loans for the purchase of these homes. In other words, future home-owners are required to invest their time along with the skilled Habitat tradesmen and to work should



Michelle, a soon to be homeowner shown here in the blue tee shirt, works happily alongside some of the ASA crew members.

der-to-shoulder with the volunteers, like the ASA crew.

The Miami ASA crew arrived early Friday morning at the Abraham Villas, Habitat for Humanity site in Miami. This project included several clusters of one- and two-bedroom townhomes in various stages of completion. As directed, the ASA crew members were armed with hammers, nail aprons—furnished by Serious Materials—and gloves as they were instructed to do. The crew was immediately put to work painting. So much for the hammers. The crew's assigned task for the day was to apply two and in some places three coats of paint to all walls and ceilings of one of the townhomes. This unit and one other were scheduled for floor tile the next day and the painting had to be finished before the tile could be installed. The ASA crew proved to be good painters, hard workers, and very productive. Not only did they finish their assigned townhome, they also finished another one when the volunteers who were supposed to paint the other townhome were misdirected to another Habitat project site. Without hesitation, the ASA crew jumped in and painted the second one too. Note that beautiful, skillful paint job on the walls (No, not on their clothes.) in the above photo.

The ASA crew with Irwin and John as Habitat for Humanity supervisors are pictured above, sans Kenric VanWyk



who left earlier to catch a plane and Dave Adams who was taking the photo.

The ASA crew consisted of: Dave Adams, D. L. Adams Associates, Inc.; Michael Canney, Applied Physics Laboratory, Univ. of Washington; Margaret Frisk, Accompanying person, Florida Atlantic University; Thomas Pellegrino, Advanced Resources Inc.; Joe and Ruth Perrell, Massachusetts Institute of Technology; Mike Spencer, Lewis S. Goodfriend & Associates; Brandon Tinianov, Serious

Materials, Inc.; Kenric Van Wyk, Acoustics by Design; Jie Yang, Applied Physics Laboratory, University of Washington

Thanks to each of you for your hard work and for representing the Acoustical Society of America in such a grand fashion. We're proud of you and we're proud of how you've shown once again that ASA members do have hearts. And, thank you Brandon for coordinating this event. Let's do it again. It was great fun.--David Adams

USA Meetings Calendar

2008

- 18-22 May 157th Meeting of the Acoustical Society of America, Portland, OR [Acoustical Society of America, Suite 1NO1, 2 Huntington Quadrangle, Melville, NY 11747-4502; Tel.: 516-576-2360; Fax: 516-576-2377; Email: asa@aip.org; WWW: <http://asa.aip.org>].
- 24-28 June 5th International Middle-Ear Mechanics in Research and Otology (MEMRO), Stanford University, Stanford, CA [<http://memro.2009.stanford.edu>].
- 26-30 October 158th Meeting of the Acoustical Society of America, San Antonio, TX [Acoustical Society of America, Suite 1NO1, 2 Huntington Quadrangle, Melville, NY 11747-4502; Tel.: 516-576-2360; Fax: 516-576-2377; Email: asa@aip.org; WWW: <http://asa.aip.org>].

2010

- 19-23 April 158th Meeting of the Acoustical Society of America, Baltimore, MD [Acoustical Society of America, Suite 1NO1, 2 Huntington Quadrangle, Melville, NY 11747-4502; Tel.: 516-576-2360; Fax: 516-576-2377; Email: asa@aip.org; WWW: <http://asa.aip.org>].
- 15-19 November 2nd Pan-American/Iberian Conference on Acoustics (Joint Meeting of the Acoustical Society of America, Mexican Institute of Acoustics, and Iberoamerican Federation on Acoustics), Cancun, Mexico [Acoustical Society of America, Suite 1NO1, 2 Huntington Quadrangle, Melville, NY 11747-4502; Tel.: 516-576-2360; Fax: 516-576-2377; Email: asa@aip.org; WWW: <http://asa.aip.org>].

ANNOUNCEMENT OF THE 2009 ELECTION

In accordance with the provisions of the bylaws, the following Nominating Committee was appointed to prepare a slate for the election to take place on 8 May 2009:

Anthony A. Atchley, Chair
Fredericka Bell-Berti
Courtney B. Burroughs
Brandon Tinianov
Lisa Zurk

The bylaws of the Society require that the Executive Director publish at least 90 days prior to the election date, an announcement of the election and the Nominating Committee's nominations for the offices to be filled.

Additional candidates for these offices may be provided by any Member or Fellow in good standing by letter received by the Executive Director not less than 60 days prior to the election date, and the name of any eligible candidate so proposed by 50 Members or Fellows shall be entered on the ballot.

Biographical information about the candidates and statements of objectives of the candidates for President-Elect and Vice President-Elect will be mailed with the ballots.

Charles E. Schmid
Executive Director

For President-Elect



George V. Frisk



Donna L. Neff

For Vice President-Elect



James V. Candy



Judy R. Dubno

For Members of the Executive Council



Juan I. Arvelo



Damian J. Doria



*Brenda L.
Lonsbury-Martin*



James H. Miller



Shrikanth Narayanan



Scott D. Sommerfeldt

Walter G. Mayer
Georgetown University
Washington, DC 20057



Hiroya Fujisaki

Hiroya Fujisaki receives ISCA medal

Hiroya Fujisaki was awarded the Scientific Achievement Medal by the International Speech Communication Association (ISCA) at the Interspeech 2008 conference held in Brisbane, Australia, in September 2008.

Hiroya Fujisaki is Professor Emeritus at the University of Tokyo, where he was Professor of Electronic Engineering in the School of Engineering, but also Professor of Speech Science in the Research Institute of Logopedics and Phoniatrics (School of Medicine), and Lecturer in the Dept. of Linguistics (School of Letters). He received BS, MS, and PhD degrees from the University of Tokyo and was a Fulbright Scholar at the Massachusetts Institute of Technology from 1958 to 1961.

Professor Fujisaki's research interests are in languages, processing of language (both spoken and written) by humans and machines, as well as in human and artificial intelligence, with special emphasis on modeling. His works include a model of language use, a model of the cognitive processes in speech sound identification/discrimination (known as the dual channel model), and a model for the process of fundamental frequency control in speech (known as the command-response model, or the Fujisaki model).

He also played a key role in activating the speech research community of Japan, and in defining and promoting the field of spoken language processing internationally by founding the International Conference on Spoken Language Processing (ICSLP) in 1990.

For his academic works and technical leadership, he has received a number of awards including the Distinguished Paper Awards both from the Institute of Electrical Engineers of Japan and from the Institute of Electrical Communication Engineers of Japan (1968), the Distinguished Achievement Award from the Institute of Electrical Communication Engineers of Japan (1973), the Meritorious Service Award from the IEEE Acoustics, Speech, and Signal Processing Society (1988), the Distinguished Service Award from the Acoustical Society of America (1988), and the Third Millennium Medal from the IEEE (2000). He was named Person of Merit in Science and Technology by the Mayor of Tokyo (1989).

Hiroya Fujisaki is an honorary member of the Acoustical Society of Japan, a fellow of the Acoustical Society of America, a fellow of the Institute of Electronics, Information and Communication Engineers, a life member of IEEE and of the Information Processing Society of Japan, a member of the Engineering Academy of Japan, and a corresponding member of the Göttingen Academy of Sciences.

He was involved in the organization of the joint meetings of the Acoustical Society of America and the Acoustical Society of Japan (ASJ) in 1978, 1988 and 1996, and served as ASJ chair of the meeting in 1988.

ASA members named Fellows of the International Speech Communication Association

ASA Fellows were among the first fellows elected by the International Speech Communication Association (ISCA) which began its fellow program in 2008 to recognize and honor outstanding



Sadaoki Furui

members who have made significant contributions to the field of speech communication science and technology.

Sadaoki Furui was cited "in recognition of his research in speech and speaker recognition and his contributions to ISCA as a board member and President." He is currently a Professor of the Department of Computer Science, Graduate School of Information Science and Engineering, Tokyo Institute of Technology. He is also Dean of the Graduate School of Information Science and Engineering. Professor Furui served as the Cochair of the 4th joint meeting of the Acoustical Society of America and the Acoustical Society of Japan held in Honolulu in 2006.

Hiroya Fujisaki, Professor Emeritus at the University of Tokyo, was cited "in recognition of his pioneering research in speech analysis, perception, prosody and modeling, and his leadership activities that helped defining and promoting the field of spoken language processing.

Douglas Cato awarded Australian Defence Award

Douglas H. Cato, a lead researcher with the Defence Science and Technology Organisation and Adjunct Professor at the University of Sydney in Australia, received the Chief of the



Douglas Cato

Defence Force and Secretary's Environment and Heritage Award for his exceptional research on management of acoustic disturbance that has led the Royal Australian Navy's mitigation strategies to be internationally recognized as among the world's best.

Dr. Cato's research and advice has enabled the Australian Navy to continue its vital training activities at sea without significantly impacting on the marine environment. His work on "sounds in the ocean" spans several decades, and includes significant contributions to understanding of marine mammal acoustics, the effects of noise and their use of sound for communication. Starting out as a scientist with the Royal Australian Navy, Dr. Cato moved across to Defence Science and Technology Organisation (DSTO) when Defence laboratories were amalgamated in the 1970s, but he has been working in the underwater acoustics field since the mid-1960s.

ASA members named Fellows of the Audio Engineering Society

The Audio Engineering Society (AES) presented its Fellowship award to members of the Acoustical Society of America (ASA) at its 125th Convention in October 2008. The Fellowship Award is given to a member who had rendered conspicuous service or is recognized to have made a valuable contribution to the advancement in or dissemination of knowledge of audio engineering or in the promotion of its application in practice.

Prof. Ing. Angelo Farina, Full Professor of Environmental Technical Physics at the Industrial Engineering Department of the University of Parma, was cited "for advancement in impulse response and distortion measurements."

Angelo Farina received the "Laurea" degree in Civil Engineering in 1982 and a Ph.D in Technical Physics in 1987, both from the University of Bologna. He has been an Assistant Professor at the University of Bologna since 1 November 1986 and at the University of Parma since 1 March 1992. Associated professor in Environmental Technical Physics since November 1998, and Full Professor since May 2005, now teaching Applied Acoustics.

Angelo Farina is a Full Member of the Audio Engineering Society, the Acoustical Society of America and the Italian Acoustics Association. He is author of more than 240 scientific papers, and of three software tools for acoustical simulations and measurements: Ramsete, Aurora and Disia.

Peter Mapp, principal of Peter Mapp Associates, a specialist Acoustic Consultancy based in Colchester, England, was cited "for work on sound reinforcement and speech intelligibility." Mr. Mapp holds an Honours degree in Applied Physics and a Masters



Angelo Farina

degree in Acoustics.

He is the author of the *Audio System Designer*, an acoustic and electro-acoustics reference book as well as being a co author / contributor to 7 other reference books and has authored over 100 papers and articles concerning acoustics, sound systems design and speech intelligibility. He was the first UK recipient of the Institute of Acoustics Peter Barnett Memorial Award in recognition of his extensive work and research in the fields of Electroacoustics and Speech Intelligibility and in 2005 he was elected a Fellow of the Acoustical Society of America in recognition of his work on speech intelligibility.



Peter Mapp

International Meetings Calendar

2009

17-19 March	Spring Meeting of the Acoustical Society of Japan, Tokyo, Japan (www.asj.gr.jp/index-en.html)	14-18 September	Germany (ictca2009.com). 5th Animal Sonar Symposium, Kyoto, Japan (cse.fra.affrc.go.jp/akamatsu/AnimalSonar.html).
23-26 March	International Conference on Acoustics (NAG/DAGA 2009), Rotterdam, The Netherlands (www.nag-daga.nl).	15-17 September	Autumn Meeting of the Acoustical Society of Japan, Koriyama, Japan (www.asj.gr.jp/index-en.html).
31-2 Mar/Apr	5th International Conference on Bio-Acoustics, Loughborough, UK (bioacoustics2009.lboro.ac.uk).	19-23 September	IEEE 2009 Ultrasonics Symposium, Rome, Italy (e-mail: pappalar@uniroma3.it).
5-9 April	Noise and Vibration: Emerging Methods (NOVEM 2009), Oxford, UK (www.isvr.soton.ac.uk/NOVEM2009).	21-23 September	10th Western Pacific Acoustics Conference (WESPAC), Beijing, China (www.wepacx.org).
13-17 April	2nd International Conference on Shallow Water Acoustics, Shanghai, China (www.apl.washington.edu/projects/SWAC09/index.html).	23-25 September	Pacific Rim Underwater Acoustics Conference (PRUAC), Xi'an, China (e-mail: lfh@mail.ioa.ac.cn).
9-24 April	International Conference on Acoustics, Speech, and Signal Processing, Taipei, R.O.C. (icassp09.com).	23-25 September	TECNIACUSTICA2010, Cádiz, Spain (www.sea-acustica.es).
19-22 May	XXI Session of the Russian Acoustical Society, Moscow, Russia (www.akin.ru/main.html).	26-28 October	Euronoise 2009, Edinburgh, UK (www.euronoise2009.org.uk).
17-19 June	3rd International Conference on Wind Turbine Noise, Aalborg, Denmark (www.windturbinenoise2009.org).	2010	
22-26 June	3rd International Conference on Underwater Acoustic Measurements: Technologies and Results, Nafplion, Peloponnese, Greece (www.uam2009.gr).	13-16 June	INTERNOISE2010, Lisbon, Portugal, (www.internoise2010.org).
5-9 July	16th International Congress on Sound and Vibration, Krakow, Poland (www.icsv16.org).	23-27 August	20th International Congress on Acoustics (ICA2010), Sydney, Australia (www.ica2010sydney.org).
23-28 August	Inter-noise 2009, Ottawa, Ont., Canada (www.internoise2009.com).	26-30 September	Interspeech 2010, Makuhari, Japan (www.interspeech2010.org).
6-10 September	InterSpeech 2009, Brighton, UK (www.interspeech2009.org).	2011	
9-11 September	9th International Conference on Theoretical and Computational Acoustics, Dresden,	27-31 August	Interspeech 2011, Florence, Italy (www.interspeech2011.org).
		4-7 September	International Congress on Ultrasonics, Gdansk, Poland.
		2013	
		2-7 June	21st International Congress on Acoustics (ICA2013), Montréal, Canada.

Co-sponsored Meeting Reports

FIRST INTERNATIONAL SYMPOSIUM ON AUDIBLE ACOUSTICS IN MEDICINE AND PHYSIOLOGY

Audible acoustic measurement and analysis techniques are being enhanced and applied to a growing array of biomedical research and clinical problems. This emerging field is of increasing importance in:

- orthopedic and sports medicine
- ear, nose, and throat diagnostics and treatment
- audiology and speech-language pathology
- critical care
- sleep medicine
- pulmonary medicine
- cardiology

The primary goal of this symposium was to bring together a wide range of researchers, technology developers, and clinicians to enhance their programs through exposure to novel technologies, techniques, and applications in this diverse field. It was cosponsored by the Acoustical Society of America and the IEEE Engineering in Medicine and Biology Society

The inaugural International Symposium on Audible Acoustics in Medicine and Physiology, held at Purdue University in West Lafayette, Indiana, USA on 8-9 September 2008, sparked wide interest and participation. The symposium was held in the new state-of-the-art Martin C. Jischke Hall of Biomedical Engineering, home of Purdue's Weldon School of Biomedical Engineering. Located a one hour's drive from Indianapolis and two hours from Chicago, Purdue's West Lafayette, Indiana campus and adjacent Discovery Park provide proximity and easy access to a variety of biomedical industry clusters. Attendees stayed at the Purdue Memorial Union Club Hotel on campus, providing easy access to the symposium, schools, and other amenities. Since pre-registration was filled months before the symposium, overall registration was expanded to accommodate a total of 87 attendees instead of the originally announced 50. An informal reception was held on 7 September, with more than 40 participants arriving early to network with colleagues. A walking tour of the Purdue campus was conducted the following morning that allowed participants to visit relevant laboratory and acoustic-related facilities on campus.

The symposium began with Andrew Daubenspeck of Dartmouth College giving an excellent overview of acoustic plethysmography and its application to monitor noninvasively small laboratory animals. John Earis of the University of Liverpool provided great insights into the abilities of optoelectronic plethysmography to provide measures of respiration in humans in conjunction with the transmission of sounds in the thorax. Rob Tepper of the Indiana University School of Medicine reported on a study to relate the amplitude of crackle sounds measured in isolated lung preparations to the size of the airway where these diagnostic sounds arise. Ozan Akkus of Purdue University provided a comprehensive view of musculoskeletal acoustic emissions and their

current evaluation in the detection and monitoring of stress fractures in athletes. Ron Miles from Binghamton University linked the hearing abilities of insects to a novel design of a directional microphone for hearing aid applications.

At the Symposium dinner, Bernie Krause of Wild Sanctuary put forth a fascinating and wonderful plenary audio demonstration of natural soundscapes from around the world. He related the temporal and spectral components that comprise these soundscapes to the many species that inhabit them. He noted though that many of the soundscapes can unfortunately no longer be heard at those sites due to habitat destruction in recent years.

On the second day of the Symposium, Bob Hillman of the Massachusetts General Hospital gave a thorough overview of advances in the acoustic monitoring of voice disorders and their growing impact on patient care. Jessica Huber of Purdue University focused on the study of voice problems in patients with Parkinson's disease and the importance of targeted speech therapies. Janet Slifka from the Massachusetts Institute of Technology overviewed the state-of-the-art in understanding pauses in spontaneous speech as they relate to automatic speech recognition. Mike Heinz of Purdue University discussed the inter-relations between acoustic fine structure and amplitude envelopes and how these relate to the perception of sounds such as speech and music. Martin Kompis from the University of Berne presented the use of adaptive noise reduction techniques to improve the performance of hearing aids. Bob Shannon of the House Ear Institute provided a comprehensive overview of cochlear implants including recent clinical advances. Tom Royston of the University of Illinois—Chicago focused on finite boundary and element modeling of the acoustic properties of the human thorax in health and disease. Jacky Smith from the University of Manchester gave a thorough presentation of cough analysis as applied to patient diagnosis and care. Ian Wells and John Beeton, both from the Swansea Metropolitan University, teamed-up to describe their efforts to categorize snoring sounds as they relate to specific etiologies. Lastly, Jeff Mansfield of SonarMed, Inc. provided insights into the use of sound to guide the placement and monitor the position of breathing tubes in neonates.

In addition to the oral presentations, 26 abstracts from around the world were selected from roughly twice that number of submissions as poster presentations covering a wide variety of ongoing research projects. The poster session was both vibrant and informative, with a wealth of ideas exchanged and linkages formed.

The symposium ended with all agreeing that it would be very desirable if it could be a regular event, e.g., occurring every few years with a growing number of related themes.

George R. Wodicka

Instrumentation

Dick Stern

*Applied Research Laboratory, The Pennsylvania State University
PO Box 30, State College, Pennsylvania 16804*

Acoustics Today welcomes contributions for “Instrumentation.” There is no charge for this service. Submissions of about 250 words that may be edited in MSWord or plain text files should be e-mailed to <acousticstoday@aip.org>. Graphics must be at least 300 dpi. Please send the text and graphics in separate files.



Eckel Industries, Inc., Cambridge, MA, announces a new addition to their Acoustic Lay-in Panels (ALPs). These ceiling panels provide a simple and effective method for upgrading/correcting the performance and appearance of acoustic ceilings in commercial, religious, and institutional facilities. With the introduction of the 2x2 or 2x4 "V" ridged style of ALPs (V-ALPs), additional degrees of ceiling design freedom has become available. Contact: eckel@eckelusa.com for more information.



Scantek, Inc., an ISO 17025 NIST/NVLAP accredited Calibration Laboratory announces the RION NX-28FT, a program card for RION's newest sound level meter, the NA-28. The NX-28FT turns the NA-28 into a capable FFT analyzer with 8,000 lines resolution and 20 kHz frequency range (not changeable). The NA-28 can measure 1/3rd, 1/1/ octave bands simultaneously. In addition, the NA-28: meets ISO 1996-2:2007 Annex C; all pass and frequency provided simultaneously, inst, max, from 1 to 999 s; 100 dB dynamic range; hanning and rectangular weighting; sorts up to 20 “peaks” by level, then frequency; up to 40 x zoom; trigger-internal and external; stores on CF card; can optionally store wave form

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Editor's Note—The items printed in “Instrumentation” are reported for informational purposes only and are not necessarily endorsements by the Editor, *Acoustics Today*, or the Acoustical Society of America.

The Business of Acoustics

Dick Stern

Applied Research Laboratory, The Pennsylvania State University
PO Box 30, State College, Pennsylvania 16804

Acoustics Today welcomes contributions for “The Business of Acoustics” There is no charge for this service. Submissions of about 500 words that may be edited in MSWord or plain text files should be e-mailed to <AcousticsToday@aip.org>.

ETS-Lindgren announced the opening of its new Acoustic Research Laboratory featuring state-of-the-art chambers for acoustic test services. With its hemi-anechoic chamber, two reverberation chambers, impedance tubes and supporting acoustic test equipment and software, the laboratory now offers product noise emission testing and structural/architectural acoustic testing. Acoustic field testing services are also available upon request. The laboratory is ISO 17025 accredited under the US Department of Commerce NIST National Voluntary Laboratory Accreditation Program (NVLAP).

Product noise emission testing is commonly performed in the double-walled hemi-anechoic chamber that is designed to measure very low noise emissions from products and devices at 80 Hz and above. Outside chamber dimensions are 8.5 m long x 8.5 m wide x 7 m high. This chamber is ideal for testing sound power and pressure levels as well as small fan noise. Products tested include Information Technology Equipment (ITE) such as laptop computers and associated printers, home appliances, garden equipment - essentially any noise emitting device may be tested in this chamber. Commonly referenced standards for testing in this chamber include ISO 3744, ISO 3745, ISO 7779, ISO 11201, and ECMA 74.

Structural/architectural acoustic testing is performed in the reverberation chambers. With transmission loss testing of wall samples, windows, doors, automobile panels and the



like, customers can determine how much sound energy is transmitted through a product sample at specific frequencies. Sound absorption testing may also be performed in these chambers to determine how much sound energy is absorbed by products. Sound insulation products, fabrics, and wall absorbers for theaters are a few such products tested. The source chamber measures 7.4 m long x 5.9 m wide x 4.8 m high; the receive chamber measures 7.4 m long x 9.2 m wide x 6 m high. ASTM E90, ASTM C423, ASTM E596, and ISO 3741 are the most commonly referenced standards for testing in these chambers.

“We’re very excited about the acoustic testing services we can now offer our customers,” said Douglas Winker, Ph.D., Acoustic Engineer for ETS-

Lindgren. “We designed these chambers for the best performance possible and worked closely with our facility personnel to ensure the parent building that houses these chambers enhances their performance. For example, the hemi-anechoic inner chamber sits on a 50 ton isolated concrete slab. The reverberation chambers sit on individual floating concrete slabs.” Dr. Winker added, “With our NVLAP accreditation, customers can be confident that we have a total quality system in place with instrumentation traceable to NIST and experienced technicians who produce accurate measurement data.” For more information on acoustic testing services, visit www.ets-lindgren.com/labservices.

Editor’s Note—The items printed in “The Business of Acoustics” are reported for informational purposes only and are not necessarily endorsements by the Editor, *Acoustics Today*, or the Acoustical Society of America.

Passings

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David Middleton

1920–2008

David Middleton, a physicist whose original research led to major advancements in the understanding of communication systems—from radar during World War II to the wireless communication systems of our present age—died on 16 November 2008.

Dr. Middleton was a scientist, a researcher, and a founder of the field of statistical communication theory. He devoted his entire career to studying signal processing and the transfer of information from one point in space-time to another, with numerous applications in radar, underwater listening devices, satellite technology, and signal processing. Dr.



Middleton was able to relate engineering problems of communications to the physical properties of communication channels. According to Vincent Poor, Dean of Electrical Engineering at Princeton University, Dr. Middleton's research was unusual in the way he "emphasized the close relationships between the underlying physics and the intended engineering applications." His theoretical models of communication channels and systems have contributed to the explosive growth of data and wireless communications systems.

David began his career in 1943 at the Harvard Radio Research Laboratory as special research assistant to Professor J. H. Van Vleck (later a Nobel Laureate in physics), with whom he took his Ph.D. in 1947. Together Dr. Middleton and Van Vleck (and simultaneously but independently, D. O. North at RCA Laboratories) developed the matched-filter principle critical to data communications and an enduring concept in the field today. In 1943 Dr. Middleton began the analysis of signals and noise passing through nonlinear devices, such as the "chaff," or aluminum strips, used to jam radar signals to protect American ships and aircraft from detection.

Published in 1960 and widely translated into many languages, Dr. Middleton's seminal work, *An Introduction to*

Statistical Communication Theory, played a major role in integrating statistical methods into the education of engineers in communications, radiolocation, and related fields. Leon Cohen, Professor of Physics at Hunter College in New York, wrote: "Dr. Middleton's book is one of those texts that is so extraordinary for its clarity and depth that one marvels at it and the author. It is perhaps the greatest book ever written on noise, probability theory, and stochastic processes. ...The classic book on noise, written with style and elegance, [it] covers a panoramic view unmatched by any other publication."

From 1954 to 2008 Dr. Middleton was a consultant to universities, industry, and the federal government. During the Cold War era of the 1950s through the 1980s, his theoretical work for the government was applied to antisubmarine warfare systems, in particular to passive and active sonar systems to track Soviet submarines. During the Détente of the 1970s, when U.S. and Russian scientists began pursuing joint projects, he served as scientific editor for several Russian texts in his field and made presentations in the former Soviet Union, where he was officially recognized and highly regarded in his field.

Dr. Middleton's work in statistical communication theory included the handling of random processes and the application of decision theory to signal detection and estimation. In statistical physics, he contributed to a greater understanding of propagation and scattering in random media, with an emphasis on the underwater environment. After 1968, his work expanded to include electromagnetic compatibility, with particular attention to non-Gaussian noise and interference models, and nonlinear signal processing for manmade and natural electromagnetic and acoustic environments. He served on the U.S. Naval Advisory Research Committee (1970-77) and the Scientific Advisory Board of the Supercomputing Research Center, Institute of Defense

Acoustics Today welcomes contributions for "Passings." Submissions of about 250 words that may be edited in MSWord or plain text files should be e-mailed to AcousticsToday@aip.org. Photography may be informal, but must be at least 300 dpi. Please send the text and photography in separate files.

Analysis (1988-91).

Dr. Middleton published a second book, *Topics in Communication Theory* (1965) and over 170 papers. Significant among them is his 2002 paper, "New Results in Applied Scattering Theory," which contains a synthesis of his methods for determining the statistical characteristics of non-Gaussian noise affecting signal reception. These methods have contributed to solving long-time, complex problems in radar, sonar, and radio astronomy, as well as problems where non-Gaussian noise is often encountered.

At the time of his death, he was actively working on the sequel to his first book, *Elements of Non-Gaussian Statistical*

Communication Theory: A Space-Time Treatment (to be published posthumously). It summarizes his work of over 65 years in statistical communication theory as well as presenting results from more recent research gained by adding non-linear effects and time analysis to earlier methods.

Dr. Middleton was a member of several scientific societies, among them the Acoustical Society of America, IEEE, the American Physical Society, the National Academy of Engineering, the New York Academy of Sciences, and the AAAS. He received numerous prizes and awards for his work. In August 2008 the IEEE and Princeton University hosted a symposium in honor of his long and distinguished career.

We have learned of the deaths of the following ASA members:

Louis Herstein III
Charles Tepper



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For further information please contact:

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Advertising Sales & Production

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