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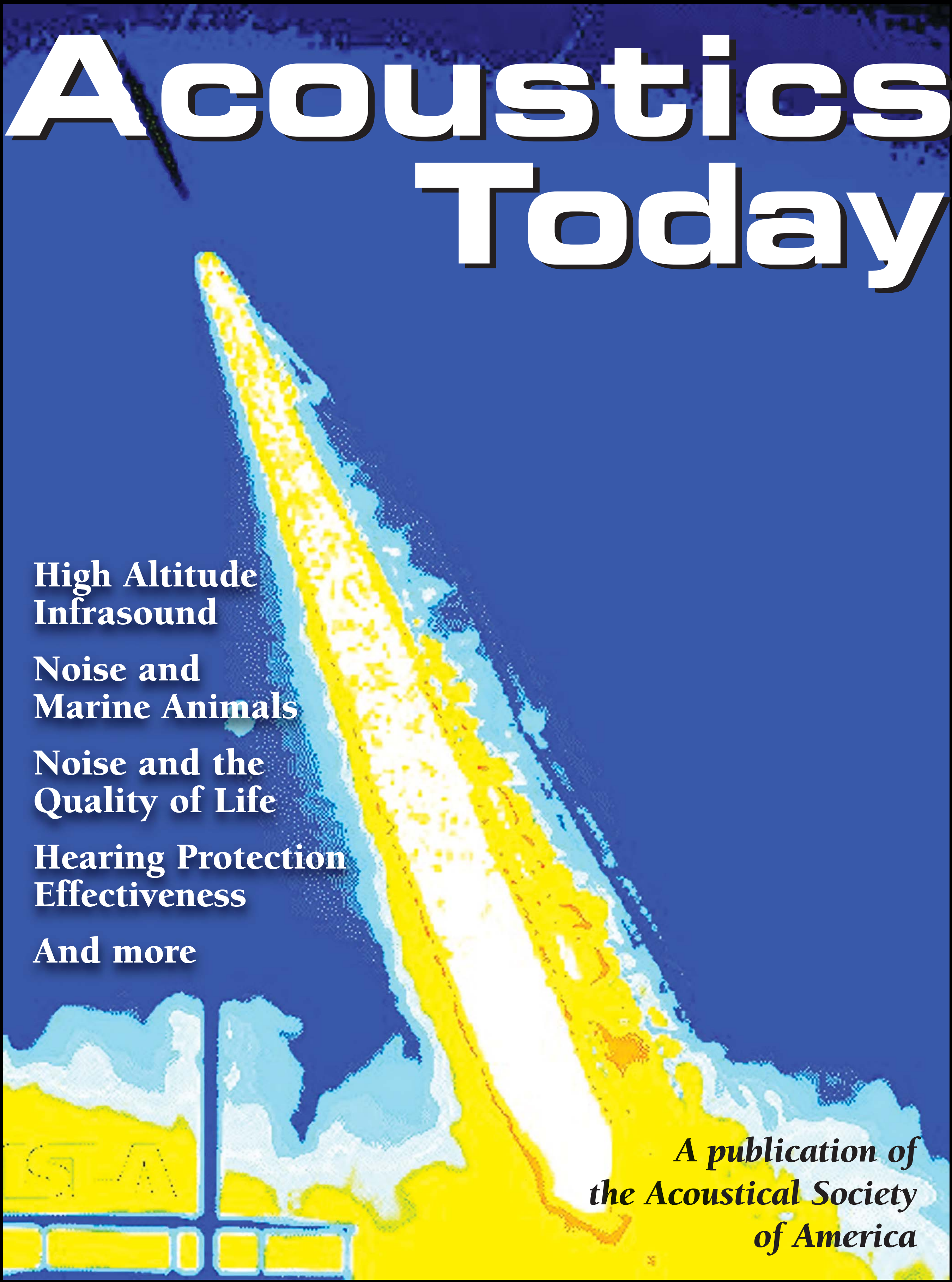
Acoustics Today



High Altitude Infrasound

Noise and Marine Animals

Noise and the Quality of Life

Hearing Protection Effectiveness

And more

A publication of the Acoustical Society of America

Infrasound Sources Reach High Altitudes Using Rockets

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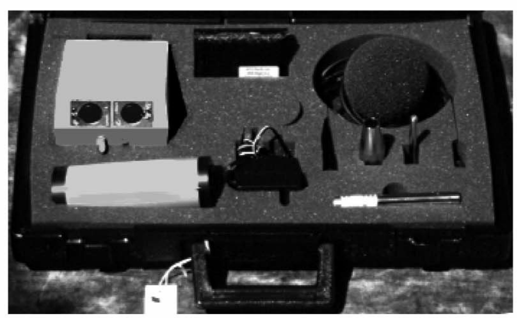

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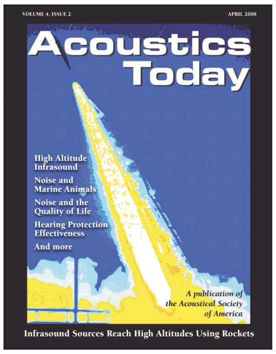
Acoustics Today

A Publication of the Acoustical Society of America

Volume 4, Issue 2 **April 2008**



Cover: An infrared photograph of the launch of an Orion rocket carrying approximately 30 kg of high explosive. The rocket was launched in the pre-dawn hours from the White Sands Missile Range in southern New Mexico. The explosives were detonated at an altitude of 31 km as the rocket was on the downward arc of its ballistic trajectory. The time-indexed infrared imagery provided corroboration of launch and detonation times. Image: Milton Garcés, Infrasound Laboratory of the University of Hawaii (ISLA).

Articles:

Departments:

Business Directory

59 Classified

62 Index to Advertisers

Acoustical Society of America Student Council Mentoring Award

Nomination deadline: September 29, 2008

Purpose

The Student Council Mentoring Award is designed to recognize a person who has demonstrated exceptional ability in guiding the academic and/or professional growth of his/her students and junior colleagues. Any ASA member, other than those currently serving on the Student Council, may submit a nomination for this award.

Selection criteria

The nominee must be a member of the ASA in order to be eligible for this award. The intent of the award is to recognize those who show excellence in a wide variety of mentoring areas. To this end, a nominee should demonstrate outstanding aptitude in the following areas:

- Research and Publications:
  - Offers sound academic advice
  - Provides direction in thesis and/or dissertation work
  - Lends guidance in non-thesis research endeavors
  - Assists in developing papers and publications

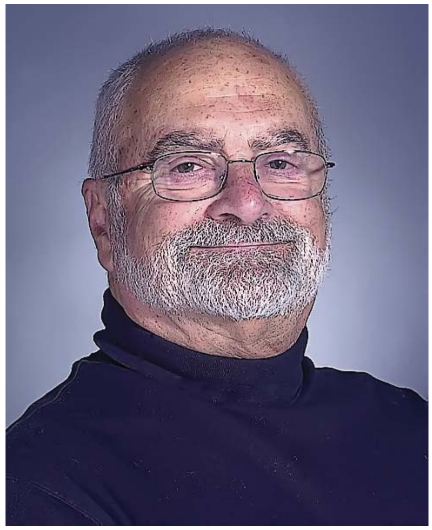
- Interpersonal and Motivational Skills:
  - Available and approachable
  - Establishes good rapport with students
  - Motivates and excites students about research activities
  - Serves as a beneficial role model
  - Listens patiently, nurtures self sufficiency, and encourages feedback
  - Maintains and communicates the highest ethical standards

- Career Development:
  - Imparts informed advice relating to career searches
  - Prepares students for interviews and serves as a resource in CV/resume preparation
  - Establishes opportunities for networking and professional connections
  - Supports students' post-graduation progress and development

Submission Process

Nominations are due by September 29, 2008. Nomination forms and additional information can be found at www.acosoc.org/student/mentor/mentor.html. Each nomination requires at least one nominator, designated as the primary nominator. The primary nominator should submit a Primary Nomination Form with the nominee's current curriculum vitae and a letter describing why the nominee is an outstanding mentor. Up to three (3) additional support letters will strengthen the nomination. Each supporting nominator should submit a Supporting Nomination Form with a letter justifying the nomination. All nomination documentation should be submitted in electronic format (PDF or Microsoft Word) to: asa@aip.org with the subject line "Student Mentoring Award." The recipient will be chosen by vote of the Student Council, and the award certificate will be presented at the 157th Meeting of the ASA in Portland, OR.

FROM THE EDITOR



*A*coustics Today is about to take another major step. The magazine has been quite successful and I am very pleased with the response of its contributors and readers. More than just an informative magazine to members of the Society, *Acoustics Today* has been archived and its articles have been cited in other publications. In addition, our members (usually the authors) have asked whether articles were available for distribution to their students or colleagues. We have given only limited permission to the authors for a variety of reasons—after all, it is a member benefit. However, that is about to change. *Acoustics Today* will now become an even greater member benefit. In addition to the print copy that every member and non-member subscriber receives, it will also be available on-line simultaneously. Members and non-member subscribers will be able to download articles or even an entire issue of the magazine for their personal or professional use or for distribution to their students or colleagues. Of course, the article may not be altered from its original printing and those pages that include advertising may not be modified. If the article is to be reprinted in another publication (or translated into another language and reprinted) then permission from the Acoustical Society of America (ASA) is required. There is no cost to members and non-member subscribers for this service. Non-members of the Society will also be able to purchase articles and issues much as they do for an article from JASA. In lieu of abstracts, the first twenty-five words of the article will also be placed on-line. *Acoustics Today* on-line should be available around September and will be found in the ASA Digital Library.

A new department was introduced in the January 2008 issue of *Acoustics Today*, the Business of Acoustics. The department welcomes contributions from companies or individuals that have major announcements that would have widespread member interest. 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.

Finally, I am always actively soliciting contributions to *Acoustics Today* from readers who are interested in writing an article for the magazine. If you have never written an article about your work in a manner that is both informative and understandable by an acoustician that is not necessarily an expert in your specialty, you will find that it is an exciting challenge. Please e-mail your thoughts and ideas to me at acousticstoday@aip.org. Thanks.

Dick Stern, Editor

THE VICE PRESIDENT'S VIEW

George V. Frisk
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I have always had a passion for live musical performances and have bemoaned the fact that these days live music is often replaced by recordings. When was the last time you attended a wedding reception or a ballet performance where a live band or orchestra was featured? These occasions are rare indeed, and their scarcity is presumably driven by financial considerations. Yet, the value of live performances cannot be measured in monetary terms because, in fact, they add a dimension to the entire artistic experience which is invaluable.

I was reminded of the impact of live music at a recent performance of the Miami City Ballet, which my wife and I attended at the Broward Center for the Performing Arts in Fort Lauderdale. Not only did this event include a thirty-two piece pit orchestra, but it was preceded by a presentation by Edward Villela, Founding Director of the Miami Ballet, who presented an overview of the ballets that were going to be performed. But the most impressive aspect of the afternoon occurred during the last ballet, which was choreographed by Twylla Tharp and accompanied with music composed by Elvis Costello. This work, entitled "Nightspot," also included an on-stage dance band that was situated in the background behind what appeared to be a red haze or veil. With the dancers out in front, the result was the creation of a complete audiovisual experience that conveyed the sensual and dynamic environment surrounding the Miami nightclub scene.

A second recent and memorable experience was a concert by the New York Philharmonic under the direction of Maestro Lorin Maazel. It was broadcast from North Korea on public television and therefore was not, strictly speaking, a "live" event. However, the camera work was of such high quality, that it felt as if the viewer had been transported to North Korea and was sitting there in the concert hall. Depending upon the particular point in the piece being performed, the camera would focus on specific sections or individuals within the orchestra. Of course, this approach is often used in televised concerts, but in this particular case, the extraordinarily high quality of the results suggested that the person behind the camera was perhaps also a musician intimately familiar with the music. Again, it was the last piece that elevated this concert to the level of a remarkable audiovisual happening. As its final work, the orchestra performed the Overture to the opera, "Candide," by the late Leonard Bernstein, on the occasion of what would have been his ninetieth birthday. The amazing thing was that Maestro Maazel, paying homage to Bernstein, left the stage and let the orchestra perform the piece without a conductor. This was an amazing technical achievement, as the overture is rather complex and moves along at a rapid clip. But it was the emotional impact resulting from the image in our mind's eye of Leonard Bernstein on the podium conducting his own work that created an unforgettable moment. This was an event that had to be seen and heard to fully appreciate it.

These two recent experiences reminded me of other live musical performances that I have enjoyed over the years. My exposure to live music began during my childhood in Schenectady, NY, where my mother regularly took me to a series of concerts sponsored by an organization called the Civic Music Association. Although Schenectady was not exactly a cultural mecca, it benefited from its proximity (165 miles) to New York City and other cultural centers. One performance that sticks in my mind was that of Maestro George Szell and the Cleveland Orchestra. The moment Maestro Szell came onto the podium, the orchestra immediately began a rousing rendition of the Star Spangled Banner (which was not on the program), and the audience hopped out of their seats and stood up at attention. The image of the stern European Maestro, the lively orchestra, the responsive audience, and the stimulating music persists in my mind to this day.

After I entered high school and switched from the clarinet to the saxophone section in the school band, I became enamored with jazz, particularly big band jazz. Somehow I managed to see the Count Basie Band at the Armory in Albany, NY, and this event remains one of my most memorable ones. Of course, the music was terrific, but seeing individual virtuosos within each section stand up and play dazzling solos was what really impressed me. This was also the first time I saw the pyrotechnics of a big band drummer (Sonny Payne) and, as a result, became hooked on big bands forever. During this period, I also snuck into a small jazz club on Upper Union St. in Schenectady and heard Ben Webster, a legendary tenor saxophonist. This was another unforgettable moment in which the smoky club, the imposing Webster, and his large, robust sound all melded into one artistic impression.

Over the years, I have continued to enjoy live performances including those by Miles Davis, Dizzy Gillespie, Milt Jackson, Rahsaan Roland Kirk, Oscar Peterson, Duke Ellington, and many others. My only regret is that I never saw John Coltrane or Charles Mingus live, which, I am told, were amazing events. I can still see the look on my mother's face, though, when I first hooked up our record player to the speaker in our television and played Coltrane's interpretation of "My Favorite Things." She appeared to be wondering where she had gone wrong in raising her son.

My goal in this article has been to convey the significance and impact that live musical performances have on our cultural lives. Historically, the Acoustical Society of America has played a key role in promoting this idea through its tutorials, special sessions, and a variety of artistic events at plenary sessions and banquets. It is critical to continue this tradition in the future and to remember that our intellectual and emotional wellbeing is significantly enhanced by the experience of both hearing *and* seeing artistic performances.

HIGH-ALTITUDE INFRASOUND CALIBRATION EXPERIMENTS

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Introduction

Infrasound (acoustic signals below the 20 Hz limit of human hearing) has been known since the eruption of Krakatoa in 1883. This event registered on barometers around the world. In 1909, barometers also registered a strong signal from the now-famous Tunguska event. As illustrated by these two cataclysmic events, infrasound energy can travel reasonably unattenuated for thousands of kilometers through refractive ducts in the atmosphere. Recognizing the utility of this energy as a tool for the remote study of atmospheric sources, and as a probe of the atmosphere, infrasound was commonly used to monitor atmospheric nuclear tests starting in the 1940's. With the Limited Test-Ban Treaty that eliminated atmospheric nuclear testing and with the advent of satellite technology, infrasound research had declined dramatically by the early 1970's. The recent Comprehensive Nuclear Test-Ban Treaty (CTBT) that banned nuclear tests of all yields, in all environments, included the use of a worldwide network of infrasound receiving arrays. This has led to a re-birth of infrasound as a technology for monitoring the Earth's atmosphere and shallow crust for nuclear tests as well as other natural phenomena.

"An obstacle to refining our knowledge of infrasound propagation and improving source location techniques has been the lack of sources with known yield, location, and time."

The re-birth and study of infrasound has led to improvements in instrumentation such as microbarometers and has benefited from advances in digital signal processing and recent improvements in knowledge of the middle- and upper-atmosphere. New infrasound stations, such as those deployed as part of the CTBT, have led to dramatic increases in the quality and quantity of data available. However, the physics of global infrasound propagation is not fully understood and significant challenges remain before better advantage of this wealth of new data can be taken. This has led to dynamic research programs in areas such as evaluation of signal propagation codes, atmospheric models, development of infrasound as a remote sensing tool (e.g., earthquakes, volcanoes), and operational infrasound source location and characterization. An obstacle to refining our knowledge of infrasound propagation and improving source location techniques has been the lack of sources with known yield, location, and time.

To improve understanding of the most pressing research issues, a calibration experiment was organized involving six rockets, each carrying a small payload of chemical explosives. The rockets were launched from White Sands Missile Range (WSMR) in southern New Mexico during 2005-2006.[1,2,3] Two rockets were launched during each of three WSMR experiments. The carefully tracked rockets flew a northward trajectory tens of kilometers into the stratosphere, where the explosives were detonated. The resulting infrasonic signals were recorded at sites throughout the southwestern US to distances of nearly 1000 km.

The WSMR tests have provided a high-quality set of measurements of travel-time, signal amplitude and frequency to help address specific challenges in infrasound propagation modeling and source location. First, as increased numbers of infrasound events have been analyzed during the past decade, a systematic tendency to overestimate observed travel times has been clearly identified.[4] Data from the WSMR tests will provide precise travel time data to address this issue. Second, the significance of internal wave scattering of acoustic energy in the stratospheric and thermospheric ducts has also been identified but is not completely understood.[5,6,7] Scattering is often invoked to explain observations of energy leakage from elevated ducts and possibly signals in some classic zones of silence.[8] The spatial coverage of the WSMR data provide a means for direct observation of scattered acoustic energy. Another challenge addressed through analysis of the WSMR data includes a better understanding of thermospheric attenuation.[9] Finally, the WSMR experiments also provided an opportunity to validate the scaling relationships between yield and dominant frequency as well as between yield and pressure amplitude for elevated sources. This article describes the general characteristics and preliminary results of the experiments. Experiment participants are preparing more detailed analyses of the large quantity of data collected.

Experiment design considerations

The scheduling of the experiments, as well as the geographic distribution of the stations, was intended to maximize the probability of observing signals under differing atmospheric conditions. Long-range infrasound propagation is primarily controlled by high-altitude winds and by the static sound speed that depends on the air temperature. Vertical gradients in the static sound speed and high-altitude wind profiles enhance or diminish atmospheric ducting between the ground and the lower, middle, and upper atmosphere, allowing infrasound waves to propagate to distances of hundreds to thousands of kilometers.

Tropospheric infrasound arrivals result from acoustic energy propagating in lower-atmosphere ducts. These ducts are a transient phenomenon involving temperature inversions in the lower atmosphere that may arise early in the day due to cool ground-level air temperatures or the tropospheric jet stream. Stratospheric arrivals, caused by ducting between the ground and stratopause, are significantly impacted by seasonal variations in the zonal (east-west) stratospheric winds. In the northern hemisphere, these winds flow to the east in the winter and the west in the summer. Spring and fall are transition periods. This feature results in directional ducting of the sound. For example, summertime conditions favor long-range

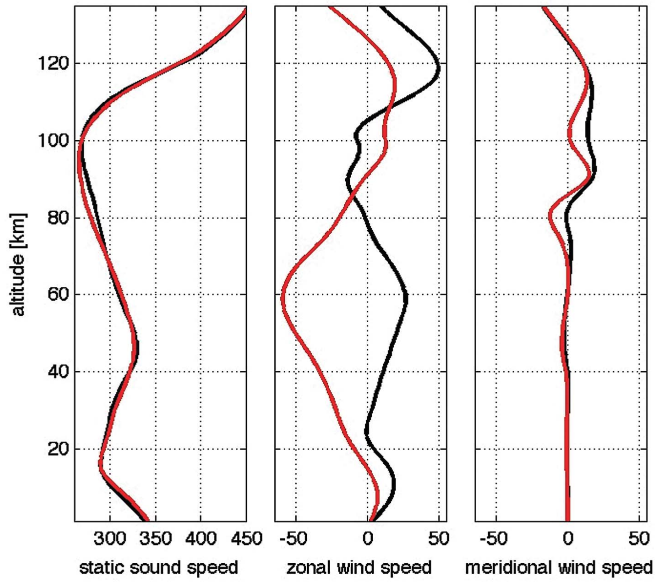

Fig. 1. Static sound speed profiles for WSMR2 (black line) and WSMR3 (red line) at 33.2°N, 106.5°W, near the center of the region in which the detonations took place (left). Zonal winds (positive from west to east) for WSMR2 (black) and WSMR3 (red) (middle). Right panel is same as for middle, but for the mean meridional wind speed profile (positive northward).

acoustic observations to the west of a source, but not to the east. Thermospheric arrivals, resulting from downward refraction of acoustic energy by the steep sound speed gradients of the upper atmosphere, are more rarely observed due to high acoustic absorption within the thin upper atmosphere.[9] More generally, the significance of natural atmospheric variability on infrasound propagation characteristics has been investigated and presented by several authors.[10,11,12]

To evaluate the likely existence of stratospheric ducting for the WSMR experiments a series of computations was performed. In Fig. 1, profiles of static sound speed as well as zonal and meridional (north-south) wind components are shown as a function of altitude for dates and locations corresponding to the second and third WSMR experiments (WSMR2 and WSMR3, respectively). These profiles are based on the Naval Research Laboratory Mass Spectrometer and Incoherent Scatter Radar Model-00/Horizontal Wind Model-93 (NRLMSISE-00/HWM-93) upper atmospheric empirical models.[13,14] As shown, static sound speeds at the ground were predicted to be greater than those within the stratosphere for these dates, and one would not predict stratospheric ducting. However, the stratospheric winds must also be considered, and this was done via ray tracing computations using the atmospheric profiles illustrated in Fig. 1.

To highlight the direct arrivals and stratospherically ducted arrivals, only the lower 60 km of the atmospheric profiles (Fig. 1) were used in the computations. Ray tracing for acoustic sound transmission in a windy environment relied on the physics governing acoustic refraction of rays in an advected media.[15] Rays were launched over a series of azimuths and declination angles from the source point and the locations at which the rays intersect with the ground surface are marked by dots in Fig. 2, color-coded by time of arrival after the detonation. As shown, enhanced propagation

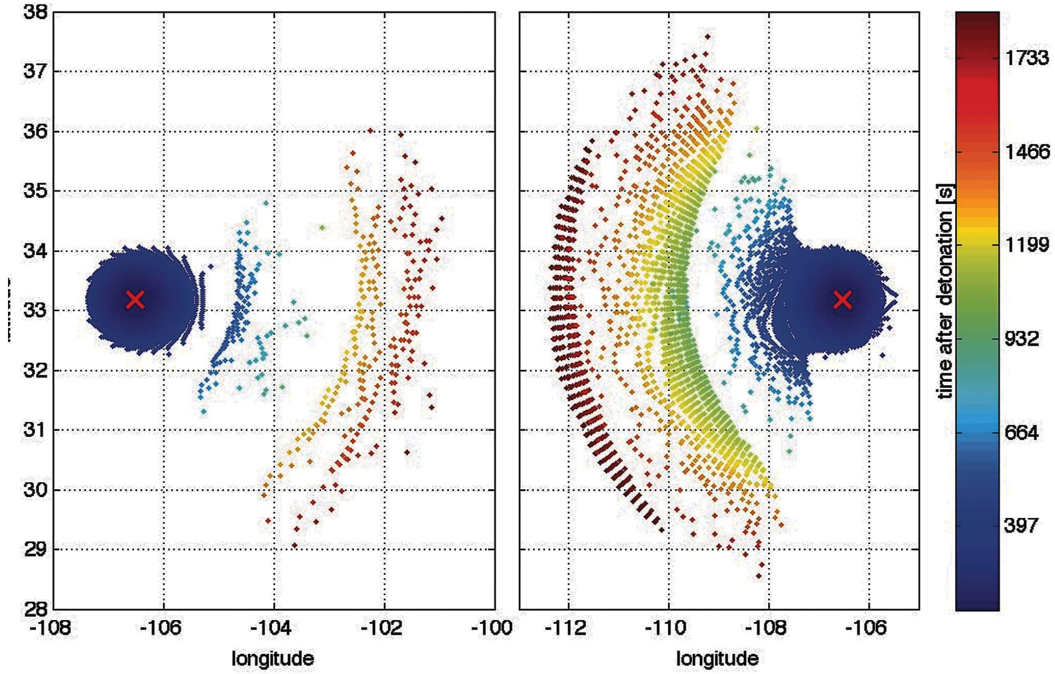

Fig. 2. Maps of ray endpoints that reach the ground for WSMR2 (left) and WSMR3 (right). The rays were propagated through atmospheric profiles shown in Fig. 1, starting at 33.175° N, and 106.515° W, altitude 40 km, the center of the region in which the detonations took place (marked on each map by a red X). For illustration, we have not considered rays that turn in the thermosphere; these would arrive significantly later. The ray endpoints are color coded according to the predicted arrival time in seconds after detonation.

to the east is predicted for WSMR2 and to the west for WSMR3.

Atmospheric and signal propagation modeling guided the general station distribution, though specific station sites were chosen based on land access, local winds and terrain, and logistical considerations. The maps in Figs. 3-5 show the relative locations of explosions and recording stations in each of the three experiments, and also indicate whether signals were observed. The dates of the WSMR experiments were selected to sample three different characteristic high-altitude wind patterns (fall, spring, and summer). Figures 4 and 5 illustrate the different deployments designed to take advantage of the predominantly westerly winds of spring (WSMR2) versus the predominantly easterly winds of summer (WSMR3).

Each of the three WSMR experiments consisted of two explosions separated by 4 to 6 hours, to understand the influence of atmospheric variability on this time scale better. Surface wind conditions and station operator logistics were also a consideration in determining the event timing.

Infrasound stations

A total of 30 infrasound stations participated in the three experiments (Table 1). The stations were located in the southern and western US at distances between 35 and 1213 km from the explosions.[16] All but three of the stations used infrasound arrays. In addition to acoustic measurements, some stations also recorded meteorological data (surface wind speed, wind direction, and temperature). One station (HELSTF, at a distance of 60 km) also recorded seismic data. Six optical fiber infrasound sensors (OFIS)[17,18] were co-located with a 4-element infrasound array at station BACA. At another set of stations (NMT, NMT2, NMT3) a dense array of microphones was used to create a "distributed sensor."[19] Five of the thirty stations are permanent, while the others were deployed temporarily for these experiments. Of the five permanent stations, four are operated for research (DLIAR, NVIAR, SGAR, and TXIAR), and one (I57US) is operated as part of the Comprehensive Nuclear-Test-Ban Treaty Organization's International Monitoring System.[20]

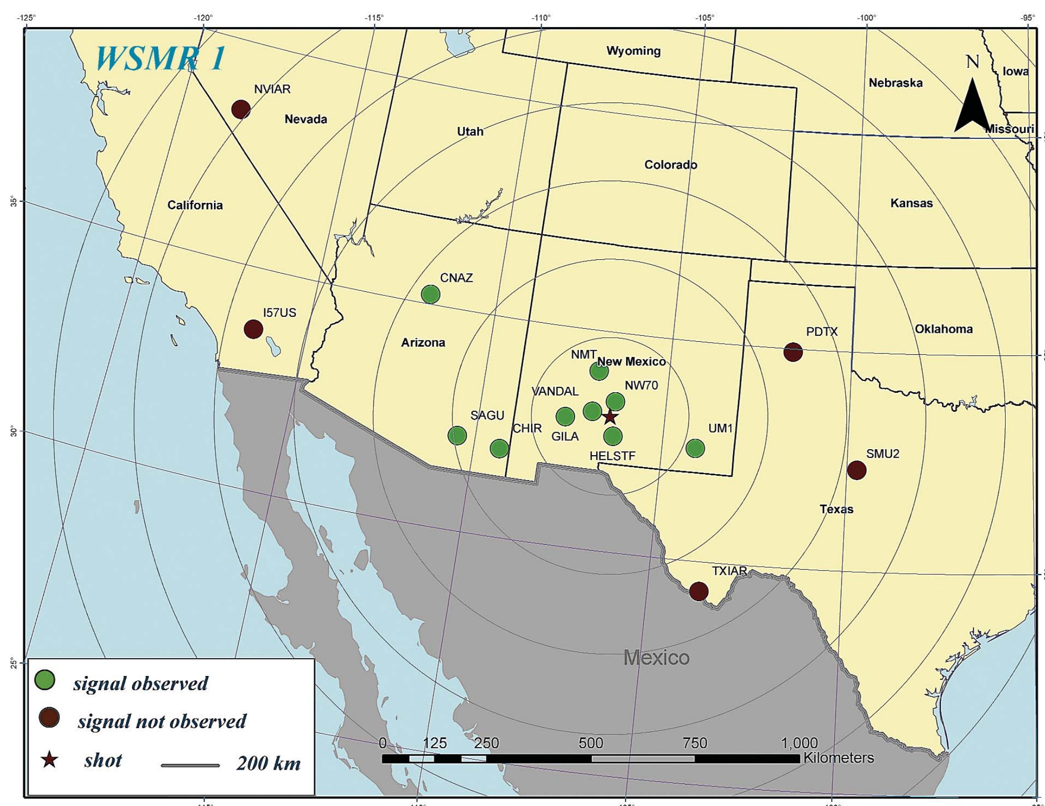

Fig. 3. Infrasound stations participating in the WSMR experiment on Septemper 9, 2005 (WSMR1). The explosion site is marked with a red star. Epicentral distance circles every 200 km from the explosion site are also indicated. The station symbols indicate whether signals were observed or not.

The temporary stations typically consisted of arrays of three to five elements, with a spatial separation of roughly 100 to 300 m (Fig. 6). Teams were deployed to these recording sites one or two days before each experiment to set up equipment and record the stable, pre-event noise levels. A variety of acoustic transducers were used. These ranged from commercially available infrasound sensors, traditional laboratory grade microphones, and experimental transducers. While the detailed instrument responses varied somewhat between stations, all sites were capable of recording frequencies ranging from audible to sub-audible (infrasonic).

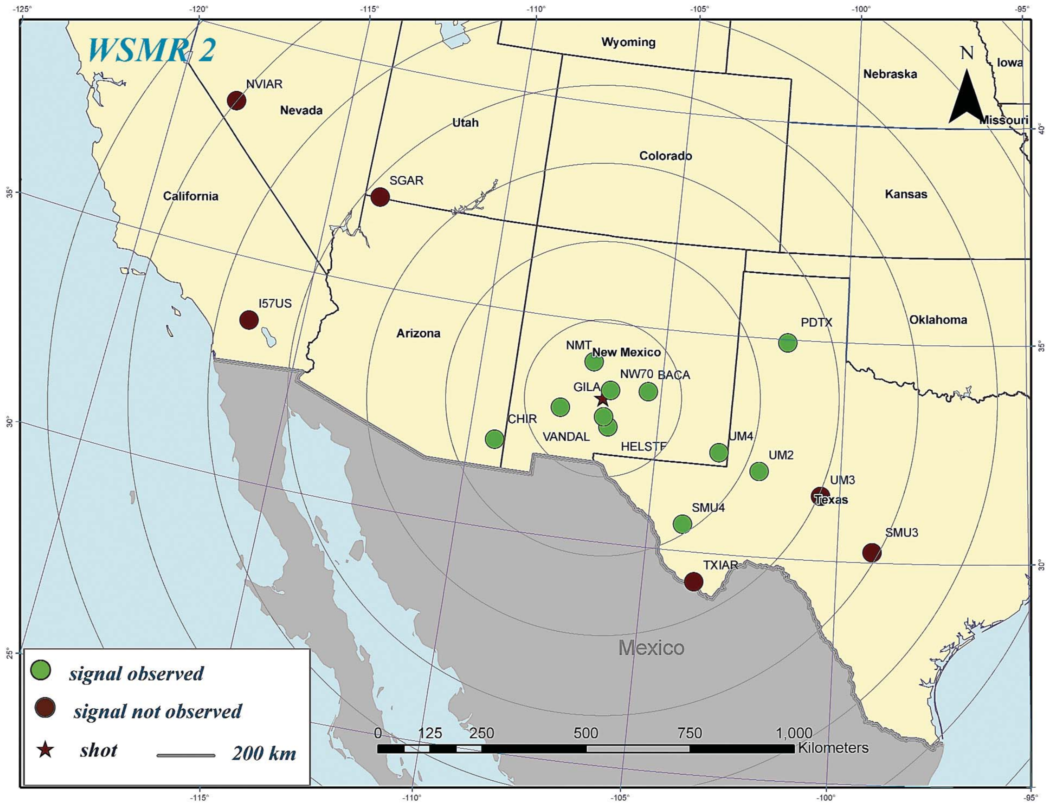

Fig. 4. As for Figure 3, but for the experiment of March 25, 2006 (WSMR2).

Arrays provide significant advantages over single sensors. The multiple time-synchronized recordings from sensors distributed across an area can be processed to estimate the azimuth of incident signals as well as their speed across the ground—parameters essential for evaluating atmospheric models. Combining multiple recordings also increases the ratio of coherent signal to incoherent noise due to wind and thus can be essential for extracting weak signals from noise at the more distant stations or improving understanding of the signal structure at all distances. Wind speeds generally increase after sunrise, due to solar heating of the surface, and thus each of the six explosions were set-off before dawn.

Nearly all of the sites used some type of noise reduction mechanism (i.e., windscreens) attached directly to the transducers. One of the simpler schemes is the use of porous hose (i.e., garden "soaker" hose) to provide a means for filtering out short wavelength pressure fluctuations (Fig. 7). However, multiple noise-reduction systems were employed. For the Optical Fiber Infrasound Sensors (OFIS) and dense microphone arrays, the increased spatial extent of the sensors themselves provides noise reduction as an integral element of the instrument design. In general, the diverse suite of stations operated well, with few recording failures.

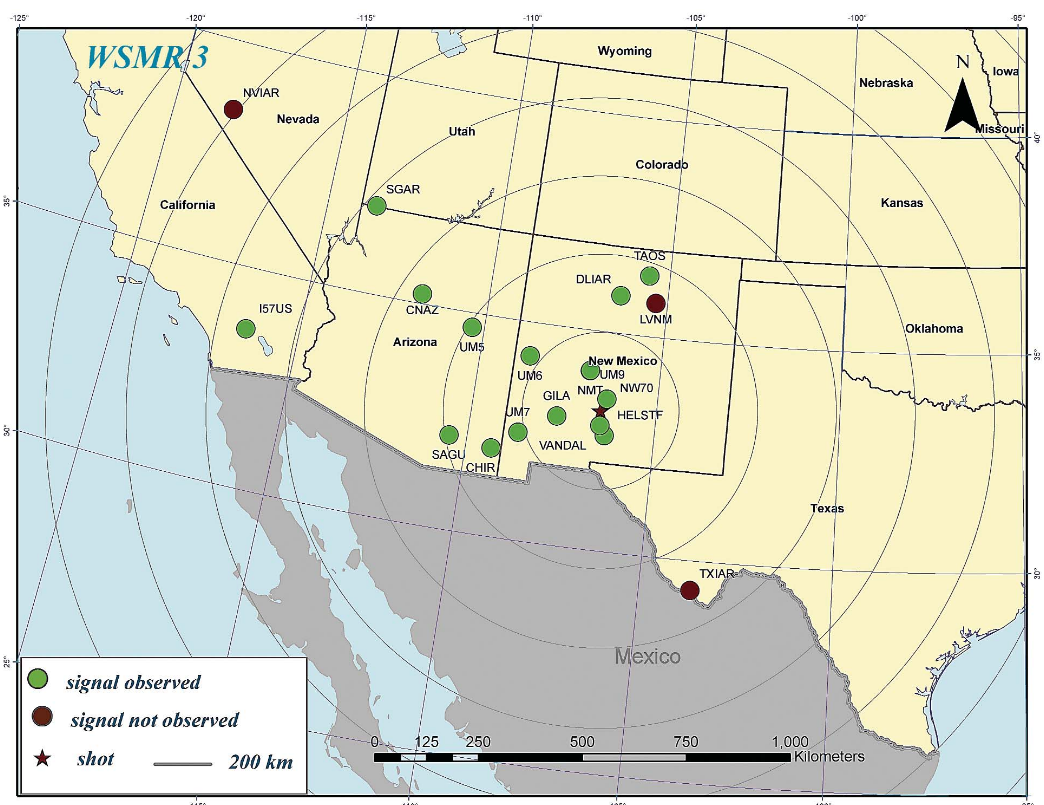

Fig. 5. As for Figure 4, but for the experiment of July 21, 2006 (WSMR3).

The explosions

Three experiments were carried out, in the fall of 2005 and in the spring and summer of 2006. Two explosive charges, of approximately 30 kg TNT equivalent, were launched and detonated during each experiment, with launches roughly

Table 1. Stations which participated in the WSMR infrasound calibration experiments.

Station	Operator	Distance (km)	Station Characteristics		
			Elements	Aperture (m)	Sampling (sps)
BACA	UCSD / UH	114.5	10	122	200
CHIR	UCSD / UH	292.2	4	110	100
CNAZ	SMU	548.3	4	203	40
DLIAR	LANL	300.2	5	1,340	10
GILA	UCSD / UH	113.0	4	100	100
HELSTF	ARL	60.3	4	38	50.1
I57US	UCSD/IMS	925.5	8	1,452	20
LVNM	Miltec	308.0	25	22	300
NMT	Miltec	116.8	25	7.6	80
NMT2	Miltec	95.1	93	30	200
NMT3	Miltec	109.8	93	30	200
NVIAR	LANL	1213.1	4	1,576	40
NW70	LANL	33.0	3	35	200
PDTX	UA	489.8	6	255	200
SAGU	UCSD / UH	389.7	4	91	100
SGAR	LANL	772.9	4	173	20
SMU2	SMU	638.3	4	151	40
SMU3	SMU	782.8	4	155	40
SMU4	SMU	376.4	4	160	40
TAOS	SMU	355.3	4	572	40
TXIAR	SMU	505.0	4	1,428	40
UM1	UM	230.2	9	0	42.8
UM2	UM	437.0	4	175	100
UM3	UM	603.2	4	242	100
UM4	UM	323.6	4	271	100
UM5	UM	381.4	4	295	5000
UM6	UM	229.4	4	289	200
UM7	UM	216.8	4	239	500
UM9	UM	109.0	4	240	500
VANDAL	ARDEC/ARL	36.5	4	38	50.1

ARDEC=Army Research, Development and Engineering Center, ARL=Army Research Laboratory, LANL=Los Alamos National Laboratory, Miltec=Miltec Corporation, SMU=Southern Methodist University, UA=University of Alaska, UCSD=University of California, San Diego, UH=University of Hawaii, UM=University of Mississippi

four hours apart. The Naval Surface Warfare Center group at WSMR was contracted to prepare and launch the rockets. The original intent was to detonate the charges at an altitude of approximately 50 km to maximize the long distance propagation of energy. The rocket design called for the explosive payload to detonate within the rocket, rather than being ejected prior to detonation. Thus, the explosion would result in the breakup of the rocket—the dimensions of the resultant debris pattern on the ground being a function of explosion altitude. Based on model results predicting the dimensions of the debris field, the initial WSMR explosions took place at roughly 30 km altitude. Empirical evidence gathered through the experiment permitted a gradual increase in the altitude of subsequent explosions. The final explosion of the six shots took place at about 49 km altitude.

The experiment utilized single-stage, rail-launched Orion rockets (Fig. 8). The rockets passed through a launch and a ballistic phase, with the explosive charges detonated during the ballistic phase after the missile passed apogee (Fig. 9). All six of the detonations took place within a virtual "box" 20 km high, 9 km wide (east-west) and 24 km long (north-south), centered at 40 km altitude at 33.175° N, and 106.515° W.

Preliminary estimates of the explosion parameters (time and altitude) were provided by WSMR staff to infrasound team members who were present at the launch, and these estimates were relayed to participants in the field. After each experiment, WSMR personnel provided detailed radar data that gave three-component rocket position (latitude, longitude and altitude), velocity, and acceleration as a function of time. The radar data were analyzed to pinpoint the detonation coordinates. After analysis of the radar data, the remaining uncertainties in the explosion location and time were on the order of several kilometers and several seconds, respectively. In addition, infrared cameras operated by M. Garcés (U. Hawaii) and by WSMR were used for two of the experiments to provide additional corroboration of launch and detonation times.

Observations

In the exploratory study of the data, basic observations about the spatial distribution of the recorded signals, and various parameters of the signals were made. It is these preliminary findings that will form the basis of more in-depth analyses.

Fig. 6. Site view of station BACA, showing 60-m long optical fiber array elements.

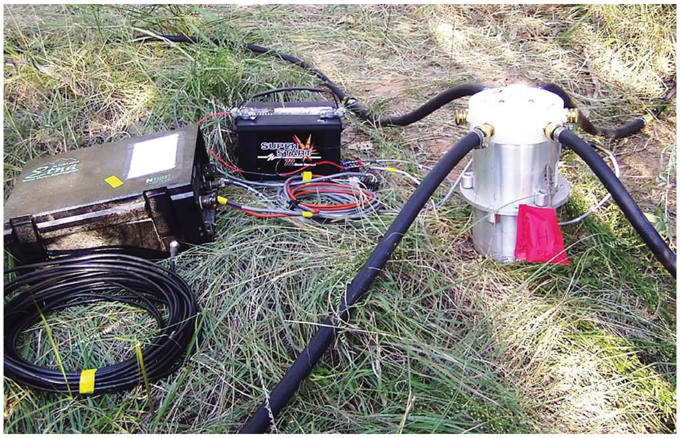

Fig. 7. Close up of infrasound sensor connected to four porous hoses. The porous hoses act as a windscreen for the sensor and are connected to a central manifold (the white segment) at the top of the sensor.

Fig. 8. Orion rocket attached to launch rail.

The distribution of recorded signals

Signals from the explosions of the three experiments were recorded at array stations to a range of approximately 900 km. Twenty four of the thirty stations recorded signals from at least one of the explosions.

The spatial distribution of the observations, as seen in Figs. 3 to 5, provides insight into the dominant propagation mode of the sound. For the September 2005 test (Fig. 3), the predicted zonal wind direction was to the west. Therefore, the station distribution favored this direction, where most of the acoustic energy would be expected to return back to the ground. The observations (green dots) confirm this ducting of acoustic energy—long range observations (greater than 400 km) were only observed in the westward direction.

The March 2006 test (Fig. 4) is a good example of observations driven by stratospheric winds to the east. In the July 2006 test (Fig. 5), the winds transitioned back to the west and the resulting observations fell in that direction. Further study of these acoustic "footprints" will provide an opportunity to refine understanding of the atmosphere and its effect on acoustic propagation.

Waveforms

Figures 10 and 11 show examples of signals recorded at the two closest arrays, NW70 and VANDAL (less than 100 km), as well as at two arrays further away, GILA and CHIR (100–300 km). The time series in these figures are aligned to the approximate signal onset. The simple pulse-like signals (N-waves) recorded at the two stations at close range (Fig. 10) contrast with the increasing complexity and reduced signal-to-noise ratio (SNR) of the multi-pathed waveforms at the more distant stations (Fig. 11). The two CHIR waveforms for the WSMR3 explosions were separated by only four hours in time, yet the waveforms are quite different—a dramatic illustration of the effects of atmospheric variability on long-range infrasound propagation.

At many stations there were several distinct signal arrivals from each explosion. Signals associated with the explosions were identified based on the expected arrival time, as well as on the stability of azimuth and phase velocity estimates and the value of the F-statistic during the time windows of stable azimuth and phase velocity. The beginning and end of such stable data windows were picked manually. Arrival times for stations at close distances (less than 100 km) were also measured manually. Signal parameters were calculated for each apparent discrete arrival in the selected data windows. In addition, root-mean-square (RMS) noise values were measured, both for time windows prior to the first signal arrival as well as in a time window spanning the expected arrival time (for those cases where no signal was observed). Average and RMS wind speed was also calculated from the time windows of received or expected arrivals.

Signal group velocity

The observed group velocity of all signals, defined as the (distance)/(arrival time–explosion time), is plotted in Fig. 12 (where the distance has been corrected for the altitude of the source). For the WSMR2 experiment the signals propagating eastward (with the wind) show increased velocities, whereas in WSMR3 it is just the opposite. These observations are consistent with the distribution of observations noted in Figs. 3-5, as well as with the modeling presented in Fig. 2.

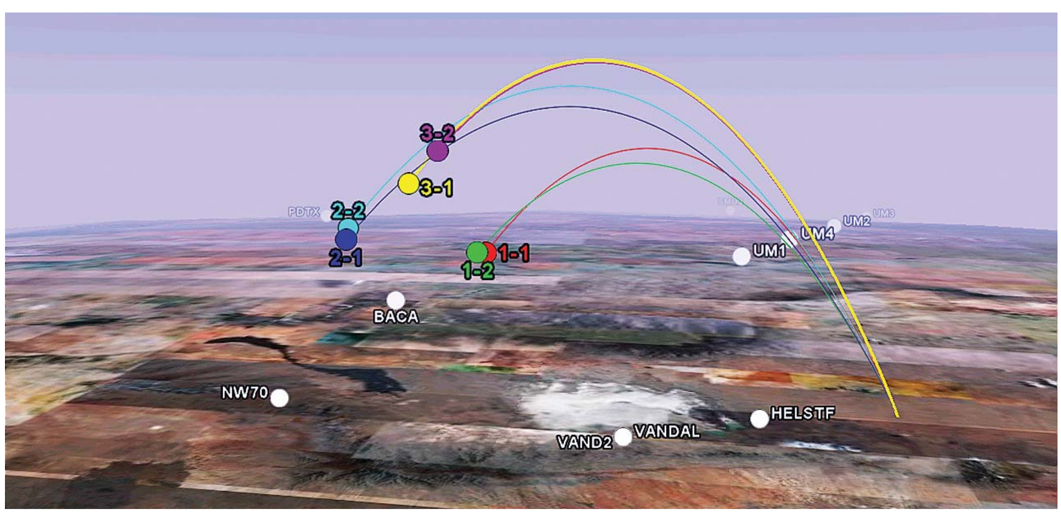

Fig. 9. Rocket trajectories and explosion locations (colored circles) for the WSMR infrasound experiments (view looking to east). White circles indicate the sites of some of the closer recording stations.

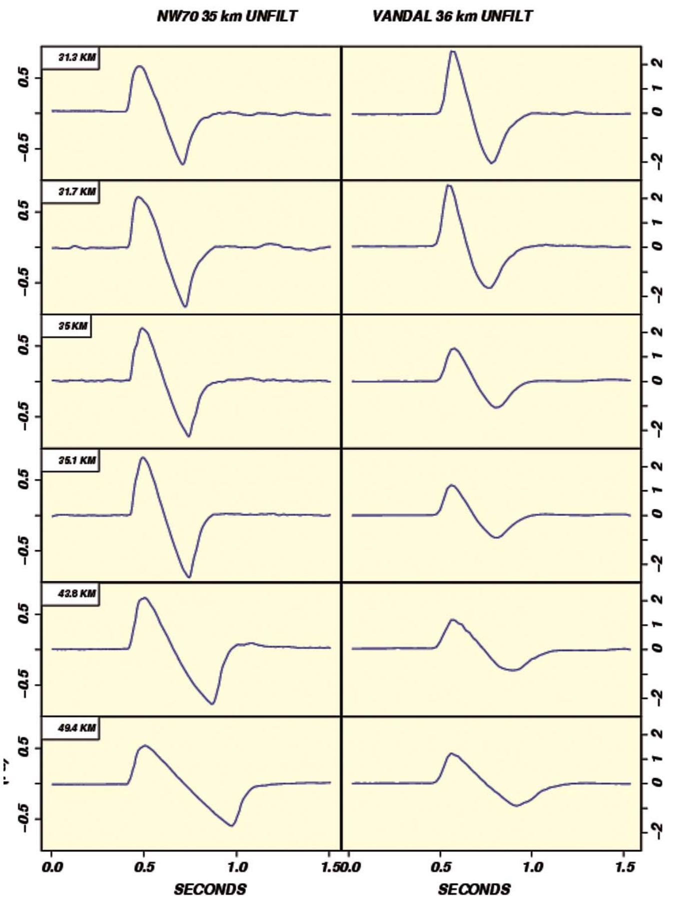

Fig. 10. Signals at the two closest stations, NW70 (left) and VANDAL (right), from the six explosions. The amplitude scale is the same for every explosion for each station. The signals represent the beam of the unfiltered array elements steered towards the explosions. With higher altitude (later shots, towards bottom of figure) the pulse-like shapes of the signals are broadened, with some variation in amplitude.

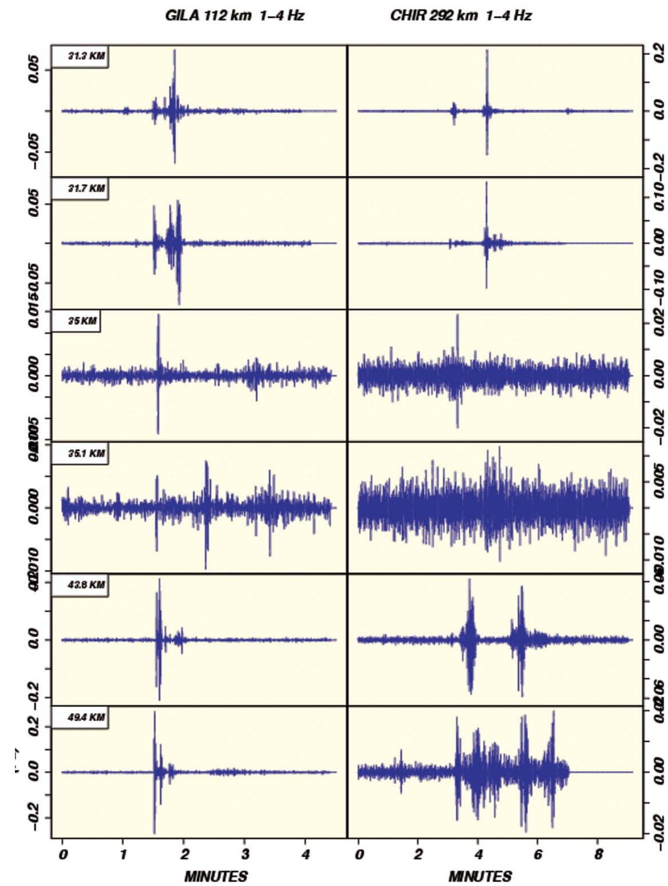

Fig. 11. Signals at the stations GILA (left) and CHIR (right), from the six explosions. The amplitude scale is normalized for each trace. The signals represent weighted beams (bandpass filtered between 1-4 Hz) of the array elements steered towards the explosions.

Signal amplitude

The maximum observed amplitudes are plotted in Fig. 13 that shows attenuation with distance. This decrease can be related to enhanced sound absorption at high altitudes. Atmospheric density falls off exponentially with altitude, so the mean free path between molecular collisions increases accordingly. This results in greater attenuation of sound energy at high frequencies (short wavelengths) than at low frequencies. The attenuation is proportional to the square of the frequency, thus sound energy undergoes greater attenuation for sources at high altitudes than at low altitudes, especially at high frequencies.

Noise amplitudes were measured at all stations, including those for which no signal was detected. The noise levels were then compared to observed signal amplitudes across the experiments. These comparisons clearly indicate that some stations "missed" observations due to periods of increased local noise levels—during which times the noise levels exceeded the expected signal levels.

Signal duration

Signal duration varied from a few seconds for the closest stations up to about a minute for the more distant stations. With a few exceptions, azimuth residuals (observed–true azimuths) are fairly consistent with no obvious bias and have standard errors around five degrees with no striking dependence on array distance.

Signal period vs. explosion yield and altitude

The dominant period of each recorded signal was calculated using an autoregressive (AR) process of order 16 with Burg's method.[21] The AR method is a parametric method, widely used in statistics and has direct applications in many areas of interest. The method provides an estimate of the spectrum and the fundamental (or system) frequencies of the time series.

Table 2 gives the altitude of the sources, the dominant periods and calculated yields for each of the signals. The periods given in the table were derived by calculating the mean dominant period for each array of sensors (at least four) and then the mean of all arrays. Arrays that were close to the source that recorded N-waves or decaying N-waves and the arrays with very low signal-to-noise ratio were excluded from the analysis.

Previous empirical formulas for estimating yields of explosions were derived from a historic dataset of nuclear explosions conducted above ground at the Nevada Test Site (NTS). The dominant period of the recorded infrasound signal from the explosions was used to calculate the yield.[22] The formula is given as:

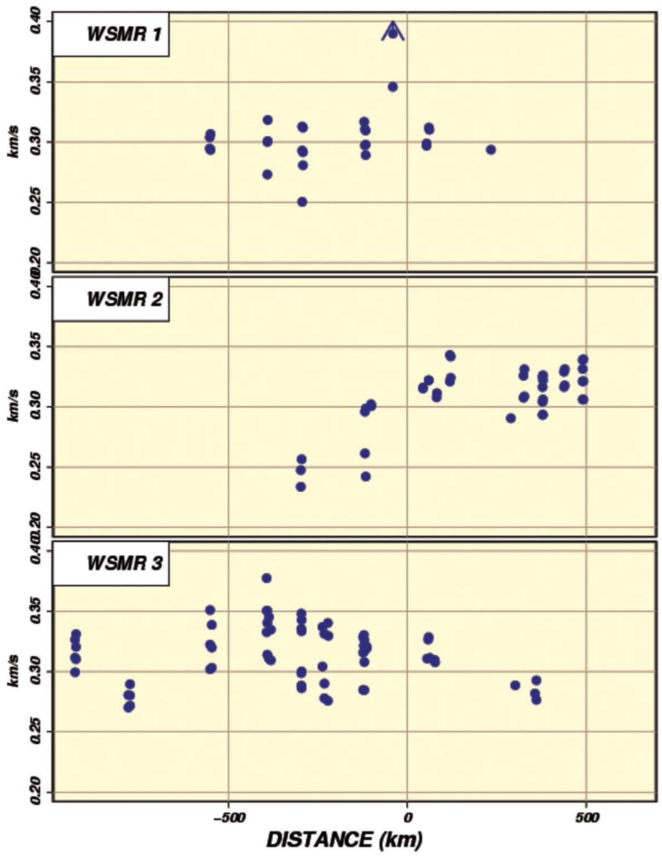

Fig. 12. Group velocity, distance/(observed arrival time – explosion time), plotted as a function of distance (range) for identified arrivals. The top, middle, and bottom panels correspond to the first, second, and third WSMR experiments, respectively. Stations to the west and to the east of the explosion locations are plotted with negative and positive distances, respectively. Data falling outside the ranges of the plots are indicated with arrowheads.

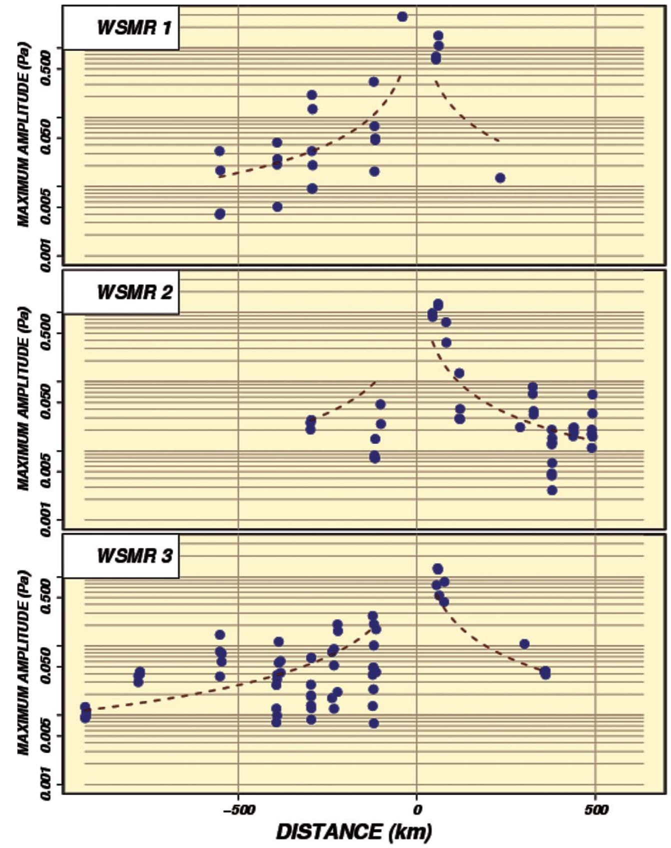

Fig. 13. Maximum pressure amplitude as a function of distance. Dashed lines correspond to amplitude attenuation as distance-1.36. See caption to Fig. 12 for an explanation of figure conventions.

$$Y_0 = (2) \times 2.38 \times T^{3.34} \tag{1}$$

where Y_0 is the yield in tons of the explosion at the Earth's surface and T is the dominant period of the signal. The physical basis for this relationship is found in an increased acoustic transit time of the explosion blast radius with increased explosive yield. The constant (2.38) was derived empirically. The doubling factor in brackets compensates for the non-nuclear nature of the explosions.

Because the explosions were not at the surface a further altitude correction is necessary. With constant period, the blast energy, or yield, Y, will scale with the ambient pressure, which falls off exponentially with increasing altitude. Once a yield (or energy) is calculated from the formula given above, it is scaled using the following formula:

$$Y(z) = Y_0 \exp^{-Z/H} \tag{2}$$

where Z is the altitude of the explosion and H is the pressure scale of the atmosphere (about 7 km).

There is definitely an increase in the dominant periods with altitude,[16] as shown in Fig. 14, but if we apply the same formula for all explosions the yields computed for the WSMR3 experiments were a factor of 2–4 smaller than the lower altitude experiments. To our knowledge this effect is reported for the first time, and the members of the team were not able to explain this difference. At higher altitudes the yield/dominant period relationship appears to fail. Future work on the yield/period relationship will attempt to add confidence intervals on the yield estimates.

Table 2. Altitude of the sources, the observed dominant frequencies/periods, and calculated yields for each of the explosions.

Event	Frequency (Hz)	Period (sec)	Altitude (km)	Yield (lb)
WSMR1-1	2.21	0.452	31.3	9.39
WSMR1-2	2.16	0.463	31.7	9.57
WSMR2-1	2.04	0.490	35	7.23
WSMR2-2	1.91	0.524	35.1	9.01
WSMR3-1	1.64	0.609	43.8	4.26
WSMR3-2	1.50	0.666	49.6	2.51

Concluding comments

Infrasound signals from the WSMR experiments were recorded at 24 out of 30 temporary and permanent stations at distances ranging up to 900 km. The recorded signals span a range of signal to noise ratios, and measurements of basic signal characteristics are consistent

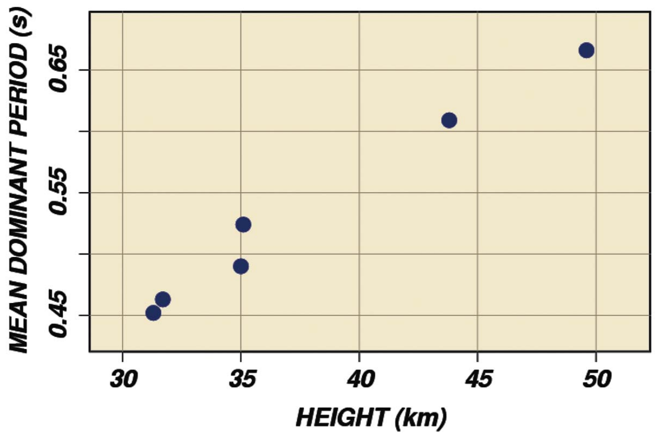

Fig. 14. Mean dominant period as a function of explosion height. This shows increasing period with height, as pointed out earlier by Herrin et al.[16]

across the multiple explosions. Beginning at about 100 km distance, the waveforms for explosions separated by only four hours in time showed significant variations due to atmospheric effects.

The data collected during the WSMR experiments, combined with the precise data on the six explosions, are proving to be of significant value across the entire spectrum of infrasound research, including source studies, propagation, instrumentation and data processing. Focused analyses using the WSMR data to answer questions both fundamental and practical are underway. For example, the WSMR data will fuel studies of a broad suite of processing algorithms to gauge the relative utility of each approach for detecting and characterizing signals. Furthermore, there are a number of important questions in propagation modeling to be investigated: Can accurate model attenuation and accurate absolute, or at least relative, signal amplitudes be predicted? In doing so, can it be predicted which stations should be able to record signals above the noise? How accurately can the timing of the arrivals at each station be predicted? Is the azimuth bias due to crosswinds accurately predicted? Can multipathing be predicted, or the overall waveform structure at each station? Do predictions improve noticeably with up-to-date atmospheric specifications? Comparisons between the predictions and the observations will provide a means to quantify the performance of the existing models, identify deficiencies in the models where physical processes may not be accounted for, and ultimately expand understanding of the interaction between propagating sound waves and atmospheric dynamics. The data are also being used to test advanced instrumentation concepts, including optical fiber infrasound sensors and the distributed sensor.

Progress in these areas, however, should also improve the ability to use infrasound data to monitor the atmosphere and the shallow earth for nuclear explosions. In this arena, event detection, location and identification are key issues. The WSMR data will be used to determine if waveform recordings can be used to identify unambiguously the source as an explosion, and to determine accurately both the geographic position of the source and its altitude. The experiments used an unusually high density of infrasound sensors, and thus there is a rare opportunity to assess the station density required to obtain sufficiently accurate location estimates and learn more about the range from which useful information about the source can be extracted.

In summary, the WSMR experiments will foster basic research as well as provide further insights relevant to nuclear monitoring in addition to proving useful in testing the use of infrasound data for monitoring natural hazards.

Participants

In addition to the authors of this article, the following people participated in various aspects of the WSMR experiments:

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K. Veith, ITT Corporation;
J. Behrens, R. Wright, BAI, Inc.

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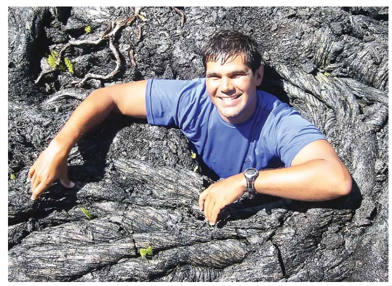

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Paul Golden is the Director of the Geophysics Laboratory at Southern Methodist University and is responsible for planning and implementation of the technical, financial, and scientific efforts of the Laboratory. In this role he oversees daily operations and adherence to schedules and budgets. His scientific interests include seismic data acquisition and analysis, basic research in infrasound phenomenology and seismo-acoustic studies. He has been involved in high-profile national and international programs over his 20+ year career.

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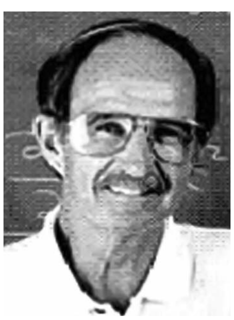

Gene Herrin is the Shuler-Foscue Professor at Southern Methodist University whose research interests encompass infrasound, seismology, and other topics. His primary research interests in seismology include: (1) extension of seismological observations to high frequencies, (2) seismic observations in deep boreholes, (3) processing of high frequency seismic data, (4) design of advanced seismic instruments and observatories, and (5) research in the seismic verification of nuclear arms-control treaties.

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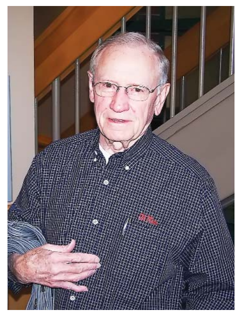
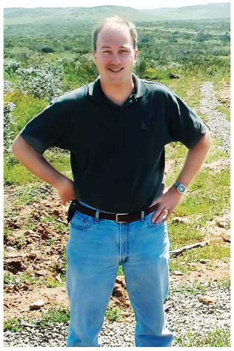


Doug Shields received a Ph.D. from Vanderbilt University in 1956. He brought acoustics research to the University of Mississippi in 1959. At Ole Miss he has served as Professor of Physics and Associate Dean of Liberal Arts. Since 1988 he has worked as a senior research scientist at the National Center for Physical Acoustics. Dr. Shields's early work was in the use of acoustics to study vibrational relaxation processes in gases. More recently he has been involved in building distributed arrays of infrasound sensors to filter wind noise from infrasound signals.

Curt Szuberla is Assistant Professor of Physics at the Geophysical Institute and University of Alaska Fairbanks (UAF). Before joining the Geophysical Institute as a Ph.D. student in 1992, Szuberla served as an Airborne and Ranger-qualified infantry officer in the U.S. Army and is a graduate of the U.S. Military Academy. Following graduate school, he taught high school physics and mathematics at North Pole High School for eight years. Since 2000, as a consultant and now a faculty member, he has helped to build an internationally recognized infrasound research program at UAF, known as the Wilson Infrasound Observatories.



Kris Walker is currently a postdoctoral researcher at the University of California, San Diego. During the last 11 years, he has been working on problems in solid earth and atmospheric geophysics involving active- and passive-source seismic imaging, seismic velocity anisotropy characterization, potential field modeling, array-analysis techniques, and acoustic sensor development.

Rodney Whitaker graduated from Indiana University, Bloomington, Indiana, with a Ph.D. in Astronomy in November, 1976. His work at Los Alamos National Laboratory began with a post-doctoral position in late 1976, and about one year later he became a technical staff member. For several years he worked on finite difference simulations of atmospheric nuclear explosions and their effects. These numerical calculations included radiation transport and hydrodynamics. This work also led to interesting calculations related to star formation in inter-stellar molecular clouds. In the early 1980s, Dr. Whittaker began work on low frequency atmospheric acoustics or infrasound, and this work has continued to the present. During this period, he gained experience in all aspects of the program at Los Alamos: field deployment and operations, data collection, signal processing, source modeling, wave propagation, and interpretation. In addition to underground tests, the program collected data on earthquakes, large conventional surface explosions, microbaroms, and a few other man made sources. The large surface explosions were in the range of a few kilotons of explosive.

Bob Woodward is the Director of the EarthScope USArray project for the Incorporated Research Institutions for Seismology (IRIS). Prior to joining IRIS he worked for Science Applications International Corporation (SAIC), where he managed a variety of geophysical research and development projects, advanced technology research and development activities, and large-scale systems integration efforts. Prior to his work with SAIC, Bob managed the Data Collection Center at the USGS Albuquerque Seismological Laboratory, collecting and managing data from the Global Seismographic Network. Bob earned a B.A. in Geophysics and Applied Mathematics from the University of California, Berkeley and a Ph.D. at Scripps Institution of Oceanography, University of California, San Diego,

COMING TO TERMS WITH THE EFFECTS OF OCEAN NOISE ON MARINE ANIMALS

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"The challenge is to balance our sound producing activities so they do not impact the health and safety of creatures, large and small, that live in the sea."

From the sound that threatened "to deafen whales" with a low frequency hum throughout the world's oceans (Anderson, 1991) to present day military exercises using active sonar, controversy about the effects of sound on the marine environment has continued for over two decades. Marine animals use sound for communication, navigation, detection of predators and prey, and identification of their habitats. But the ocean is filled with many interfering sounds, some naturally occurring such as earthquakes and volcanic eruptions, and others resulting from human activity. The largest contributor to anthropogenic (human-caused) sound in the ocean is commercial shipping, which accounts for over 90% of international commerce. But other contributors, such as active sonar and seismic air guns, have very high source levels even though they affect smaller defined areas. Active sonar is used not only by the world's navies to detect and track potentially hostile underwater intruders, but also by scientific researchers to study the ocean environment and the animals that live there. Likewise sound pulses created by arrays of seismic air guns are used for geophysical research to understand structures and processes beneath the seafloor as well as by oil and gas companies to locate and quantify reserves of hydrocarbon fuels. The challenge is to balance these activities so they do not impact the health and safety of creatures, large and small, that live in the sea.

The public is acutely aware of potentially harmful interactions between marine animals and anthropogenic sound (Simmonds *et al.*, 2003; Wartzok *et al.*, 2003/04; Jasny *et al.*, 2005). As this article goes to press, the U.S. Navy finds itself in a 30-day period during which it can file an appeal to the U.S. Supreme Court for exemption from environmental laws[1] that protect whales and other marine mammals so that it can fully conduct sonar training exercises off the coast of California. President Bush had exempted the Navy from applicable environmental laws on the basis of national security so that sonar training activities could continue without restrictions. But on February 29th of this year the U.S. Court of Appeals for the 9th Circuit upheld a lower court ruling that requires the Navy to limit sonar training off the California coast to minimize harm to marine life (*The Washington Post*, 2008). Now for the first time, it appears that the debate over effects of sound on marine mammals could be headed to the highest court in the land.

How did it begin?

Concern about potential adverse effects of anthropogenic sound on marine life accelerated in the early 1980's when endangered gray whales off the coast of California and bowhead whales in the Beaufort Sea displayed avoidance responses when exposed to playbacks of noise from drillships and dredges (Richardson *et al.*, 1990). But beginning in 1990, considerable public awareness about the effects of anthropogenic sound on marine animals materialized when plans for the Heard Island Feasibility Test (HIFT) coincided with advanced development of the U.S. Navy's Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) Sonar. Because sound at low frequencies can travel further underwater than sound produced at higher frequencies, SURTASS LFA was designed to emit signals at frequencies between 100 and 500 Hz using an array of 8 transducers, each with a source level of 215 dB re 1 μPa at 1 m (DoN, 2001), which could propagate from tens to hundreds of nautical miles (nm), effectively covering an ocean basin, to provide longer detection ranges for small, relatively quiet diesel-electric submarines and thus more time for defensive action.[2]

At the same time, the Office of Naval Research (ONR), the National Science Foundation (NSF), the Department of Energy (DOE), and the National Oceanic and Atmospheric Administration (NOAA) were sponsoring researchers led by Walter Munk at the Scripps Institution of Oceanography to plan and conduct the HIFT in attempt to demonstrate a method to monitor climate changes on a global scale. Taking advantage of known, long distance sound wave paths often referred to as the "deep sound channel," the Heard Island experiment was designed to show that measuring sound speed in the world's oceans could be used to monitor global warming (Cohen, 1991). The experiment consisted of transmitting acoustic signals at a frequency of 57 Hz (sometimes described by the press as a "low frequency hum") from Heard Island in the southern Indian Ocean and then measuring their time of arrival at various points around the world. The speed of sound in water increases with increasing temperature, so small changes in temperature of the ocean basins could be determined by measuring the amount of time it took for these sounds to travel from one point to another (Baggeroer and Munk, 1992; Munk *et al.*, 1994). This experiment created an outcry from several environmental groups, whose members feared that the HIFT sound transmissions would interfere with low frequency communications among large baleen whales (mysticetes)[3] or even physically harm these animals. The experiment began in January 1991, but with scientists onboard ships to monitor marine mammal activities in the vicinity of the sound source. No adverse reactions were observed (Bowles *et al.*, 1994).

The U.S. Navy's response to public outcry in the 1990's was twofold. First was initiation of environmental risk assessments and preparation of documents and requests for permits needed for HIFT and SURTASS LFA in compliance with national environmental laws. Second was funding for scientific research to understand the interactions between marine animals and sound. ONR funded the National Research Council (NRC) in 1992 to establish a Committee on Low-Frequency Sound and Marine Mammals, and produce a report on the state-of-knowledge and recommendations for changes in the regulatory process[4] to facilitate scientific studies as well as research needed to evaluate effects of low-frequency sounds on marine mammals and their major prey (NRC, 1994). ONR also began to sponsor research on the effects of low frequency sound on marine mammals and fish. Initially the primary concern was hearing and communication. So experimental studies to determine the effects of underwater sound on hearing in odontocetes (toothed whales) and pinnipeds (seals, sea lions and walrus) were initiated with captive animals—and continue today—at the Space and Naval Warfare Systems Center San Diego (SSC San Diego), the Hawaii Institute of Marine Biology (HIMB) at the University of Hawaii, and Long Marine Laboratory at the University of California, Santa Cruz (UCSC). In addition a SURTASS LFA Scientific Research Program (SRP) began in 1997 to quantify the reactions of large whales to low frequency broadcasts (Croll *et al.*, 2001).

The debate continued as plans were made for the offspring of the HIFT—a long term monitoring project, acoustic thermometry of the ocean climate (ATOC), using a lower power source operating at 75 Hz over a smaller region of the Pacific Ocean. Even though the ATOC sound projectors had lower source levels than those used for the HIFT (195 dB vs. 221 dB re 1 μPa at 1 m), public outcry caused the final project to be significantly delayed and scaled back. The final environmental impact statement set aside about $3 million of funding to study the effects of ATOC sound transmissions on marine mammals—the first two years of the project—so that it could be stopped if any adverse effects were observed. This ATOC Marine Mammal Research Program (MMRP) was reviewed by a new NRC study panel to update the 1994 NRC report with MMRP data and results of any other relevant research, and to identify continuing knowledge gaps. The review (NRC, 2000) indicated that results of the MMRP were inconclusive as to whether or not ATOC sound transmissions had any effect on marine mammals (Au *et al.*, 1997; Frankel and Clark, 2000; Frankel and Clark, 2002).

Attention turns to mid-frequency sonar, seismic air guns, and impact pile driving

Mid-frequency active sonar has been in operation since the 1940's and is the standard modality for localizing submarines. But in 1996 exposure to military sonar during a North Atlantic Treaty Organization (NATO) Undersea Research Centre exercise was postulated as the cause of a mass stranding of 12 beaked whales in Greece (Frantzis, 1998).[5] Similar mass stranding events during military exercises in the Bahamas and Madeira in 2000 (Evans and England, 2001; Cox *et al.*, 2006), and the Canary Islands in 2002 (Evans and Miller, 2004), each involving between 4 and 18 whales within two days, confirmed that beaked whales, and in particular Cuvier's beaked whale (*Ziphius cavirostris*), are sensitive to mid-frequency sonar, which operates in the 1 – 10 kHz bandwidth with source levels as high as 235 dB re 1 μPa at 1 m (Evans and England, 2001). In these four events about half of the stranded animals died, but the mechanisms that caused the animals to strand and contributed to pathological traumas revealed during necropsies are unknown (Ketten, 2005).

Subsequent mass stranding events coincident with the use of mid-frequency sonar in the Haro Strait near the state of Washington in 2003 (Norman *et al.*, 2004; National Marine Fisheries Service, 2005), and off the coasts of Hawaii in 2004 (Southall *et al.*, 2006) and North Carolina in 2005 (Hohn *et al.*, 2006) involved other species, including harbor porpoises, melon-headed whales and short-finned pilot whales, respectively. Medical examinations and necropsies of animals affected in these events, however, indicated that beaked whales are most susceptible to acoustic trauma when exposed to mid-frequency sonar transmissions (Freitas, 2004; Ketten, 2005; Fernández *et al.*, 2005).

Seismic air gun surveys for hydrocarbon exploration or oceanographic research are similar to active sonar operations. An air gun array towed by a vessel emits acoustic pulses directed vertically downward that penetrate the seabed. Refracted and/or reflected waves from different sediment layers are recorded by sensors on streamers towed behind the air gun array and used to reconstruct a picture of the substrate below the seafloor. Most all the acoustic energy in an air gun pulse is below 1000 Hz; however, sound pressure level (SPL) and spectral content vary spatially depending on the local undersea environment. Peak-to-peak source levels of emissions from air gun arrays can exceed 250 dB re 1 μPa at 1 m. Although the Department of Fisheries and Oceans (DFO) Canada, the U.S. Department of the Interior Minerals Management Service (MMS), as well as oil and gas companies worldwide had investigated the effects of noise on marine life from offshore industrial activities and seismic exploration for many years (e.g., Falk and Lawrence, 1973; Pearson *et al.*, 1987 and 1992; Richardson *et al.*, 1990, Richardson *et al.*, 1995), two beaked whales stranded September 2002 in the Gulf of California in association with seismic air gun use (Cox *et al.*, 2006). This stranding occurred coincidentally with a seismic air gun survey by the NSF-supported oceanographic research vessel, *Maurice Ewing*; however, the *Ewing* was also operating mid-frequency active sonar at the time. Since 2003, legal challenges and risk assessments for documentation of environmental impact statements have significantly hampered oceanographic research funded by NSF.

In the autumn of 2000 while the U.S. Navy was still trying to understand conditions that contributed to the March 2000 stranding of beaked whales in the Bahamas, the California Department of Transportation (Caltrans) was responding to a fish kill that occurred during a pile installation demonstration project (PIDP) for the San Francisco-Oakland Bay Bridge (SFOBB) East Span Seismic Safety

Project (East Span Project), a major public works effort to make the SFOBB "earthquake proof" (Caltrans, 2001). In addition to marine mammals, the major issues were endangered salmon species and impact on commercial fisheries. During the PIDP three 2.4-m diameter steel pipe piles were driven into the seabed with two different sizes of hydraulic impact hammers in effort to identify potential problems and test effectiveness of sound attenuation equipment. The immediate mortality zone for fishes was estimated to be within 10-12 meters of a pile without attenuation devices, but the potential for significant acoustic impacts extended far beyond this range.

A global environmental issue

The beaked whale stranding events, an increasing number of seismic surveys to meet the worldwide demand for oil and natural gas, and continued offshore pile driving activities at the start of the 21st century pushed the issue of ocean noise and marine animals to new heights. In 2003 the U.S. Congress passed legislation that directed the Marine Mammal Commission (MMC) to "fund an international conference or series of conferences to share findings, survey acoustic threats to marine mammals, and develop means of reducing those threats while maintaining the oceans as a global highway of international commerce." In response, the MMC convened a Federal Advisory Committee on Acoustic Impacts on Marine Mammals (MM FACA), consisting of 28 representatives from various stakeholders, including non-governmental environmental organizations, the U.S. Navy, oil and gas companies, geophysical contractors, shipping industry, government agencies, and the scientific research community (MMC, 2007). The MM FACA met six times in plenary meetings from February 2004 through September 2005 (more information can be found at http://www.mmc.gov/sound/). In addition, the MMC convened two international workshops—the Beaked Whale Technical Workshop in Baltimore, April 2004, and the Policy on Sound and Marine Mammals: An International Workshop in London, September 2004. But at their last plenary meeting, the MM FACA still could not reach consensus on recommendations to address the marine mammals and noise issue, so the report to Congress included a findings report and recommendations from the MMC, plus seven individual statements from the various stakeholder groups (MMC, 2007).

In October 2004, the European Parliament called for a moratorium on deployment of all active naval sonar until a global assessment of its impact on marine life could be completed (European Parliament, 2004).[6] This was followed by the first Inter-Governmental Conference on Sonar and Marine Mammals, convened in Lerici, Italy, in May 2005 by ONR-Global and the NATO Undersea Research Center. In 2005 the International Council for the Exploration of the Sea (ICES) headquartered in Copenhagen, also issued a report on the impacts of sonar on cetaceans and fish (ICES, 2005).

Although global attention was focused primarily on sonar and beaked whales during this period, Caltrans continued to work on the pile driving and fish issue. The Bay Planning Coalition and Caltrans organized and sponsored a Pile Driving Educational Workshop in October 2003. At this time NOAA Fisheries was requiring acoustic monitoring of all pile driving operations along the California coast, no matter how large or small. The additional costs for monitoring were threatening to put small piling contractors out of business. In 2004 Caltrans formed the Fisheries Hydroacoustics Working Group (FHWG), which included environmental, scientific and engineering experts, and representatives from NOAA Fisheries, California Department of Fish and Game, and the U.S. Department of Transportation (DOT), to work towards consensus on noise exposure criteria for fish. They also teamed with the DOT, and state departments of transportation in Washington and Oregon to form a pooled fund to support research needed to understand the effects of pile driving sound on fish. The first research project was funded in 2006.

The oil and gas industry also focused its efforts to address the effects of sound from offshore exploration and production (E&P) activities on marine life. In August 2005 the International Association of Oil and Gas Producers held an International Workshop on Sound in the Marine Environment in Halifax with over 50 participants from the global research community to help draft a research agenda for a proposed funded research program to address important issues and information gaps. Then, in May 2006, seven international companies formed an executive committee to run the second phase of a joint industry program (JIP) to address E&P Sound and Marine Life. Since that time corporate membership in the JIP has more than doubled. This group regularly posts requests for proposals on its website, www.soundandmarinelife.org. During its first 12 months, the JIP issued 27 research contracts for nearly $8 million dollars (JIP, 2007). This level of funding will help fill critical data gaps needed to understand and improve mitigation of acoustic impacts in the ocean environment.

Progress in understanding the effects of sound on marine animals

Research on effects of sound in the marine environment has focused primarily on understanding criteria and thresholds for physiological and behavioral effects, location and abundance of marine animals, and sound source characteristics and propagation paths. These studies include laboratory experiments on captive animals where received sound levels are carefully measured and correlated with tissue damage, changes in hearing sensitivity, and/or changes in behavior; controlled exposure experiments in the wild to determine behavioral responses where the sound incident on an animal or group of animals is measured and the transmission path between the sound source and animal receivers is defined; and numerical modeling efforts to integrate large data sets with physical understanding to form predictive models to aid in risk analyses and environmental planning. In addition, research on monitoring and mitigation of potential acoustic impacts has facilitated advances in both fixed and deployable passive acoustic monitoring systems for detection, classification and localization of marine mammals. These systems can also be used in the field to study the behavior of vocalizing and echolocating marine mammals.

Although many questions remain to be answered, much

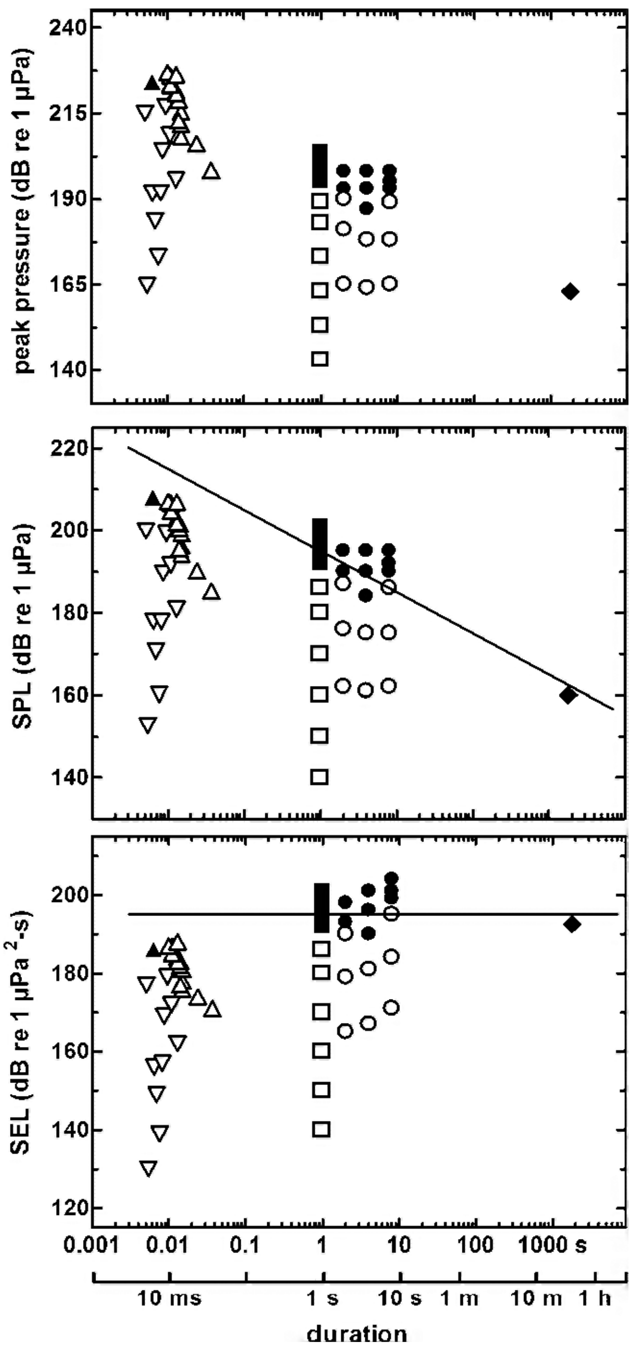

Fig. 1. Summary of bottlenose dolphin and white whale temporary threshold shift (TTS) experimental data showing relationship between level and duration of exposures that produce measurable TTS adapted from Fig. 9 of Finneran et al. (2005). Data are from Finneran et al. (2000 and 2002) (triangles–explosion simulator and watergun sources), Schlundt et al. (2000) (squares–pure tones), Nachtigall et al. (2003 and 2004) (diamonds–band-limited white noise), and Finneran et al. (2005) (circles–3 kHz pure tones). Closed symbols represent exposures where TTS was observed and open symbols indicate exposures that did not produce a measurable TTS. Solid lines represent an equal-energy condition.

progress has been made in several areas during the last two decades. Research activity is evident by the increase in number of scientific publications and special conferences, workshops and symposia over the last 10 years. The state of scientific knowledge and recommendations for future research on marine mammals and noise through 2005 are summarized in the latest reports published by the NRC (2003, 2005). These reports were researched and written by balanced study panels of scientific experts and anonymously peer-reviewed prior to publication. The proceedings of an International Conference on the Effects of Noise on Aquatic Life, held August 2007 in Nyborg, Denmark—the first to include both marine mammals and fish—will soon be published in the journal, *Bioacoustics*. So the following provides only a brief summary of past findings and an update on research activity since 2005.

Probably the most progress in any area during the last 15 years has been achieved in quantifying the effects of sound exposure on hearing in dolphins, white whales, seals, sea lions, and several species of fish. Exposure to excessive sound energy may reduce hearing sensitivity by producing an elevated hearing threshold, also known as a threshold shift. If the hearing threshold returns to the pre-exposure level after a period of time, the shift is a temporary threshold shift or TTS. If the threshold does not return to the pre-exposure level, then it becomes a permanent threshold shift (PTS).[7] Through TTS experiments, scientists at SSC San Diego, HIMB and UCSC have greatly advanced our understanding of the effects of sound on hearing in odontocetes and pinnipeds (Kastak and Schusterman, 1995; Ridgway *et al.*, 1997; Kastak and Schusterman, 1999; Kastak *et al.*, 1999; Schlundt *et al.*, 2000; Finneran *et al.*, 2000; Kastak and Schusterman, 2002; Finneran *et al.*, 2002; Nachtigall *et al.*, 2003; Finneran *et al.*, 2003; Nachtigall *et al.*, 2004; Kastak *et al.*, 2005; Finneran *et al.*, 2005; Yuen *et al.*, 2005; Kastak *et al.*, 2007). One outcome of this research indicates that TTS in dolphins and white whales depends on the duration as well as SPL, and onset of TTS correlates with sound exposure level (SEL) for several different types of sound sources.

Finneran *et al.* (2005) concluded that collectively these data indicate an SEL of 195 dB re 1 μPa^2-s as a reasonable threshold for the onset of TTS in dolphins and white whales. But in the absence of data for other species, these findings (Fig. 1) have provided a useful baseline to estimate effects of sound on hearing in other odontocetes. Current hearing research efforts are focused on understanding the effects of lengthy continuous exposures, and of intermittent exposure and recovery to multiple pulses such as those transmitted by active sonar or a seismic air gun.

Several workshops and research studies have also addressed effects of sound exposure on hearing and tissue injury in fish. In 2004 Caltrans supported a comprehensive literature review complete with recommendations for noise exposure criteria (based on available data at that time) and research needed to understand the effects of pile driving sound on fish (Hastings and Popper, 2005). These recommendations for research have provided a framework for projects to be supported through the Transportation Pooled Fund Program. The federal courts directed the U.S. Navy to look at the effects of LFA transmissions on fish after acceptance of the final Overseas Environmental Impact Statement and final Environmental Impact Statement for SURTASS LFA (DoN, 2001). In response, the Navy funded a controlled exposure experiment (CEE) on caged fish at Seneca Lake (see Fig. 2) to prepare for a supplemental environmental impact statement. Results recently published by Popper *et al.* (2007) indicate that freshwater rainbow trout did not have any auditory or non-auditory tissue damage even though they experienced a significant amount of TTS after continuous exposures to LFA transmissions for 216 seconds. Additional data on other species are still being analyzed. The Chief of Naval Operations Environmental Readiness Division (CNO N45) sponsored a Workshop on Mid-Frequency Sonar and Marine Fishes in April 2007 to reach consensus among the scientific community and other stakeholders on research recommendations to address this issue (Read *et al.*, 2007). Presently a CEE with mid-frequency sonar, similar to that conducted for SURTASS LFA, is in progress at Seneca Lake.

Fish have suffered hearing loss and damage to auditory sensory cells when exposed to seismic air gun emissions. Previous studies indicated that lengthy exposure to low frequency continuous tones (Hastings *et al.*, 1996) with an SPL of 180 dB re 1 μPa or multiple emissions from a seismic air gun at close range (McCauley *et al.*, 2003) could destroy sensory hair cells in the inner ears of fish. But in a recent study by Popper *et al.* (2005), fish that received a cumulative sound exposure similar to that reported in the McCauley *et al.* (2003) study when exposed to multiple emissions from a small air gun array in a river delta, experienced only TTS that recovered within 18-24 hours without hair cell damage. Understanding the differences among results of these studies is a topic of current research.

Studying the behavior of marine animals in the wild is very difficult, but much progress has been achieved in understanding both natural behaviors and the effects of sound on short-term behaviors of many marine animals. Because of potential effects on commercial fisheries, the behavior of fish in response to exposure to seismic air gun emissions has been studied for many years primarily via visual observation or underwater video (Falk and Lawrence, 1973; Pearson *et al.*, 1987 and 1992; Løkkeborg and Soldal, 1993; Wardle *et al.*, 2001, Thomsen 2002; Gausland, 2003; Hassel *et al.*, 2004). Although catch rates are reported to decrease after air gun shooting and some fish have shown aversive reactions to the sound, overall the data are not easily extrapolated to other field operations. Research in this area as well as in behavioral responses of fish to other types of underwater sound is ongoing.

Richardson *et al.* (1995) provide the most comprehensive summary of short-term behavioral responses to sound by marine mammals for a number of different offshore industrial activities. Changes in behavior attributed to underwater sound vary with age, sex, activity engaged in at the time of exposure (e.g., resting, foraging, socializing), perceived motion of the sound, and the nature of the sound source. Two CEE studies with SURTASS LFA signals indicated temporary alterations in behavior of marine mammals. Migrating gray whales avoided a stationary underwater sound projector playing back SURTASS LFA sonar signals when the source was located in their migratory path off the California coast (Tyack and Clark, 1998; NRC, 2003). But the whales seemed to ignore the sound source when it was located seaward of their migratory path, even when received levels were higher, indicating that the location of the sound source, not just its level, was critical to their behavioral

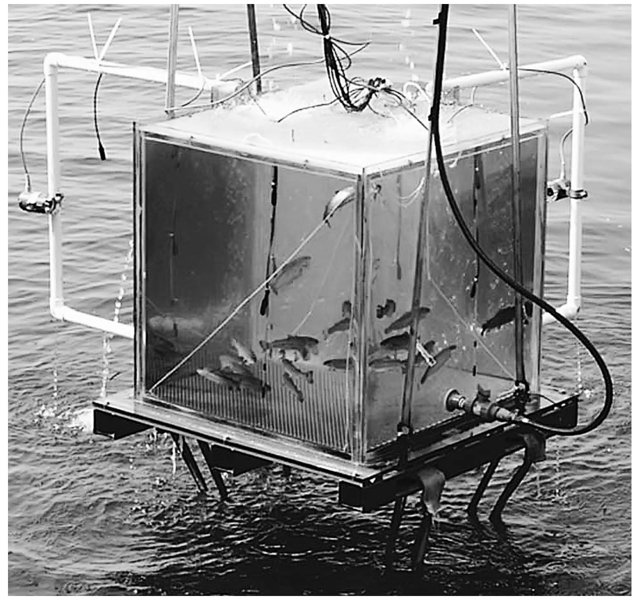

Fig. 2. Rainbow trout in test tank being removed from Seneca Lake after exposure to the U.S. Navy's Surveillance Towed Array Sensor System, Low Frequency Active (SURTASS LFA) transmissions. Photo from Popper et al. (2007).

response. In the second study, Miller *et al.* (2000) found that some, but not all, humpback whales exposed to SURTASS LFA signals made louder and longer songs during exposure. But the song duration and loudness returned to normal levels immediately afterwards. The long term significance of these changes in behavior is unknown.

In the mid-1990's advances in satellite tag technology enabled several large scale natural behavioral studies of marine mammals (Mate *et al.*, 1998 and 1999; Lagerquist *et al.,* 2000). Satellite-monitored tags transmit a radio signal that allows tracking day-to-day movements of animals that migrate over tens of thousands of miles in the ocean each year. The tags are safely implanted in the skin-blubber layer of marine mammals (Fig. 3), and similar externally mounted tags have been used on turtles, fish, and even seabirds. This information has established previously unknown migratory corridors, feeding grounds, and movement patterns of several populations of whales. Perhaps the most ambitious and successful project is Tagging of Pacific Predators (TOPP), which began in 2000 and is part of the Census of Marine Life (www.coml.org), a 10-year worldwide effort to assess diversity and abundance of life in the oceans. TOPP is managed by a team of scientists from Stanford University's Hopkins Marine Lab, NOAA Southwest Fisheries Science Center, and UCSC (see www.topp.org for more information). The use of these tags has dramatically improved understanding of the range and habitat use of large whales, sharks, tuna, turtles, and many other marine species. These data are critical for planning and mitigating potential adverse impacts of sound-producing activities in the ocean.

During the last decade many passive acoustic monitoring (PAM) tools have been developed that are useful for large scale natural behavioral studies. These include low cost, hand-deployable listening arrays and 'leave-behind' retrievable devices that are now widely used by scientists to assess the underwater acoustic environment and study animal

Fig. 3. Satellite tag on a sperm whale.

movement and behavior. An example of the latter is the Autonomous Acoustic Recording Packages (ARPs) developed at the Scripps Institution of Oceanography (Wiggins, 2003). These packages are mounted on the sea floor and provide continuous monitoring of whale migrations and regional populations for a year or more. ARPs have been deployed to record baleen whale sounds in the Bering Sea, Beaufort Sea, Gulf of Alaska, off the coast of southern California, near the West Antarctic Peninsula, and near Hawaii. NOAA Fisheries uses these types of passive acoustic recording instruments in their marine mammal censuses.

Since 2003, three biennial International Workshops on the Detection and Classification of Marine Mammals Using Passive Acoustics (Halifax 2003, Monaco 2005, and Boston 2007) have produced three special issues of peer-reviewed scientific journals that represent the state-of-the-art in signal processing for automatic detection, classification and localization of multiple marine species. These signal processing techniques have been applied to small deployable hydrophone arrays as well as to development of the Marine Mammal Monitoring on Navy Ranges (M3R) program. This program was funded by ONR to develop data acquisition and signal processing systems to detect, classify and localize different groups of whales on a range in real time by recording sounds through the range's existing array of bottom-mounted hydrophones. Classification is limited to families of whales (e.g., beaked whales, sperm whales, pilot whales, etc.) that echolocate while foraging. With support of CNO N45, this system is now being ported to multiple ranges to be used for monitoring marine mammal activity; however, these systems can also be used to study the natural behavior of animals and their responses to sound exposure.

Perhaps the two most important recent technological developments for studying the effects of sound on marine animals in the wild are acoustic data logger tags that can be used to examine their behavior in response to received sound (Burgess *et al.*, 1998; Johnson and Tyack, 2003), and field portable instrumentation to assess hearing sensitivity of untrained non-captive animals by measuring auditory evoked potentials (Casper *et al.*, 2003; Nachtigall *et al.*, 2005; Finneran and Houser, 2006; Houser *et al.*, 2007).

Acoustic data logger tags are relatively inexpensive, easily programmed, miniature sensor packages that are attached by suction cups to the body surface and can be carried by even small marine mammals and sea turtles. The tags record sounds as received by the animal simultaneously with records of swimming and diving movements as well as social sounds or sonar use by the animals themselves. They can even be configured to record heart rate and respiration if needed. These tags have been used to study the underwater behavior and calls of blue whales off the California coast and beaked whales in the Bahamas, Canary Islands, and Mediterranean Sea (Johnson *et al.*, 2004; Madsen *et al.*, 2005). Madsen *et al.* (2006) used acoustic data logger tags to quantify the sound received by foraging sperm whales from seismic air gun emissions in a CEE in the Gulf of Mexico. They found that simple spherical spreading models could not be used to predict sound levels received by the animals, and that the received sound contained significant energy all the way up to 3 kHz when whales were near the surface.

Less than 10 years ago, knowledge of hearing in fish and marine mammals was generated through behavioral studies using captive animals trained to participate in hearing test procedures. This behavioral approach was expensive, time-consuming, and limited to only a very small number of captive individuals and species. An alternative to obtaining behavioral measures of hearing sensitivity is an electrophysiological technique based on the measurement of small voltages produced by the brain in response to sound. These volt-

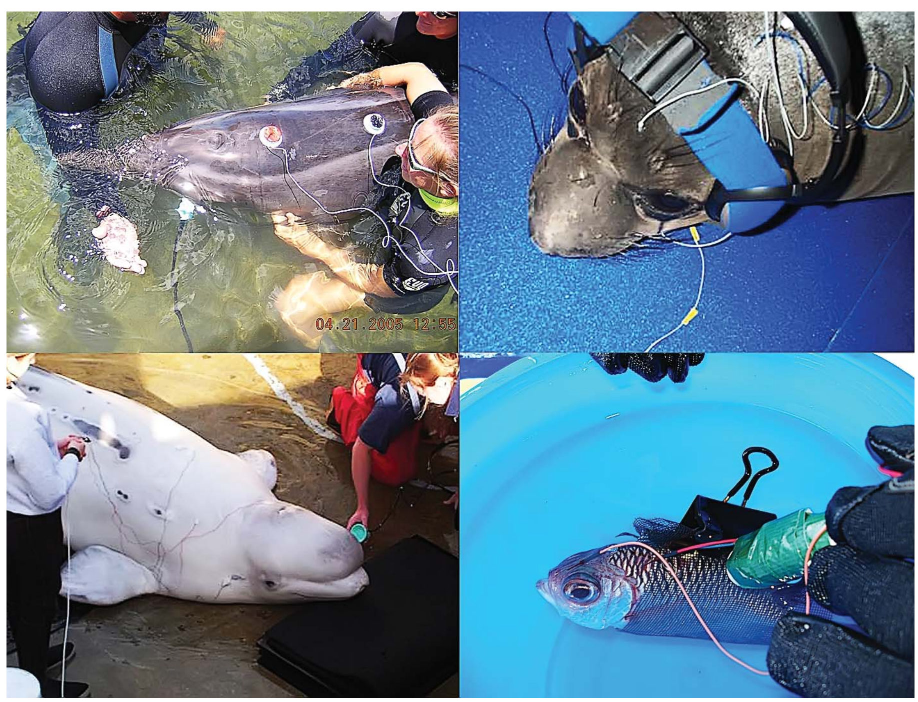

Fig. 4. Clockwise from top left: Auditory evoked potential (AEP) measurements using surface electrodes on a stranded rough toothed dolphin (Cook, Manire and Mann, U. South Florida); needle electrodes and headphones for sound stimulus on elephant seal pup in air (Houser and Reichmuth, UCSC); needle electrodes on reef fish (Hastings, ARL Penn State); and surface electrodes on white whale in air with sound stimulus presented with jaw phone (Finneran and Houser, SSC San Diego).

ages are called auditory evoked potentials (AEPs). They are measured via electrodes on the surface of the animal's head or small needle electrodes inserted just beneath the skin (Fig. 4). This method has been applied to study hearing of human infants and land animals. Adaptation of this methodology to fish and marine mammals occurred almost simultaneously. But marine mammal scientists quickly developed field portable systems (Fig. 5) because of the need to obtain data on multiple species of non-captive animals. New hearing data for a number of species is now being collected. The state-of-the-art for AEP measurements in marine mammals is summarized in a special issue of *Aquatic Animals* published in 2007 (Vol. 33, No. 1).

Beaked whales and sonar

Understanding why beaked whales are unusually sensitive to mid-frequency sonar is necessary to manage and mitigate its potentially adverse effects (Cox *et al.*, 2006). The collective knowledge about beaked whales presented and discussed at the Marine Mammal Commission's April 2004 Beaked Whale Technical Workshop, was published in a special issue of the *Journal of Cetacean Research and Management* in 2006 (Vol. 7, No. 3). After the workshop, much more became known about the deep diving foraging behavior of these animals because of successful field studies using acoustic data logger tags (Johnson *et al.*, 2004, Madsen *et al.*, 2005). In addition AEP measurements have been made on one stranded juvenile beaked whale (Cook *et al.*, 2006)—a very small amount of data, but better than nothing at all.

At the 2004 Workshop, participants discussed several potential mechanisms for the stranding behavior and subsequent deaths of beaked whales. The consensus was that the most plausible mechanism was an acoustically induced change in their normal deep diving foraging behavior, which caused them to surface too quickly and develop significant gas bubbles that damaged multiple organs or interfered with normal physiological function, similar to a human diver getting the "bends" or decompression sickness (Jepson *et al.*, 2003). Thus workshop participants recommended that CEE's to determine beaked whale behavioral responses to mid-frequency sounds should be a top research priority (Cox *et al.*, 2006).

Subsequently an international research team was formed and plans were made for a multi-year Behavioral Response Study (BRS) of beaked and pilot whales (pilot whales were involved in the 2005 North Carolina mass stranding). Last year marked the first field season of the BRS, which took place in the Bahamas' Tongue of the Ocean and utilized the M3R passive acoustic monitoring system in place at the Navy's Atlantic Undersea Test and Evaluation Center (AUTEC) on Andros Island. During this landmark study acoustic data logger tags will be attached to whales to record their sound exposure and track their response to mid-frequency active sonar and other playback sounds. It is a huge undertaking with funding provided by CNO N45, CNO Submarine Warfare Division, ONR, the oil and gas E&P Sound and Marine Life JIP, the DoD/DOE Strategic Environmental Research and Development Program (SERDP), and NOAA Fisheries Office of Science and Technology. The results of this study will be forthcoming over the next few years and hopefully will help solve the mystery of how these animals react to mid-frequency sonar.

The second research priority recommended by the 2004 Workshop participants was for studies of the anatomy, physiology and pathology of beaked whales. Another fundamental aspect of the interaction of beaked whales with mid-frequency

Fig. 5. Field portable system developed at Space and Naval Warfare Systems Center (SSC) San Diego consisting of bioamp (in Pelican case, bottom photo, shown with system running onboard a ship), ruggedized computer with data acquisition hardware, and Evoked Response Study Tool (EVREST) software developed by J. J. Finneran for generating sound stimulus signal, recording and storing auditory evoked potentials (AEPs), and analyzing data.

sound is the potential consequences of the size of their body and anatomical features with respect to the wavelength of mid-frequency sonar transmissions. MacLeod and D'Amico (2006) compared body lengths of Cuvier's beaked whales from the mass strandings in Greece 1996 and Canaries 2002 with those of all types of Cuvier's beaked whale strandings from around the world, and found that the beaked whales which stranded coincident with sonar transmissions had body lengths less than 5.5 meters. Underwater the wavelength of sound at 3 kHz, the dominant frequency of tactical sonar transmissions, is approximately 0.5 m. Thus the characteristic dimensions of their overall size and prominent anatomical features are between about 0.1 and 10 times the wavelength of incident sound (0.05 – 5 meters). In this regime sound is partially reflected, scattered, and diffracted and these secondary waves constructively and destructively interfere with the incident sound and each other to produce regions of high and low sound intensity levels throughout the whale's body. Therefore because of their anatomy, a simple model will not accurately predict the interaction between mid-frequency sonar and Cuvier's beaked whale. To address this issue, the National Oceanographic Partnership Program funded a 3-year project last year to develop a sophisticated computational model of a "virtual beaked whale" that will accurately model this complex acoustic interaction. Results of this effort will also be forthcoming within the next 2-3 years.

Progress on recommendations for noise exposure criteria

In the absence of data, scientists and government regulators have always been precautionary in recommending noise exposure criteria for marine animals. The observations of bowhead and gray whales exposed to drilling and dredging sounds in the early 1980's indicated that a received broadband SPL of 120 dB re 1 μPa was the threshold for behavioral disturbance of baleen whales; however, strict worldwide adherence to this criterion would have effectively shut down all scientific research in the ocean—even the research needed to learn more about the effects of sound on other marine species.

In 1995, based on observations of whales exposed to seismic air gun pulses and ATOC signals, NOAA Fisheries set a sound pressure limit of 180 dB re 1 μPa that could not be exceeded for mysticetes and sperm whales, and 190 dB re 1 μPa for most odontocetes and pinnipeds. However in the late 1990's, the 180 dB limit began to be applied to all species and all sounds (including SURTASS LFA) after an expert panel convened by the High Energy Seismic Survey (HESS) team decided that the best available data in 1997 indicated that received sound pressure levels exceeding 180 ±10 dB, averaged over the pulse duration, could potentially have adverse effects with the ±10 dB variability depending on species (HESS 1999). Given the new hearing data for dolphins and white whales since that time, the 195 dB re 1 μPa^2-s SEL level for onset of TTS has recently been applied to many odontocete species.

A panel of scientific experts that was originally convened and supported by NOAA Fisheries, has met for several years and just recently completed the most comprehensive set of recommendations for marine mammal noise exposure criteria. The results of their efforts were published in a special issue of the journal, *Aquatic Mammals* (Southall *et al.*, 2007). These recommendations, which account for different types of sounds and different effects for multiple species, are yet to be vetted in the scientific and environmental communities.

Recommendations for noise exposure criteria for fish have followed a similar path, but with more emphasis on hearing and direct injury instead of behavior. Because of the relatively small size of most fish with respect to underwater acoustic wavelengths, their whole body will oscillate back and forth when exposed to most anthropogenic sound sources, making non-auditory tissue damage more likely than in marine mammals. Because smaller fish have less inertial resistance to motion, they are more at risk. The first recommendation for a noise exposure limit for fish was made in 1990 for a U.S. Navy intermediate scale submarine test facility being built on Lake Pend Oreille in Bayview, Idaho (Hastings, 1990). Very little data were available at that time so the recommendation for "no harm" was 150 dB re 1 μPa based on earlier data showing that goldfish had TTS after being exposed to pure tones near this level for 4 hours (Popper and Clarke, 1976). After the PIDP in 2000, Caltrans actively supported an assessment of all available data to establish recommendations for noise exposure criteria applicable to pulsed sound from impact pile driving. The latest recommendations (Carlson *et al.*, 2007) for direct injury exposure criteria are an SEL ranging from 183 to 213 dB re 1 μPa^2-s, depending on mass of the fish. These end points are based on data from a blast experimental study on juvenile fish (Govoni *et al.,* 2003) and the SURTASS LFA CEE on larger fish (Popper *et al.*, 2007), respectively. In addition dual criteria consisting of a peak SPL and cumulative SEL were recommended for TTS based on the results of the riverine air gun study by Popper *et al.* (2005). These data indicate that salmonids will experience a TTS of 20-25 dB after a cumulative SEL of only 185 dB re 1 μPa^2-s.

As reported in the January issue of *Acoustics Today*, in October 2007 the Accredited Standards Committee S3, Bioacoustics, approved the formation of a new subcommittee, S3/SC 1 Animal Bioacoustics (Delaney and Blaeser, 2008). Three previously existing working groups (WG) were moved into this Subcommittee, including S3/SC 1/WG 2 Effects of Sound on Fish and Turtles. This WG has been meeting since September 2004 to formulate standards for noise exposure criteria for fish and turtles. A similar working group for marine mammals would greatly facilitate establishment of standards for noise exposure criteria for these animals.

Where do we go from here?

Because beaked whales are the only group of marine mammals known to have died from exposure to anthropogenic sound, determining the causal mechanisms of those stranding events remains a top research priority in the near future. But another very critical issue is the lack of hearing data for mysticetes. There are no behavioral or electrophysiological hearing data for any species of these large baleen whales. Effects of sound on their hearing and subsequent behavior are estimated from numerical models of their middle and inner ears (Ketten, 1997 and 2000). There are no captive mysticetes, but at least one attempt has been made to measure AEP signals in the wild on a minke whale, the smallest species of this group. Other mysticete species may be too large to obtain a reliable AEP signal with commercially available electrodes. Efforts in this area need the same level of attention and planning as the BRS on beaked and pilot whales.

Finally, in order to begin to understand "biologically significant" effects on behavior as defined within the framework outlined in the latest NRC report (NRC, 2005), multi-disciplinary basic research is needed to understand the primary and synergistic effects of sound on marine ecosystems, including crustaceans, corals, sponges, sea grasses, and all other living things in the sea. Designing experiments to learn about potential changes in the marine ecosystem, including animal habitats, over long periods of time is a very difficult task. But changes in the behavior and habitats of marine animals over the long term could significantly affect their populations as well as the overall health and stability of the marine environment.**AT**

Looking towards the future

Many scientists and others concerned about global warming were deeply troubled when the HITF and ATOC projects came under such heavy fire by a number of environmental groups in the early 1990's. Here was a solution for one environmental problem—long term monitoring of global climate change—that created another very polarized environmental concern because there were little data available to address it. This dilemma is surfacing again with the development of offshore wind farms in many parts of the world in efforts to meet requirements of the Kyoto agreement to significantly reduce CO_2 emissions by 2030. Wind farms really do produce an underwater hum, albeit at a much lower level than the ATOC source, but it can be detected by many fish and marine mammals and potentially mask interspecies communications necessary for reproduction as well as other sounds important to their well being (Wahlberg and Westerberg, 2005, Henriksen *et al.*, 2007). This time though the world is very much aware of the potentially harmful effects of anthropogenic noise in the ocean and many marine scientists are already on top of the problem.

Endnotes

1 The primary environmental laws are the Marine Mammal Protection Act (MMPA) and Endangered Species Act (ESA). In addition the National Environmental Policy Act (NEPA) requires that federal actions affecting the environment be assessed to inform regulators and other decision-makers about potential consequences and alternatives to minimize impacts.

2 Most military sonar use is passive as vessels prefer to remain silent and undetected. When sonar is active, it transmits a sound pulse or "ping" that travels through the water and reflects off objects in its path. The reflected sounds, or echoes, return to a passive receiver and are electronically transformed into images on a display screen, very similar to use of medical ultrasound to form images of internal organs and monitor fetal development. Passive sonar uses only the receivers to "listen" to sounds emitted by vessels or other objects and marine mammals.

3 'Ceteceans' include whales, dolphins and porpoises, while 'pinnipeds' include seals, sea lions, and walrus. Under the Order Cetecea, there are two suborders: (1) odontocetes or toothed whales that include dolphins, porpoises, white whales, killer whales, pilot whales, beaked whales, bottlenose whales, melon-headed whales and sperm whales; and (2) mysticetes or baleen whales that include bowhead whales, right whales, gray whales, minke whales, sei whales, Bryde's whale, blue whales, fin whales and humpbacks.

4 NOAA National Marine Fisheries Service (NOAA Fisheries) is the responsible regulatory agency for issues concerning marine animals. If justified and properly documented, NOAA Fisheries Office of Protected Resources issues permits authorizing incidental takes of marine mammals for sound-producing activities in the ocean.

5 Strandings of marine mammals are normal events that occur all the time around the world. Mass strandings involve more than two animals stranding in the same place and time.

6 At this time the UK and Norway were preparing to deploy low frequency active sonar, but with a frequency bandwidth that extended into the low kHz range.

7 Many people have experienced TTS after attending a loud music concert. Currently TTS/PTS is a major concern for soldiers and marines firing high-power weapons in Iraq and Afghanistan as well as for children and teen-agers at home using ear buds to listen to music on personal music players and movies on DVD players.

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Mardi Hastings received B.S. and M.S. degrees in mechanical engineering in 1976 and 1978 from Ohio State University. She worked over five years in industry before enrolling in the doctoral program at Georgia Tech, where she studied acoustics and received a Ph.D. in mechanical engineering in 1987. She was a faculty member of mechanical and biomedical engineering at Ohio State from 1990 to 2003, and a Program Manager for Marine Mammal Science and Bioeffects of Non-lethal Weapons at the Office of Naval Research 2003-2006, prior to joining the Applied Research Lab at Penn State University as a Senior Scientist in Environmental Acoustics. Dr. Hastings has studied auditory mechanics in fish and effects of sound on marine animals for 25 years. She is the author of over 50 journal articles, and more than 100 conference papers, seminars, and workshops. She served on the National Academy of Sciences Study Committee on Potential Impacts of Ambient Noise on Marine Mammals, 2001–2002, and received a 2005 Environmental Excellence award from the U.S. Department of Transportation for her work with the California Department of Transportation on the effects of impact pile driving in San Francisco Bay. Mardi is on the Board of Directors of the Institute of Noise Control Engineering, a Fellow of the Acoustical Society of America (ASA), and a past chair of the ASA Animal Bioacoustics Technical Committee. She enjoys scuba diving, snorkeling, sailing, piano and gardening.

NOISE AS AN INDICATOR OF QUALITY OF LIFE: ADVANCES IN MEASUREMENT OF NOISE AND NOISE EFFECTS ON HUMANS AND ANIMALS IN THE ENVIRONMENT

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"Results of a special session on recent advances in the study of noise and noise effects on humans and animals to foster the dialog about methodologies and theoretical principles common to both."

A jointly-sponsored session on "Advances in Measurement of Noise and Noise Effects on Humans and Animals in the Environment" took place for the first time at the meeting of the Acoustical Society of America in New Orleans (November 2007). It was organized by Ann Bowles representing Animal Bioacoustics and Brigitte Schulte-Fortkamp representing Noise. Recent studies on both humans and animals were presented in two half-day sessions, followed by panel discussions on selecting efficient metrics with which to discuss notions of soundscape versus acoustic topology versus acoustic environment, and "meta-acoustic" influences on response to noise. The outcome of the session is summarized in this article in "snap-shot" form, with a short overview of the papers presented, proposed concepts, and main topics discussed during the panels. The corresponding abstracts can be found in the *Journal of the Acoustical Society of America*, Volume 122, Number 5, Part 2, November 2007, 154th Meeting: Acoustical Society of America, p. 9-11 and 33-35.

The purpose of the session was to bring together work from the Noise and Animal Bioacoustics Technical Committees reflecting the development of methodologies as well as new research in both fields. The organizers were most interested in highlighting commonalities between human and non-human animal studies (common problems, theories, and solutions). The invited and contributed presentations focused on models, prediction, and measurements taken from both field and laboratory studies.

Brigitte Schulte-Fortkamp presented an overview paper on evaluation of effects of environmental noise on humans. She introduced a different approach for making measurements in defined environments, pointing out the need for qualitative approaches that are appropriate to explain human reactions to noise brought about by factors other than physical acoustic characteristics. This approach is central to soundscape research.[1,2]

Danielle Dubois discussed how semantics may help understanding of both animal behavior and human cognition. She showed that contemporary cognitive models of information processing that purport to be universal cannot account for the ways that "ordinary" humans perceive and react to environmental noise in the complex "real" world. In everyday life, humans process multimodal incoming stimulations in a holistic manner. For example, humans reconceive noise as meaningful events, relating soundscape to human

Fig. 1. Soundwalk.

Fig. 2. Ranking, writing comments, and psychoacoustic evaluation.

Fig. 3. Measuring people's minds; talking to the new experts.

activities over areas and in time. Sounds are processed differently by people in diverse cultures and different meanings and evaluations can be given to the "same" acoustical event depending on living situations.

The question whether there is any significant influence on animals through environmental noise was brought up with respect to psychoacoustic measurements by Klaus Genuit and Andre Fiebig. In contrast to Schulte-Fortkamp and Dubois, who prioritized the meaning of noise, they highlighted relevance, determination, and interpretation of psychoacoustics and other hearing related parameters "in the context of environmental noise, with respect to hearing sensation of humans." The question of whether animals undergo similar psychoacoustic processes was debated at the end of their talk. Finding techniques to make these measurements represents an important challenge of animal research.

David C. Waddington and his coworkers described a practical application of these ideas, describing the assessment of residential low frequency noise complaints. They collected field measurements of both noise and citizen complaints and described results that included a considerable "top down" influence of subject attitudes on generation of noise complaints, uncorrelated with the acoustic characteristics of the noise.

Overview papers on animals showed the importance of improving technological as well as theoretical approaches to studying the effects of noise on wildlife. Due to differences in the psychoacoustic capabilities and ecology of the many species of concern, a wide range of approaches and metrics have been applied over the past twenty years to determine effects on animals, making studies somewhat difficult to compare and progress slow (Robert Kull). Issues and outcomes of experimental studies of noise impact on wildlife suggested that much of this research has been overly focused on short-term, high-amplitude exposures. More sophisticated models of effect need to be developed, with emphasis on mechanisms of injury, which are rarely documented in animals, and long-term, cumulative impact of exposure to multiple sources (A. Bowles and coworkers).

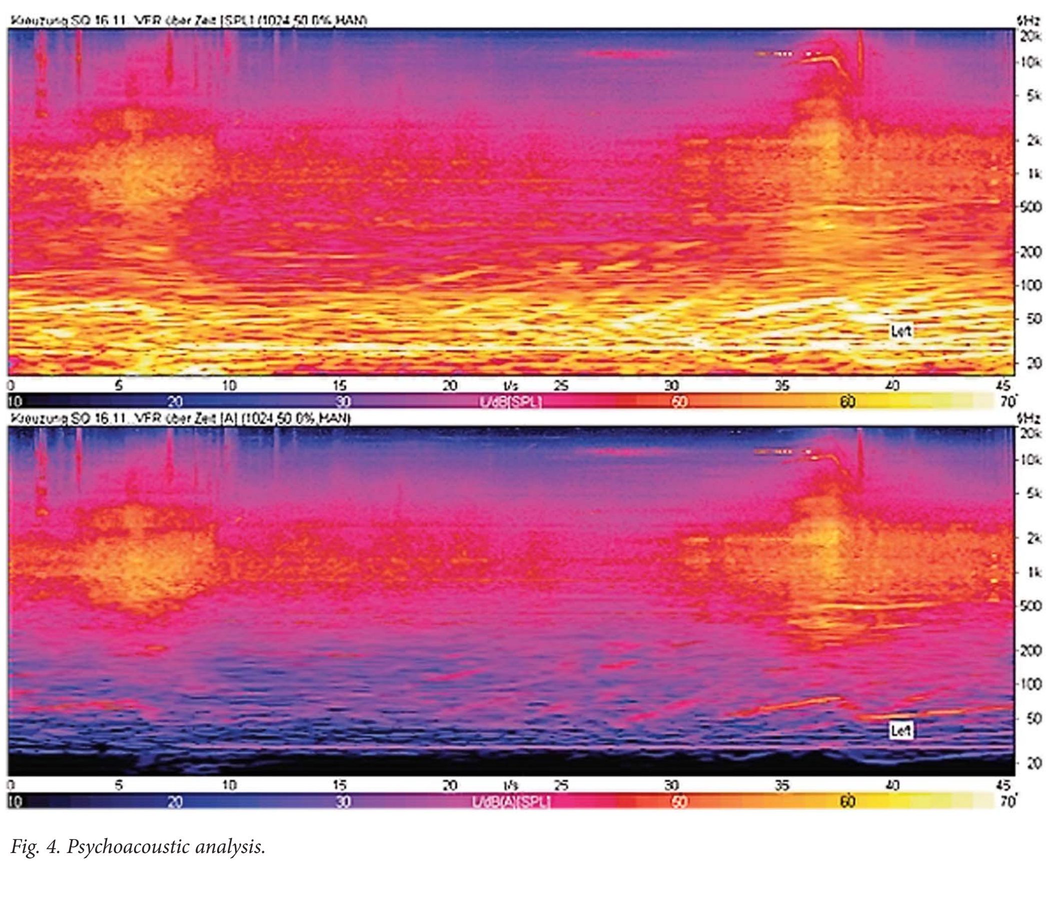

Fig. 4. Psychoacoustic analysis.

Delaney and his coworkers gave an example of an approach that may make such research possible. They reported on a study collecting continuous measurements of noise exposure to gopher tortoises using "on-board" monitoring devices. The goal of this study was to benefit the recovery and management of the gopher tortoise population under varying conditions, including exposure to military training operations.

Don Hunsaker and his coworkers reported on the effects of helicopter noise on the reproductive success of the coastal California gnatcatcher based on a 5-year field study of noise exposure with relation to reproductive success. Because the study was one of the first to collect an adequate sample of breeding attempts based on *a priori* analysis, it was possible to show that the "factors best predicting reproductive success were measures of suitable nesting habitat, not noise levels." A. Bowles reported that preliminary analysis was showing a similar outcome from a 6-year study of breeding Mexican spotted owls exposed to low-flying military jet overflights. In that case, changes in flight routes by German Air Force cooperators made it possible to demonstrate experimentally that habitat was a more parsimonious explanation for patterns of breeding success than exposure to aircraft.

In a study more comparable to research done on human speech interference, Susanna Blackwell and her coworkers examined the effects of sounds from an artificial oil production island on bowhead whale calling behavior over a three year period. Their analysis showed that an increase in transient sounds from noise, for example, boats, resulted in significantly shorter calls. They also showed that that call detection rates were dependent on the direction that the whales swam, suggesting that other perceptual features might be important, just as Schulte-Fortkamp and Dubois had described for humans.

Kathleen J. Vigness Raposa's group described an effort to model the acoustic characteristics of exposures and marine wildlife responses using a system called the Marine Wildlife Behavior Database (MWBD). Their system is designed to assist environmental planners in estimating impacts of proposed new projects. The MWBD includes specific standards for measuring and characterizing behavior in a manner that allows movements or other behaviors to be integrated into models of noise propagation.

Metrics to characterize human responses to noise are still a subject of active investigation, even after over 40 years of research. Ambivalence about noise and noise effects in human soundscapes forces us to think about whether noise has only negative implications, such as annoyance, or whether features such as sound quality and previous experience are important. Assessments that include multiple noise sources and sensory qualities will be needed for effective and efficient evaluation.[3] Richard Horonjeff introduced a hierarchical method for single-observer, continuous sound source logging that has been applied in a number of national parks over the last 15 years. His method allows the relative importance of exposures to human observers to be evaluated, something that is still a challenge in studies of animals whose behaviors are more difficult to translate into a perceptual continuum such as annoyance.

Table 1. Noise disturbances affecting the percentage of the population in Germany, according to the source and level of noise.

Level and Source	Extreme, high	Extreme, high, medium	Extreme, high, medium, low
Road	10	30	60
Neigborhood	6	17	43
Air traffic	4	12	32
Trade, Industry	2	7	19
Rail	3	8	20

Source: Federal Environment Agency, Germany 2004

From a comparative point of view, it is important to realize that nearly all of the effort to develop efficient metrics has concentrated on only one of about 58,000 vertebrate species, all of which are thought to be capable of hearing (over 5,400 mammal, 10,000 bird, 8,200 reptile, 6,200 amphibian, and 28,000 fish species [Integrated Taxonomic Information System, http://www.itis.gov/]). Lacking species-targeted alternatives, much of the work on animals has been conducted using metrics designed for humans, but a number of session authors emphasized the risks of this approach. Mardi Hastings and her coworkers gave an excellent example by reviewing exposure metrics for evaluation of effects of sound on fish hearing. They described several studies indicating that the equal energy hypothesis does not apply when evaluating auditory effects of noise on fish.

West and his coworkers described the other side of the problem, the identification of outcome measures for animals. They reviewed the literature on potential noise impact on birds. They described that 'takes' (significant effects on individuals) "can be physiological, behavioral, or ecological, but must be verifiably correlated with significant changes in species viability." This aspect of the National Environmental Policy Act law underscores the greatest differences in studies of humans and animals—while mechanisms of injury to animals may eventually prove to be similar to those identified in humans, the measurement of outcomes is different because impact on humans is assessed based on individual effects, while it is based on population-level effects in wildlife, such as effects on reproductive success.

Sheyna Wisdom referred to the role of science in assessing noise impacts on wildlife under the National Environmental Policy Act. Principles of adaptive management (management that changes with new information on impacts or population trends) are used by wildlife managers to implement policies. However, development of management methods is extremely challenging in the face of large data gaps. Managers must both protect wildlife and yet enable humans to function without unnecessary constraint.

Commonalities in impact research on humans and wildlife were clearer when research was conducted in areas where both humans and animals were impacted by noise. Kurt Fristrup gave examples of applying noise metrics in park lands managed by the U.S. National Park Service which is responsible for the experience of both humans and wildlife.

He pointed out that, while hearing is a ubiquitous sense among vertebrates, there is a great need for models of effect that capture the idiosyncrasies of species auditory capabilities, a range of possible mechanisms of injury, and variable real-world noise environments.

Plotkin and his coworkers described key components of an adaptive management system for exposure to sonic booms that has been designed to ensure preservation of a highly valued ecosystem in Labrador, Canada. They described efforts to monitor, predict and manage military aircraft training activities at Goose Bay, a sensitive ecosystem under airspace that has been host to military flying operations since World War II. Since 1995, a local organization funded by a consortium of stakeholders, the Institute for Environmental Monitoring and Research, has conducted effects research and negotiated mitigation of the effects of low altitude flight operations, serving to protect the welfare of aboriginal people as well as the survival of wildlife species.

David Dall'Osto and Peter H. Dahl presented a pilot study to characterize environmental noise underwater in Puget Sound by describing different components of the noise budget, including injection of noise from airplane flyovers, and correlation between pressures above and below water. Their work emphasized that noise in real-world environments comes from many different sources, sometimes including the target species themselves, and may involve characterization of transmission through a variety of media.

Panel discussions focused on commonalities between studies of noise effects on humans and animals. The search for metrics relating acoustic environment to outcome measures was certainly a common concern. Commonalities were also easily understood in hearing loss. However, some panelists and authors saw a gap concerning cognitive, behavioral or social responses to noise.

Human actions are rarely interpreted as adaptive, nor are animal responses posited to be intelligent and flexible. However, the panelists considered that both perspectives are likely to be important in developing general models of effect. Recent reviews of the disturbance literature for animals have begun to characterize animal responses to disturbance as strategies, behaviors that are chosen based on context that minimize risk and cost and maximize benefits.[4] Even though effects on humans and animals are assessed very differently from a legal point of view, there was a consensus that noise could be conceptualized as an environmental challenge to be met with adaptive responses in both cases. In humans, adaptive responses are constrained by economic or social needs, whereas animals are driven to maximize survival and reproduction. However, whether human or animal, non-auditory impact is mediated by processes in the brain—perception, evaluation of risk, and response. A small first order list of predictors was agreed on during the panel discussion:

1. Acoustic features such as signal to noise ratio and absolute level, particularly those that differ greatly from background or expected noise;
2. Control and predictability;
3. Association with perceived threat (e.g., predatory or social challenge);
4. Interference with function, such as sleep interference, masking of biologically-significant signals like speech, or competition for attention

During the discussion, there was agreement that effects on attention were particularly under-appreciated. In this view, attention should be modeled as a limiting resource that can be used up by noise. In the case of wild animals, it may distract attention from important activities such as vigilance against predators or socializing. In the case of humans, it may interfere with activities that require attention, such as learning.

The concept of "soundscapes" as differentiated from physical acoustic characteristics of the environment, variously called the acoustic environment or acoustic topology, came up repeatedly during the discussion. In the sense that the term soundscape describes sounds that vary predictably over an area, the two did not seem to differ greatly. However, soundscape was also linked to human conceptual and emotional perceptions of their acoustic environment. There was an extensive discussion about the value of treating acoustic measurements of the environment as objective, given that the best information available now suggests that mental processes of both humans and animals are closely tied to effect. However, there did seem to be value in recognizing that the human-based concept of soundscape can be examined by conversing with humans, whereas animal perceptions must always be measured by indirect experimentation.

Based on this discussion, panelists noted that there was a continuum of noise exposure from completely natural to highly urban environments. They noted an urgent need to develop quantitative measures at both individual and aggregate levels in both humans and animals.

At the 156th Meeting of the Acoustical Society of America in Miami

Fig. 5. Alerting response of Mexican spotted owl chick to disturbance. Responses of owls were documented during low-altitude training overflights by Tornado aircraft flown by the German Air Force in the Gila National Forest, New Mexico (photo by A. Bowles).

Fig. 6. In experimental trials, even domestic poultry evaluate disturbances cognitively before selecting a response. In this photograph, naïve turkey poults move to a location where they can see a low flying military jet and monitor its movements (photo by A. Bowles).

(Nov-ember 2008), the search for models common to humans and non-human animals will continue in the Workshop: *Advances in measurement and noise and noise effects on humans and non-human animals in the environment*, to be organized by Brigitte Schulte-Fortkamp and Ann Bowles.

Acknowledgements

We would like to thank all presenters in the session and of course the audience contributing to the important and exciting discussion on recent and further collaboration on noise metrics, measurements on humans and animals.AT

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Photo courtesy of Sea World San Diego.

Brigitte Schulte-Fortkamp is a Professor at the Technical University Berlin, Germany. For over 20 years her research activities have been concerned with assessing transportation noise related to annoyance and quality of life from an interdisciplinary point of view. She is particularly interested in evaluation of soundscapes by means of psychoacoustics, acoustic ecology and person-environment-fit approaches. Her research concentrates not only on the impact of noise on sensitive groups such as noise sensitivity in people, but also with comfort related issues concerning defined acoustical environments. She is a fellow of the Acoustical Society of America, JASA Associate Editor for Noise, and Chair of the Technical Committee on Noise.

Ann E. Bowles is a Senior Research Scientist at the Hubbs-SeaWorld Research Institute (HSWRI). She specializes in Animal Bioacoustics, particularly the study of animal communication and effects of human-made noise. Under contract to agencies such as CalTrans, U.S. Air Force, U.S. Army, NASA, U.S. Fish and Wildlife Service, U.S. Forest Service, and National Marine Fisheries Service, as well as private organizations, she has spent 29 years studying the effects of noise and disturbance on a wide range of taxa. Her work has emphasized a general understanding of behavioral and physiological effects of noise on animals, with the ultimate goal of developing predictive models of effect. Dr. Bowles worked to bring ASA's Animal Bioacoustics Technical Committee to full committee status (1990-1996) and is now a fellow of the Society and participant in the ASA Committee on Standards. She was a panelist for the NOAA Ocean Acoustics Program, which has developed the first set of science-based recommendations of noise exposure standards for marine mammals.

HOW TO ASSESS HEARING PROTECTION EFFECTIVENESS: WHAT IS NEW IN ANSI/ASA S12.68

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"Hearing protection is essential to protect our ears from the insidious effects of noise."

In July 2007, the Acoustical Society of America published ANSI/ASA S12.68 American National Standard Methods of Estimating Effective A-Weighted Sound Pressure Levels When Hearing Protectors are Worn.[1] The standard is an advance relative to the Noise Reduction Rating (NRR) as currently mandated by the U.S. Environmental Protection Agency and it is also an advance relative to the standards that have been developed by the International Organization for Standardization (ISO). Since the promulgation of the EPA's hearing protection labeling rule in 1978, the Noise Reduction Rating has been criticized as overestimating the performance that users achieve in the workplace.[2] The NRR attenuation data are measured with subjects who have had the hearing protection fitted solely by the experimenter. ANSI/ASA S12.68 standard utilizes attenuation data that are derived from subjects who have either minimal experience with hearing protection and protector testing or with subjects who have been trained by the experimenter. Let us examine the novel techniques contained within the ANSI/ASA S12.68 standard.

First, the standard provides three methods of estimating the performance of a protector based upon the attenuation measurements for that device. The first method is a two-number Noise Reduction Statistic for A-weighting (NRS_A) which informs the user about the lower and upper range of performance that can be expected from the hearing protector. To utilize the NRS_A, the user need only measure the A-weighted noise exposure and then subtract the rating to estimate the exposure. Use of the lower number provides a conservative estimate of the exposure that most users will not exceed when wearing the device. Use of the higher number can provide an estimate of whether the protector may give one too much protection and potentially lead to impaired communication in a noisy environment. The range between the two ratings provides a more subtle indication about the use of the product. If the upper and lower numbers are relatively close together, this gives an indication that the protector was consistently fit across the test panel and that variation in performance across different noise spectra is small. Research studies have shown that varied performance across users was the single most important factor in how much attenuation one received while wearing the protector (in addition to whether it is worn whenever you enter the noisy environment).

To use the first method, the noise exposure can be measured using a sound level meter set for the A-weighting scale. Suppose that the exposure was measured to be 97 dBA, and the hearing protector represented in Fig. 1 is to be worn. The NRS_A then estimates that the exposure when wearing this protector will be between 78 and 70 dBA. The industrial hygienist or hearing conservation professional can have some level of confidence that worker exposures are below 85 dBA when the protector is worn properly.

The second method in the S12.68 standard provides a graphical approach (NRS_G) that accounts for the variability of the spectral noise environment. If a person works in an environment that has predominantly low-frequency noise, then this should be considered in estimating hearing protector performance, since attenuation is typically worse at lower frequencies. A simple approach to characterizing the proportion of noise at low frequencies is to measure both the A-weighted and C-weighted levels. The difference between the two measurements yields a C-A metric—more positive C-A values tend to indicate more low frequency exposure. The NRS_G graphical method provides two curves indicating attenuation as a function of C-A. For example, if

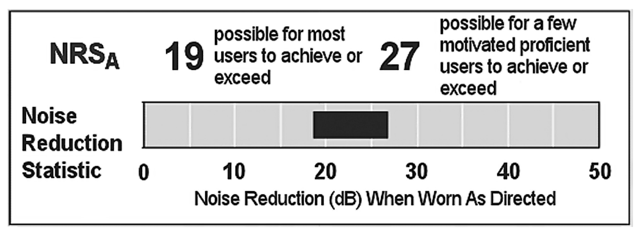

Fig. 1. Noise Reduction Statistic for A-weighting (NRS_A). The lower value represents the attenuation which is possible for most users to achieve or exceed. The upper value is what is possible for a few motivated proficient users to achieve or exceed.

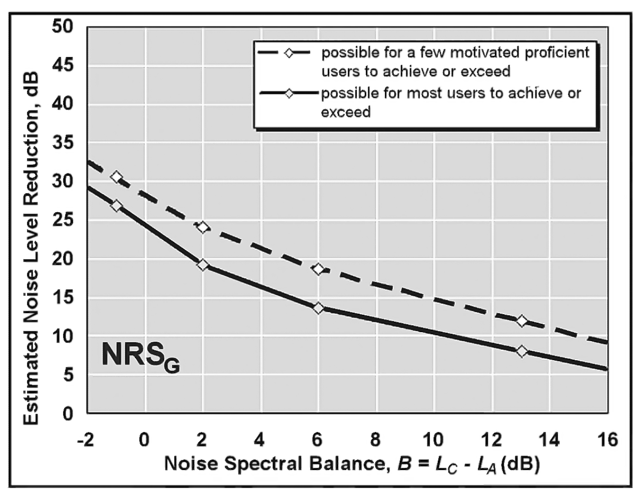

Fig. 2. Noise Reduction Statistic for A-weighting graphical method (NRS_G). The curves illustrate the effective hearing protection as a function of varying the spectral balance (L_C-L_A). The lower curve represents the attenuation which is possible for most users to achieve or exceed. The upper curve is what is possible for a few motivated proficient users to achieve or exceed.

Table 1. Noise Reduction Statistic for A-weighting sample octave band calculation.

Octave-band center frequency, *f*, Hz	125	250	500	1000	2000	4000	8000
Measured octave-band sound pressure level of the noise, L_f (NIOSH noise 43 from Annex A)	98	93	89	92	88	83	75
Frequency weighting A (from ANSI S1.4)	-16.1	-8.6	-3.2	0.0	1.2	-1.0	-1.1
A-weighted octave-band sound pressure level of the noise, $L_f + A_f$	81.9	84.4	85.8	92.0	89.2	82.0	73.9
APV_{f80} from Table C.1	6.2	7.8	19.0	26.5	27.4	32.3	31.1
$L_f + A_f - APV_{f80}$	75.7	76.6	66.8	65.5	61.8	49.7	42.8
Note: All values in decibels.							

one measured an exposure to be 100 dBC and 92 dBA then the C-A value is 8 dB. The graph in Fig. 2 indicates an NRSG lower value of about 12 dB and an upper value of about 17 dB. Using these two protector ratings, the range of exposure while wearing the hearing protector could be between 80 and 75 dBA [92-12= 80 and 92-17 = 75 dBA]. Using the guidance of acceptable exposures, the protector would be an appropriate choice for that noise. The standard provides guidance on how to interpolate the points on the curve if a more precise estimate of exposure is needed.

The third method provided in the S12.68 standard is the octave-band method. In this case the user must know the octave or one-third octave-band levels of the noise exposure (L_f). The levels are combined with the octave-band attenuation values for the protector (A_f). An example is given in Table 1.

The last row of the table is summed logarithmically to find an estimated exposure of 79.7 dBA that rounds to 80 dB. The 80th percentile of the attenuations across subjects and noises are the assumed protection values (APV_{80}) and are calculated by the mean attenuation minus a multiple (0.8416) of the standard deviation. To estimate the performance with the better fit, the APV_{20} is the mean attenuation plus a multiple (0.8416) of the standard deviation. The higher APV_{80} translates to a lower exposure level.

In the United States, occupational noise exposures are measured using the A-weighting scale. The difference between C and A weighting introduced an unnecessary conversion factor which, if forgotten, added to the inaccuracy. According to EPA, 7 decibels must be subtracted from the rating to convert between the rating from dBC and dBA. In subsequent years, the typical industrial noise has been characterized as having a C-A difference of 5 dB and 3 dB.[3,4] In the development of the S12.68 standard, Gauger and Berger developed a unique approach of calculating the noise reduction across the range of 130 noises. The overall standard deviation used in determining the two-number rating combined the variance across subjects and the variance across noise spectra. In this manner, the spectral variation is already incorporated into the rating. Furthermore, the rating was calculated for A-weighted noise spectra eliminating any conversion factor.

Now that a new ANSI standard exists, of what use is it? Since 2003, the EPA has been working on writing a revision of the hearing protector labeling regulation (40 CFR 211 Subpart B).[2] The revised regulation will address more than just the Noise Reduction Rating. It is expected to provide regulatory guidance for devices such as active noise reduction hearing protection and devices intended for impulsive noise. EPA and NIOSH sponsored an interlaboratory test of hearing protector attenuation that compared experimenter-supervised and naïve subject fitting protocols. The results from this study were reported at the December 2006 Acoustical Society Meeting in Honolulu and were integral in the development of the new rating standard.[5] As well, the results provided greater insight into the issues of how to compare ratings when products are retested or when they are tested in a different laboratory. In the new standard, an annex on computing the uncertainty associated with the rating has been included. In contrast to what has been the norm for the ISO standards where all of the elements of the measurement process are quantified (e.g., equipment calibration, threshold variance, etc.), ANSI/ASA S12.68 has applied a computational statistical approach to the attenuations measured for the subject panel. Since the variance is largely derived from the subject's unoccluded and occluded hearing thresholds and the fit of the protector, a "bootstrap" technique that resamples the attenuations of the subjects was applied to estimate the confidence interval for the Noise Reduction Statistic. For each protector test, the uncertainty for that particular device is estimated and can be used to understand the variability of the rating. For instance, the interlaboratory study compared experimenter-supervised and naïve subject fit attenuations. The uncertainty on the NRS_A was larger for the naïve subject-fit data than it was for the experimenter fit data. Different laboratories demonstrated varying degrees of uncertainty. The effect of the experimenter involvement was seen in reduced uncertainty when the subjects were required to precisely fit the product. This application of computational statistics to uncertainty can be translated to other acoustical standards as well. Sound power, occupational exposure, measurement of a person's hearing threshold all can benefit from the approach that has been pioneered in the hearing protector rating standard.

What is the bottom line? The use of the ANSI/ASA S12.68 method provides more relevant and useful numbers that describe what a person might expect when using hearing protection. However, unless one wears the protection when exposed to hazardous levels of noise, the numbers will be meaningless. Noise-induced hearing loss is entirely preventable. Just as Norm Abrams of the New Yankee

Workshop™ reminds viewers on a weekly basis to read the equipment manuals and always wear your safety glasses, we should remember that hearing protection is essential to protect our ears from the insidious effects of noise.AT

Disclaimer: "The findings and conclusions in this report are those of the author and do not necessarily represent the views of the National Institute for Occupational Safety and Health (NIOSH)."

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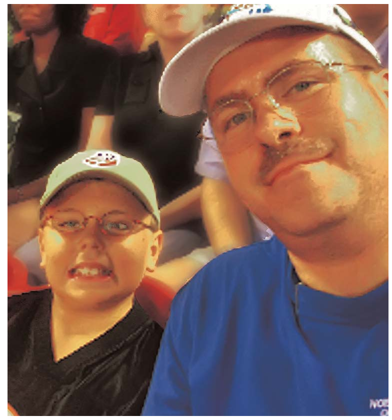
3 T. Miller, "An analysis of octave band sound pressure level databases and various metrics based on the databases studied," Master's thesis, North Carolina State University, Rayleigh, NC, 1995.

4 D. Gauger and E. H. Berger, "A New Hearing Protector Rating: The Noise Reduction Statistic for Use with A Weighting (NRSA)," a report prepared at the request of the U. S. Environmental Protection Agency, reviewed and approved by ANSI S12/WG11, E•A•R 04-01/HP, Indianapolis, IN (2004).

5 W. J. Murphy, E. H. Berger, D. Gauger, B. Witt, R. McKinley, S. Gerges, and W. Ahroon, "Results from the National Institute for Occupational Safety and Health/Environmental Protection Agency NIOSH/EPA Interlaboratory Comparison of American National Standards Institute ANSI S12.6-1997 Methods A and B," J. Acoust. Soc. Am. **120**(5, Pt. 2), 3160 (2006).



Bill regularly takes his son Aaron out to the ballgame. Aaron roots for the Reds, Bill for the Cubs.

William J. Murphy is co-leader for the Hearing Loss Prevention Team in the Division of Applied Research and Technology, National Institute for Occupational Safety and Health (NIOSH) in Cincinnati. A graduate of Iowa State University (B.S. and M.S.), he completed a Ph.D. in physics at Purdue University and joined NIOSH in 1992. He was commissioned as a scientist officer in 1993 and holds the rank of Captain in the U.S. Public Health Service. Currently he is developing ratings for the performance of passive and active hearing protection devices. He is an active member of the Acoustical Society of America, is a member of the Technical Committee on Noise, and serves as the Vice Chair of ANSI Standards Committee S12 to develop national and international acoustic standards on noise. Outside of work, Bill arranges music, plays trombone, guitar and piano, leads worship at church, and teaches high-school physics to home-schooled students. Bill and his wife Deb school their three children at home.

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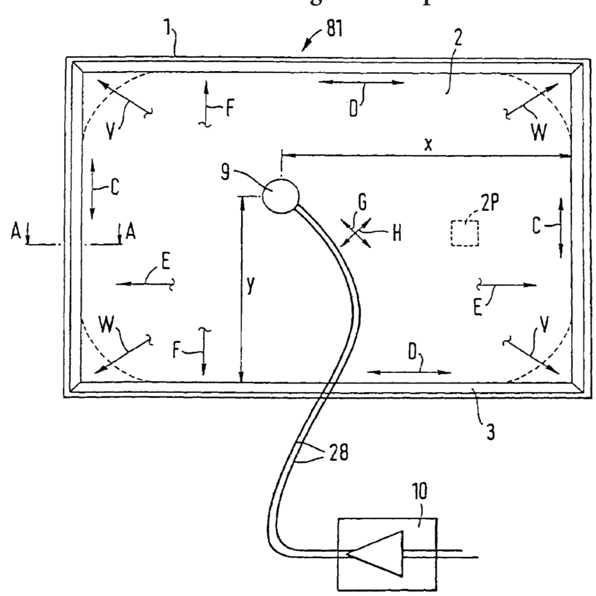
43.38.Ja ACOUSTIC DEVICE

Henry Azima et al., assignors to New Transducers Limited 2 January 2007 (Class 381Õ152); filed in United Kingdom 2 September 1995



This is a long and unusual patent. It contains more than 70 illustrations and a ten-page summary of planar loudspeaker design, including the extensive prior work patented by New Transducers Limited. In effect, the patent can serve as a handbook of the state of the art in this field. Anyone interested in planar loudspeakers is advised to order a copy.—GLA

STUDENT COUNCIL: AN OVERVIEW

Michael S. Canney
Applied Physics Laboratory, University of Washington
Seattle, Washington 98105

The Student Council (SC) of the Acoustical Society of America (ASA), formed in 1999, is charged with promoting the interests of the 1100 student members of the Society. Even though the ASA is already very student-friendly—offering free conference registration, travel subsidies, and student paper awards—there is still an interest in the ASA to do more for students, since they are an important part of the Society and are the next generation of acousticians. The primary activities of the Student Council are focused on organizing student events at meetings and disseminating student-related information. This article will provide a short overview of the organization of the Council as well as describe its various initiatives.

Organization and responsibilities

The Council consists of 14 representatives—one student from each of the 13 Technical Committees in the Society and an elected Chair. To become a Council representative, students are selected by each of the Technical Committees (TC). Once on the Council, student members typically serve a 2-year term, and are expected to attend each ASA meeting during their tenure. Most duties of the Council members take place at the meetings, and include attending the Student Council meeting as well as helping to organize student activities. Serving as a Student Council member is a great way to become more involved in the ASA. Since positions are open on each TC approximately every 2 years, we encourage anyone interested to email a member of the Council for more information about either the duties of being a member or for more information about applying for an open position on the Council.

Social functions and other events at meetings

The primary events organized by the Student Council at the biannual ASA meetings consist of both formal and informal social events, as well as educational workshops. The primary social events are the Student Icebreaker and the Student Reception. The Icebreaker, a student-only event held on the first night of the meeting, is a chance for students to meet other students at the beginning of the week thereby increasing the likelihood of student interaction throughout the meeting. The Student Reception is typically held on the third night of the meeting and is more formal than the Icebreaker. This event is open to anyone within the ASA who would like to attend, and is a great networking opportunity for students to meet ASA members from both academia and industry. In addition to these "formal" student social events, the SC also organizes "informal" student social events to enjoy the nightlife in the city hosting the meeting. Past outing events have included trips to piano bars, salsa clubs, jazz clubs, and pool halls. All of the social events are fun for the students and often lasting relationships between students are made that extend to future meetings.

In addition to social functions, the Council organizes several other events at the meetings. One event that has become very popular at meetings is the Fellowship Workshop that is presented at every third meeting. At this workshop, potential new investigators can meet with representatives from various funding agencies and inquire about the process of submitting applications that are successful in obtaining awards. The last funding workshop was held at the New Orleans meeting in the fall of 2007. At this workshop, representatives from the National Institutes of Health (NIH), the Office of Naval Research (ONR), and the National Science Foundation (NSF) discussed various funding opportunities through their organizations and gave input and advice for both graduate and post-graduate funding as well as funding for new researchers. Representatives from the ASA also discussed opportunities for awards from the Society. Each representative spent 10-15 minutes discussing their funding initiatives, after which small groups were formed where students and post-docs could ask specific questions of the representative most familiar with their research area. Overall, the event was a great success. We look forward to seeing everyone at the next Fellowship Workshop at the Portland meeting in the spring of 2009.

Other initiatives

The mentoring award is another initiative that was started in previous years by the Council. The mentoring award is designed to recognize senior members of the ASA who have had a significant impact on both their students and co-workers. The award is chosen after careful reading and deliberation of each candidate's resume, as well as personal reference letters—all of which are an incredible tribute to the many amazing mentors that exist in the ASA. The last mentoring award was presented to Dr. David Dowling from the University of Michigan at the New Orleans meeting. The next mentoring award will be presented in Portland and applications will be requested soon via an email announcement. Please take the opportunity to nominate someone who has made a significant impact on your life and research.

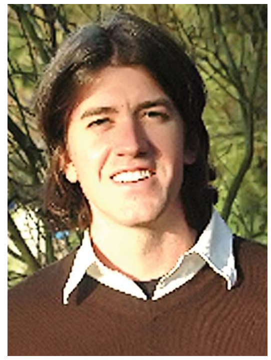
The next mentoring award will be presented in the Spring of 2009 at the Portland meeting. The deadline for submission of application materials is September 29, 2008. For further information see http://www.acosoc.org/student/mentor/mentor.html. Please take this opportunity to nominate someone who has made a significant impact on your life and research.

The Student Council is also helping to start new initiatives in the ASA. At the upcoming meeting in Miami (Fall 2008) there may be a joint acoustics demo-session with the Committee on Education in Acoustics. We look forward to this and other possible opportunities to expand the reach of the Student Council and to further our objectives of helping students play a greater role in the Society.

Paying it forward

The success of the ASA Student Council has also recently sparked interest in another council in the European Acoustics Association (EAA). The ASA Student Council looks forward to working with the EAA students to establish their student council at the Paris meeting this summer, as well as in organizing student events for the upcoming joint meeting, Acoustics'08 Paris.

The Student Council welcomes communication from anyone in the Society who has additional ideas for student initiatives. Information about the Council and all of the activities described above can be found on our webpage (www.asastudentzone.org). Contact information for current Council members in each technical committee can also be found on the webpage. Students should also check their email for our Student E-zine, which provides information on student activities prior to each meeting. AT



Michael S. Canney is a doctoral student in the Department of Bioengineering at the University of Washington, where his research is focused on therapeutic ultrasound for noninvasive surgery. He has served on the ASA Student Council since the spring of 2005 as the representative for the Biomedical Ultrasound/Bioresponse to Vibration Technical Committee. He was elected Chair of the Student Council at the Spring 2007 Acoustical Society of America meeting in Salt Lake City.

Elaine Moran
Acoustical Society of America
Melville, New York 11747

Alice Suter

Alice Suter receives Lifetime Achievement Award from NHCA

Alice H. Suter was awarded The Lifetime Achievement Award of the National Hearing Conservation Association (NHCA) at the 33rd Annual Hearing Conservation Conference held in February 2008 in Portland, Oregon. This award, established in 1999, is intended to recognize a lifetime of extraordinary accomplishments in the hearing loss prevention profession as well as in service to NHCA.

Alice Suter received a B.A. from The American University in 1959, an M.S. from Gallaudet College in 1960 and a Ph.D. in Audiology from the University of Maryland in 1977. She began her career as a teacher of the deaf at Maryland School for the Deaf. In 1968 she joined the Veterans Administration as an Audiology trainee, and began her doctoral work at the University of Maryland. In 1973 she accepted a position as a Senior Bioacoustical Scientist with the U.S. Environmental Protection Agency's Office of Noise Abatement and Control. She had a major role in developing the first national criteria for noise-induced hearing loss and other effects of noise including the psychological, extra-auditory physiological, performance, and communication effects. In 1978, Alice transferred from the U.S. EPA to the Department of Labor where she served the Occupational Safety and Health Administration (OSHA) as a Senior Scientist. In particular, she directed the team of audiologists, occupational safety and health specialists, attorneys, and economists who developed OSHA's Occupational Noise Exposure; Hearing Conservation Amendment, 29 CFR 1910.95. In 1992 she established Alice Suter and Associates, serving as a consultant to government, industry, academia, and professional organizations.

Alice served for several years on the NHCA Executive Council, including a term as Vice President, and Program Chair for an annual conference and as the editor of Hearing Conservation News (the precursor to Spectrum), and later served for 13 years on the Spectrum editorial committee.

Alice has over 50 publications and has presented a large number of lectures. She is the author of the *Hearing Conservation Manual* published by the Council for Accreditation in Occupational Hearing Conservation.

She is a Fellow of the American Speech-Language-Hearing Association, and the Acoustical Society of America (ASA). She was awarded the Distinguished Service Citation from the ASA in 1997, the Alice Hamilton Award of The American Industrial Hygiene Association, the NHCA Outstanding Leadership and Service Award (now the Michael Beall Threadgill Award), and the NHCA Outstanding Hearing Conservationist Award.

Alice Suter served as the Editor of *ECHOES*, the ASA newsletter from 1990 to 1997. She was a Member of the ASA Executive Council (1986-89) and chair of the ASA Committee on Public Relations, 1988-94.

Ted Madison receives award from the NHCA

Ted K. Madison

Ted K. Madison was awarded the Michael Beall Threadgill Award by the National Hearing Conservation Association at the 33rd Annual Hearing Conservation Conference held in February 2008 in Portland, Oregon. The Michael Beall Threadgill Award was established in 1985 to honor those individuals who have contributed in a significant way to the growth and continuing excellence of the National Hearing Conservation Association (NHCA) by their outstanding commitment of time and effort.

Ted Madison has served the NHCA as Treasurer, President-Elect, President, Past President of NHCA and is currently the liaison to the American Speech-Language-Hearing Association. Other professional involvement includes being a member of the ANSI S-12 Working Group 11, serving on the Noise Committee of the American Industrial Hygiene Association (AIHA) and as AIHA's representative to ANSI S-3. He is a member of International Safety Equipment Association, the American Auditory Society, Acoustical Society of America and a fellow of the American Academy of Audiology.

New Fellows of the Institute of Electrical and Electronics Engineers

The following ASA members have been elected Fellows of the Institute of Electrical and Electronics Engineers.

Abeer Alwan, University of California, Los Angeles, CA, USA, for contributions to speech perception and production modeling and their applications.

Tomlinson Holman, TMH Corporation, Yucca Valley, CA, USA, for contributions to the recording of cinema sound and its realistic reproduction in both cinema and home environments.

Walter Kellermann, University Erlangen-Nuremberg, Erlangen, Germany, for contributions to adaptive filtering and multi-channel acoustic signal processing.

Pai-Chi Li, National Taiwan University, Taipei, Taiwan, for contributions to ultrasonic imaging technologies.

Jian-yu Lu, University of Toledo, Toledo, OH, USA, for contributions to medical ultrasonic imaging.

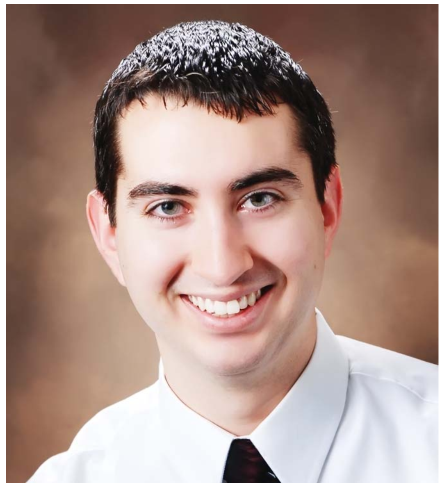
Peter Nicholas Mikhalevsky, Science Applications International, Inc., Arlington, VA, USA, for contributions to ocean acoustics and tomography.

Alex Bagnall

Cavanaugh Tocci Associates, Inc. announces new staff

Cavanaugh Tocci Associates, Inc. of Sudbury, Massachusetts has added two new consultants to their staff. Alex Bagnall and Aaron Farbo have joined the consulting staff expanding its capabilities in architectural acoustics, sound systems, and theatrical systems design.

Alex Bagnall has a Bachelor of Arts in theater from Oberlin College and a Masters of Fine Arts from Yale School of Drama. His work experience includes project manager for a Boston area design/build contractor for sound systems, lighting, and rigging; technical designer at Auerbach Pollock Friedlander, consultants in theater design



Aaron Farbo

in New York; and assistant production manager at the Kimmel Center for the Performing Arts in Philadelphia.

Aaron Farbo has a Bachelor's Degree in Mechanical Engineering with a concentration in Acoustics from University of Hartford. He is a member of ASA and has three years of acoustic consulting experience with Stewart Acoustical Consultants of Raleigh, NC. Aaron will focus on architectural acoustics for colleges, schools, worship spaces, and corporate office projects.

ASA hammers for Habitat

In November 2007, the Acoustical Society held its semi-annual meeting in downtown New Orleans, LA. In addition to bringing together over 800 scientists and engineers to exchange ideas and present research, the meeting demonstrated the Society's recognition that New Orleans is once again a place for business and tourism. The organization sought to better understand the Katrina disaster and rebuilding efforts in a technical tour hosted by the Army Corps of Engineers. But the Society wanted to do and to understand even more.

On the final day of the meeting, 35 ASA members and friends spent the day building homes with Habitat for Humanity. Habitat for Humanity is an ecumenical Christian ministry that welcomes to its work all people dedicated to the cause of eliminating poverty housing. Post-Katrina, they have created a remarkable catalyst for reconstruction for the hardest hit homes and families. The program can host up to 900 volunteers a day. Since the hurricane, over 100 homes have been completed and 147 are currently under construction. The philanthropic effort was a first for the Society and required volunteers to add an extra day to an already long week. Nevertheless, the response was overwhelming and several potential volunteers were turned away during the meeting for lack of space.

Volunteers represented virtually every technical committee and level of accomplishment of the Society; Acoustical Oceanography to Structural Acoustics: undergraduate students to Fellows. Not all volunteers were ASA veterans. As first time meeting attendee Tom LePage said, "I am new to ASA and I am delighted to discover that ASA is the kind of organization that does projects like this." Accompanying persons were there as well, working, laughing

The ASA team at the Habitat for Humanity worksite.

and even encouraging their significant others who felt more comfortable in a lab than at a construction site. (See the sidebar by Shari Berkowitz.)

Work started promptly at 8 a.m. and the group split into two teams tackling two of four houses under construction. The homes had foundations (raised almost four feet in case of future flooding), floors and the exterior shell. There was plenty of work to be done. Each house had a job leader—a young Habitat employee with carpentry/construction experience. These leaders channeled the volunteers' zeal by creating bite-sized tasks such as doorway construction, cutting holes for windows in the exterior sheathing and, to the eventual pride of a few volunteers, building wide, stable staircases in place of the existing ladders.

The progress was remarkable. In just one day (though the day represented 300 person hours), both of the homes had all of their interior framing completed. Volunteers were dirty, sore and generally exhausted by the 3:30 p.m. clean-up but, walking through the house at the end of the long day and after posing for pictures and exchanging hugs with the future homeowners, the house began a transformation from construction project to home. House number 2 was to be the home of a single mother and her seven-year old son. Walking from room to room, it was easy to imagine the little boy growing up in his new home, eating breakfast in his new kitchen and playing games in his new bedroom.

Without a doubt, the day was deemed a success by both the Society and the volunteers and the Habitat volunteer day will be a fixture at every Fall meeting. Miami, FL the site of the Fall 2009 ASA meeting, certainly has communities in need. So mark your calendars and get ready to swing a hammer or build a staircase.

Author's note: As I remember our day, I recall being surprised to see words of encouragement and blessings were scrawled all over the unfinished walls that would be concealed when the home was finished. One particularly stands out in my memory: "Find Peace Here." We, as volunteers for the day, surely did just that.

The list of volunteers and their affiliations are below. Thanks to each of you and your generous sponsors.

Brandon Tinianov

Name	Affiliation
Clemeth Abercrombie	Daly-Standlee and Associates
Dave Adams	DL Adams Associates
Heather Ames	Boston University
Ted Argo	University of Texas
Shari Berkowitz	CUNY Graduate Center
Mike Canney	University of Washington
Bill Cole	Etymonic Design Inc.
David Gagnon	University of Texas
Linda Gedemer	The Audio Group
Matt Golden	Kinetics Noise Control, Inc.
Sarah Gourlie	University of Texas
Nicolas Grimault	Université de Lyon
Pamela Harght	University of Kansas
Todd Hay	University of Texas

What I learned in New Orleans

As a doctoral student, I expect to return from the Acoustical Society meetings with my head swirling with new areas of investigation, new collegial connections and plenty to keep me thinking for the next six months. At this meeting, I got all that and more. By spending Saturday at Habitat for Humanity's Jefferson Build with 34 other ASA members, I learned many new things, some of which I will share here with you:

- How to carry 16 foot lengths of lumber: Balance them on your shoulder, and don't try to turn around, even if someone calls your name.
- How to operate a chop saw: Measure twice, cut once, wear ear protection and eye protection, take your time. Wow, that thing can cut. Hi, Kendric!
- How to practice job safety: Watch your fingers now, or look for them later. Hi, Brad!
- How to use a staple hammer to put Tyvek around a house. Like wrapping a giant present, which it kind of is.
- House building has its own jargon, such as 10" studs above a doorway being called cripples. Sawzall is a brand name, but is used interchangeably with reciprocating saw. Hey, I'm a speech language pathologist from the speech communication TC, we live for this kind of stuff.
- How to improve the sound dampening in my own home. A lunch time committee of acoustical consultants took this under consideration (hi, guys!) and the upshot is I should sell my house sooner rather than later.
- What a hurricane strap is and how to install it. In theory, anyway; in actuality, I just delivered the straps and the nails as needed. Next time I'll hammer my own.
- How to hammer framing nails (remedial class). My participation in this part of the project significantly slowed things down, so I returned to my chop saw. I loved my chop saw very much by then anyway and hated to leave it.

This only touches on the level of cooperation, camaraderie and cross-pollination that went on at the build site. Everyone really dug in and worked hard all day, and the houses were so much farther along at 3 p.m. than they were at 8 a.m., it was quite remarkable. I thank Brandon for his leadership, and I thank the ASA for the delicious lunch and the bus transportation. I thank Habitat NOLA for providing a safe, fun work environment. But most of all, I thank the other ASA members for their friendship and support in a most worthwhile effort. Who knew a speech perception type could have such a great day with a bunch of Matlab geeks, dolphin listeners and egg crate slingers? I look forward to doing it again in Miami!

Shari Berkowitz

Eric W. Healy	University of South Carolina	Eric Thorsos	University of Washington, APL
Anna Heaney	OASIS, Inc.	K. Terry Thorsos	University of Washington, APL
Kevin Heaney	OASIS, Inc.	Mark Tiede	Haskins Labs, Yale University
Don Hunsaker II	Hubbs-SeaWorld Research Inst.	Nancy Timmerman	Nancy Timmerman, PE
Tom LePage	Joyful Noise Enterprises	Brandon Tinianov	Serious Materials
Brad Libbey	US Army Night Vision	Kenric Van Wyk	Acoustics By Design
Piers Messum	University College London	Max Versace	Neurala LLC
Molly Norris	Threshold Acoustics	Douglas Wilcox	Penn State University
Steve Pettyjohn	The Acoustics & Vibration Group	Preston Wilson	University of Texas
Ken Roy	Armstrong World Industries	Mark Wochner	University of Texas

Haskins Labs appoints Ken Pugh as President and Director of Research

Joanne L. Miller, chair of the board of directors of Haskins Laboratories, announced that Kenneth R. Pugh, Ph.D., has been appointed president and director of research of Haskins Laboratories, effective immediately. Dr. Pugh becomes the sixth president and director of research since the founding of the Laboratories in 1935. Dr. Pugh succeeds Carol A. Fowler, Ph.D., who has been president and director of research at Haskins Laboratories since 1992. Dr. Pugh has been affiliated with Haskins Laboratories since 1990. He is also currently an associate professor in the department of pediatrics at the Yale University School of Medicine and the director of the Yale Reading Center. Kenneth Pugh received his undergraduate degree in psychology from the New York Institute of Technology, and his M.A. and Ph.D. in experimental psychology from The Ohio State University. He has been a visiting professor at College of the Holy Cross, University of Connecticut, and Dartmouth College. Among many other activities, he is a Corresponding Member of the Rodin Remediation Academy and a member of the Scientific Advisory Board of the International Dyslexia Association. He has published extensively in the domains of cognitive neuroscience, functional organization of the brain as it pertains to reading and language, dyslexia, and related areas. He plays a key role in several research programs supported by grants from the National Institutes of Health and other funding sources.

He will be working closely with the board of directors of Haskins Laboratories and its executive management team, which includes Philip Rubin, Ph.D., chief executive officer and vice president, Douglas Whalen, Ph.D., vice president of research, and Joseph Cardone, chief financial officer, as well as with scientists, educators and other members of the Haskins community. A major initiative will be to explore new partnerships and funding opportunities that will help the Laboratories build on its pioneering research and discoveries spanning more than seventy years and remain on the cutting edge of the science of the spoken and written word.

Haskins Laboratories was founded in 1935 by the late Dr. Caryl P. Haskins. This independent research institute has been in New Haven, Connecticut since 1970 when it formalized affiliations with Yale University and the University of Connecticut. The Laboratories' primary research focus is on the science of the spoken and written word.

University of Nebraska ASA Student Chapter hosts Royster Student Acoustics Competition

The University of Nebraska ASA Student Chapter hosted the Royster Student Acoustics Competition on Saturday, December 8, 2007, at the Peter Kiewit Institute in Omaha, Nebraska. The competition was open to a wide variety of acoustics topics related to either hearing conservation or noise control. The Roysters generously provided $5000 in scholarship funds for the competition to encourage qualified students to pursue graduate studies in these areas.

Students from the University of Nebraska, the University of Kansas, and Brigham Young University participated in the competition. The entries were evaluated by a panel of three

Students and judges at Royster Student Acoustics competition judges: Dr. Douglas Keefe of Boys Town National Research Hospital, Dr. Jeremy Baguyos of the University of Nebraska-Omaha, and Dr. Lily Wang of the University of Nebraska-Lincoln. The participants were required to submit a summary paper and detailed poster on their topic. All of the posters contained excellent technical descriptions and visually appealing graphics. The participants also gave short presentations, explaining their topics and answering questions from the judges. A group of about 15 students, professors, and researchers enjoyed the interesting and interactive presentations given by the participants.

The $5000 first prize award was split between two equally meritorious entries by David Manley and Alicia Wagner, both graduate students at the University of Nebraska. David's topic was on noise control in hospital laboratories. This project worked towards creating a more acoustically comfortable working environment for employees of hospital laboratories, as well as relieving stress and anxiety of children and patients who visit blood draw units. Alicia's project addressed the relationship between residential wall construction transmission losses and home office productivity. The purpose of the project was to identify which residential wall constructions were most effective for attenuating typical home noise distractions to improve productivity. A $300 commendation award was given to Brian Thornock, a graduate student at Brigham Young University, for his entry on how directional impulse response measurements may be used as a noise control tool.

Lauren Ronsee

Diversity in acoustics

Exposing university-level minority students and professors to acoustics is key for increasing membership diversity in the society. In an initial attempt to pursue this goal, two acoustics sessions were coordinated at the joint conference of the National Society of Black Physicists (NSBP) and the National Society of Hispanic Physicists (NSHP), which was held on February 21-24, 2008, in Washington DC.

The conference was well attended by 250 minority students and 200 professionals. About 60 exhibit booths from industry, government and professional organizations were present ready to recruit potential under-represented minorities.

This was the first time that acoustics sessions were held in this annual conference. Speakers in these sessions included Tyrone Porter, Mawuli Dzirasa, Joshua Atkins, Max Denis and Juan Arvelo. The topics ranged from medical ultrasound, transducers, noise control, signal processing and structural acoustics.

Uwe Hansen conducted hands-on demonstrations allowing students the opportunity to experience acoustic levitation, standing waves, sound transmission, structural vibrations, Doppler frequency shift and more. With their eyes (and ears) wide-open and big smiles on their faces, students gathered around the demonstration tables to confirm their observations and to take pictures and videos with their cell phones and cameras as evidence to show their friends and relatives.

In addition, Jim West was an invited plenary speaker. His talk on hospital noise was the subject of many interesting comments and exciting discussions by a large audience in an overflowing conference room.

Next year's joint conference will be held in Nashville. Plans for increasing acoustics exposure and minority membership include a poster competition. Expansion of this noble endeavor to increase diversity in acoustics requires the collective strength of many committed members. Therefore, a Committee for Diversity in Acoustics (CDA) is forming with the charter of increasing diversity in this scientific field. Interested members may contact: Juan Arvelo at chair@ASAchapterDC.org.

Juan Arvelo

USA Meetings Calendar

Listed below is a summary of meetings related to acoustics to be held in the U.S. in the near future. The month/year notation refers to the issue in which a complete meeting announcement appeared.

2008

29 June - 4 July — Joint Meeting of the Acoustical Society of America, European Acoustics Association and the French Acoustical Society, Paris, France [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].

28 July - 1 Aug — 9th International Congress on Noise as a Public Health Problem (Quintennial meeting of ICBEN, the International Commission on Biological Effects of Noise). Foxwoods Resort, Mashantucket, CT [Jerry V. Tobias, ICBEN 9, Post Office Box 1609, Groton CT 06340-1609, Tel. 860-572-0680; Web: www.icben.org. Email icben2008@att.net].

10-14 Nov — 156th Meeting of the Acoustical Society of America, Miami, FL [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].

2009

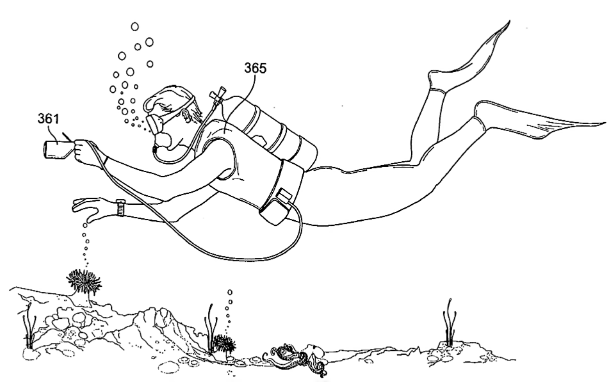
18-22 May — 157th Meeting of the Acoustical Society of America, Portland, OR[Acoustical Society of America, Suite 1NO1, 2 Huntington Quadrangle, Melville, NY 11747-4502; Tel.: 516-576-2360; Fax: 516-576-2377; Email: asa@aip.org; WWW: http://asa.aip.org].

7,272,075

43.30.Vh PERSONAL SONAR SYSTEM

Matthew Pope, Los Angeles, California

18 September 2007 (Class 367/131); filed 10 October 2006



With the fear of sharks the motivation, this document describes a surfboard or scuba mounted system that somehow detects only large animals and warns the water sports enthusiast. It also, more tractably, warns him when he drifts away from his friends.—GFE

Walter G. Mayer
Georgetown University
Washington, DC 20057

New Education Manager at the Institute of Acoustics

Keith Attenborough has been appointed Education Manager of the Institute of Acoustics as of 1 November 2007.

Keith graduated in Physics from University College London before obtaining a PhD in the Civil Engineering Department at the University of Leeds. From 1970 for 28 years he worked in the Open University (Milton Keynes UK) being promoted to a personal Chair in Acoustics in 1992. In 1996 he received the Institute of Acoustics' Rayleigh medal for distinguished contributions to acoustics. He is also Chair of the ANSI Working Group on Ground Impedance.

Keith Attenborough

Keith is a Fellow of the Acoustical Society of America and of the UK Institute of Acoustics. He is a member of the ASA and EAA Technical Committees on Noise. In addition, he is Editor-in-Chief of *Applied Acoustics*, an Associate Editor of the *Journal of the Acoustical Society of America* and on the Editorial Board of *Acta Acustica united with Acustica*.

Keith has published over 240 papers in refereed journals and conference proceedings and his research has included pioneering studies of acoustic-to-seismic coupling and blast noise reduction using granular materials. He has jointly authored the text' published by Taylor and Francis at the end of 2006.

During his 'retirement' as well as working part time for the IOA, Keith plans to continue research including laboratory simulations of blast noise propagation, development of an acoustic rain gauge and investigations into sonic crystal noise barriers.

International Meetings Calendar

2008

10-11 April	Institute of Acoustics (UK) Spring Conference, Reading, UK [www.ioa.org.uk/viewupcoming.asp]
16 April	Playing Safe. Meeting the Control of Noise at Work Regulations 2005 in Music and Entertainment, London, UK [www.ioa.org.uk/viewupcoming.asp]
17-18 April	Spring Meeting of the Swiss Acoustical Society, Bellinzona (Tessin), Switzerland [www.sga-ssa.ch]
26-29 May	The Jubilee XXV Symposium on Hydroacoustics (7th EAA International Symposium on Hydroacoustics), Jastrzebia Gora, Poland [www.amw.gdynia.pl/sha2008]
4-6 June	5th International Styrian Noise, Vibration & Harshness Congress 2008, Graz, Austria [www.accgraz.com]
29 Jun-4 Jul	Acoustics'08 Paris: 155th ASA Meeting, 5th Forum Acusticum (EAA) 9th Congrés Français d'Acoustique (SFA), Paris, France [www.acoustics08-paris.org]
6-10 July	15th International Congress on Sound and Vibration, Daejeon, Korea [www.icsv15.org]
7-10 July	18th International Symposium on Nonlinear Acoustics (ISNA18), Stockholm, Sweden [www.congrex.com/18th_isna]
21-25 July	9th International Congress on Noise as a Public Health Problem, Mashantucket, Pequot Tribal Nation (ICBEN 9, P.O. Box 1609, Groton, CT 06340-1609, USA [ww.icben.org]
27-31 July	10th Mechanics of Hearing Workshop, Keele University, UK [www.mechanicsofhearing.com]
25-28 August	1st International Conference on Water Side Security, Lyngby, Denmark [www.wss2008.org]
25-29 August	10th International Conference on Music Perception and Cognition (ICMPC 10), Sapporo, Japan [icmpc10.typepad.jp]
8-12 Sept	International Symposium on Underwater Reverberation and Clutter, Lerici, Italy [isurc2008.org]
9-11 Sept	6th International Symposium on Ultrasonic Doppler Methods for Fluid Mechanics and Fluid Engineering, Prague, Czech Republic [isud6.fsv.cvut.cz]
10-12 Sept	Autumn Meeting of the Acoustical Society of Japan, Fukuoka, Japan [www.asj.gr.jp/index-en.html]
15-17 Sept	International Conference on Noise and Vibration Engineering (ISMA2008), Leuven, Belgium [www.isma-isaac.be]
22-26 Sept	INTERSPEECH 2008–10th ICSLP, Brisbane, Australia [www.interspeech2008.org]
23-25 Sept	Underwater Noise Measurement, Southampton, UK [www.ioa.org.uk/viewupcoming.asp]
3-5 October	7th International Conference on Auditorium Acoustics (Organised by the Institute of Acoustics in collaboration with the Norwegian Acoustical Society), Oslow Norway [ioa.org.uk]
6-8 October	Acoustics Week in Canada, Vancouver, B.C., Canada [www.caa-aca.ca/vancouver2008]

14-15 Oct Underwater Noise Measurement, Southampton, UK [underwaternoise2008.lboro.ac.uk]
21-22 Oct Autumn Conference 2008, IOA Measurement and Instrumentation Group Demonstrating Current & Emerging Techniques for Sound Measurement, Oxford, UK [ioa.org.uk]
21-23 Oct International Conference on Low Frequency Noise and Vibration, Tokyo, Japan [www.lowfrequency2008.org]
21-24 Oct Acustica 2008, Coimbra, Portugal [www.spacustica.pt]
26-29 Oct Internoise 2008, Shanghai, China [www.internoise2008.org]
2-5 Nov IEEE International Ultrasonics Symposium, Beijing, China [www.ieee-uffc.org/ulmain.asp?page=symposia]
5-7 Nov Iberamerican Acoustics Congress (FIA 2008), Buenos Aires, Argentina [www.adaa.org.ar]
14-18 Nov 20th Session of the Russian Acoustical Society, Moscow, Russia [www.akin.ru]
20-21 Nov 24th Conference and Exhibition, Reproduced Sound 24 Immersive Audio, Brighton, UK [ioa.org.uk
24-26 Nov Australian Acoustical Society National Conference, Geelong, Vic, Australia [www.acoustics.asn.au]

2009

5-9 April Noise and Vibration: Emerging Methods (NOVEM 2009), oxford, UK [www.isvr.soton.ac.uk/NOVEM2009]
13-17 April 2nd International Conference on Shallow Water Acoustics, Shanghai, China [www.apl.washington.edu]
19-24 April International Conference on Acoustics, Speech, and Signal Processing, Taipei, R.O.C. [icassp09.com]
23-28 August Inter-noise 2009, Ottawa, Ontario, Canada [Contact: TBA]
6-10 Sept InterSpeech 2009, Brighton, UK [www.interspeech2009.org]

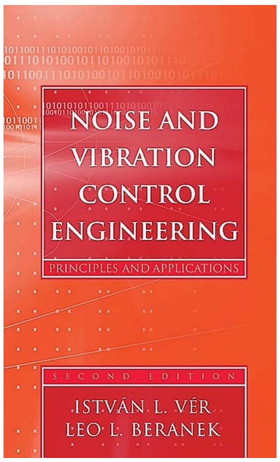
2010

23-27 August 20th International Congress on Acoustics (ICA2010), Sydney, Australia [www.acoustics.asn.au]
26-30 Sept Interspeech 2010, Makuhari, Japan [www.interspeech2010.org]

Books and Publications

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

Acoustics Today welcomes contributions for "Books and Publications." 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>. Cover graphics should accompany the text and must be at least 300 dpi. Please send the text and graphics in separate files.

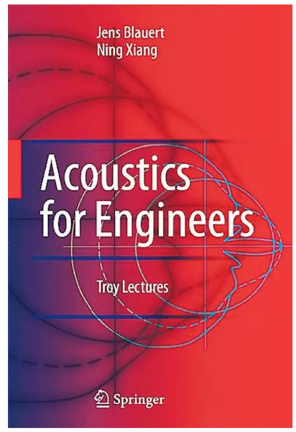


Book Title: *Noise and Vibration Control Engineering, Principles and Applications, 2nd Edition*
Editors: Istvan L. Ver and Leo L. Beranek
Publisher: John Wiley & Sons, Inc.
ISBN-13 97800-471-44942-3
Pages: 966
Binding: Hardcover

This book was written (as was its previous editions) to present the latest information on the most frequently encountered noise and vibration problems in a single volume allowing the practicing noise control engineer to find solutions to an overwhelming majority of such problems. The editors have introduced new chapters and updated those chapters where the field has advanced. New and fully rewritten chapters are:

- Noise Generation
- HVAC Systems
- Active Noise and Vibration Control
- Sound Absorbing Materials and Sound Absorbers
- Outdoor Sound Propagation
- Criteria for Noise Control in Communities, Buildings and Vehicles
- Acoustical Standards

Substantial new information has been added to Passive Silencers, Damage Risk Criteria for Hearing and Human Body Vibration. All other chapters have been reviewed for timeliness.

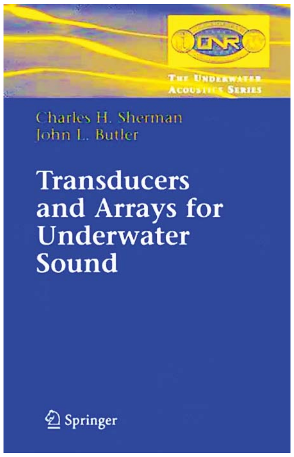


Book Title: *Acoustics for Engineers, Troy Lectures*
Authors: Jens Blauert and Ning Xiang
Publisher: Springer
ISBN: 978-3-540-76346-8
Pages: 245
Illustrations: 167
Binding: Hardcover

This book, taken from the Troy Lectures, provides the material for an introductory course in engineering acoustics for students with basic knowledge in mathematics. It is based on extensive teaching experience at the university level. Under the guidance of an academic teacher it is sufficient as the sole textbook for the subject. Each chapter deals with a well defined topic and represents the material for a two-hour lecture.

The 15 chapters alternate between more theoretical and more application-oriented concepts. They cover the following areas—Introduction; mechanical and acoustic oscillators; electromechanic and electroacoustic oscillations; electromechanic and electroacoustic analogies; electromechanic and electroacoustic transduction; magnetic-field transducers; electric-field transducers; the wave equation in fluids; horn and stepped ducts; spherical sound sources and line arrays; piston membranes, diffraction, and scattering; dissipation, reflection, and absorption; geometric acoustics and diffuse sound fields; isolation of air- and structure-borne sound; a survey of noise control.

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



Book Title: *Transducers and Arrays for Underwater Sound*
Authors: Charles H. Sherman and John L. Butler
Series Editors: Ralph R. Goodman, Homer P. Bucker, Ira Dyer and Jeffrey A. Simmen
Corrected second printing
Publisher: Springer
ISBN 978-0-387-32940-6
Pages: 612
Illustrations: 388
Binding: Hardcover

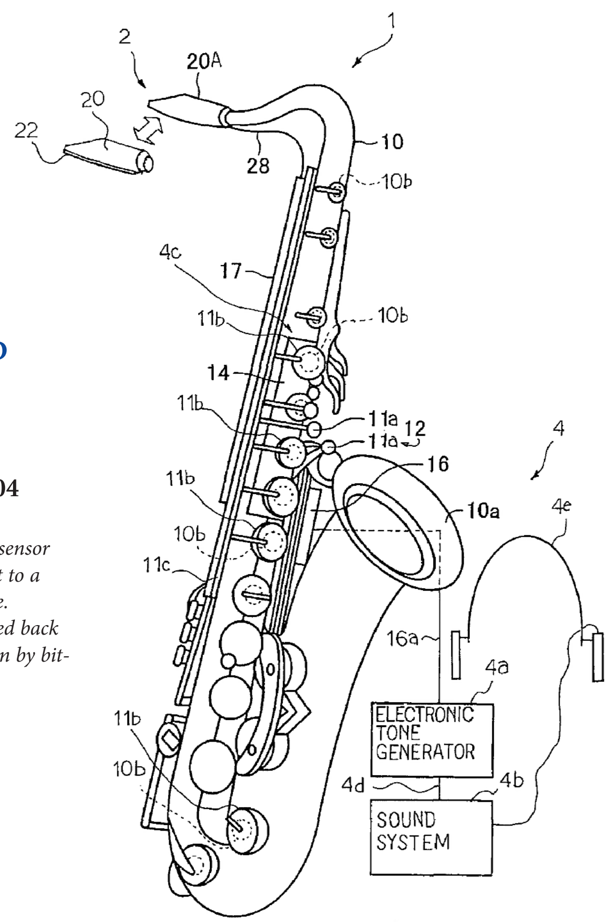
This is the second volume in the Office of Naval Research monograph series in the field of underwater acoustics. The subject of this book is the theory, development and design of electroacoustics transducers for underwater applications. It is more comprehensive than any existing book in this field. It includes the basics of the six major types of electroacoustic transducers, with emphasis on the piezoelectric ceramic transducers that are currently most widely used. It presents the basic acoustics, as well as specific acoustic data, needed in transducer design and includes analysis of nonlinear effects in transducers. A large number of specific transducer designs, including both projectors and hydrophones, are described in detail as well as methods of modeling, evaluation and measurement. Analysis of transducer arrays, including the effects of mutual radiation impedance, as well as numerical models for transducers and arrays are also covered. This book contains an extensive Appendix of useful current information, including data on the latest transduction materials, and numerous diagrams that will facilitate its use by students and practicing engineers and scientists. A complete set of exercises and solutions from the book are currently available on the Springer website.

7,049,503

43.75.Tv HYBRID WIND INSTRUMENT SELECTIVELY PRODUCING ACOUSTIC TONES AND ELECTRIC TONES AND ELECTRONIC SYSTEM USED THEREIN

Naoyuki Onozawa and Kazuhiro Fujita, assignors to Yamaha Corporation
23 May 2006 (Class 84Õ723); filed in Japan 31 March 2004

The Yamaha WX-7 was a very successful electronic clarinet: it used a velocity sensor mouthpiece and electronic switches to create a MIDI stream suitable for input to a MIDI synthesizer. In this update, Yamaha creates an electronic saxophone. The most interesting aspect is the "tounging sensor"—an infrared light is radiated back toward the player's tongue and is then sensed. The ability to control reed vibration by biting on the reed is not addressed.—MK



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.

The Automotive Sensors division of PCB Piezotronics (PCB®) has released a new Model 106M160 high intensity ICP® acoustic microphone, designed for measuring airbag deployment noise and total impulse of an inflation event occurring inside of an automotive cabin. The unit offers sensitivities of 79.8 mV/kPa (550 mV/psi); a measurement range of 189 dB (57.2 kPa); 96 dB (1.4 Pa) resolution; and frequency response of 0.05 Hz to 20 kHz filtered output, tailored to the human ear. It survives higher intensity signals, up to 216 dB, that would damage most condenser microphones beyond their 3% distortion limit. The rugged, hermetically sealed, piezoelectric pressure microphone features also ICP® output, for ease of use and reduced setup time.

Series 106 dynamic pressure sensors also include models which are ideal for measuring low-level and high-intensity sound pressure levels, acoustic and ultrasonic, with sensitivities of up to 725 mV/kPa. Sensors withstand high-static background pressures and feature solid-state construction, no moving parts, and stainless steel housings, and are well-suited for detection of rapid pressure transients, pulsations, turbulence, noise, and spikes for troubleshooting equipment and tuning processes. Available charge output units may be used in temperatures of up to +750 °F (+400 °C). Contact: mbakewell@pcb.com

PCB® Piezotronics Series 102A and 121A sensors offer intrinsic safety certifications to CSA and ATEX standards, permitting use on machinery operating in hazardous environments. Applications include monitoring dynamic pressure events such as surges, pulsations, spikes, leak detection, combustor instability, and acoustics found in operation of oil & gas well heads, pumps, gas compressors, pipe-lines, reciprocating engines, and gas turbines. Sensors may be used with ICP® signal conditioning and permit use of a variety of inexpensive 2-wire cable systems. The low-impedance signal may be transmitted over long cable distances, and sensors may be used in dirty environments with no signal degradation. PCB® can also assist with providing many other styles of dynamic pressure sensors with hazardous area approvals. Contact: mbakewell@pcb.com

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 Automotive Sensors division of PCB Piezotronics (**PCB®**) has announced release of a new high-temperature preamplifier, designed to overcome high temperature testing challenges associated with NVH powertrain and vehicle underhood testing applications, and to broaden options for NVH test engineers collecting acoustic data in high temperature areas.

Automotive engineers routinely perform NVH tests in areas around the powertrain, where elevated operating temperatures can present major measurement challenges. Underhood temperatures can peak at +125 0C under normal driving conditions, and can be significantly higher near turbochargers and exhaust system components, such as manifolds and diesel particulate filters. In the past, test engineers were limited by preamplifiers offering operating temperature ranges to + 70 0C. Model HT426E01 is a 1/2” preamplifier operating from ICP® sensor power, terminating with a BNC connector and utilizing standard coaxial cables. The model also features a low attenuation factor (-0.06 dB) and low noise characteristics, 4.9 μV, based on an A-weight scale. Contact: mbakewell@pcb.com

Scantek, Inc., is pleased to announce the availability of its newest product, the Noise Nuisance Recorder, N-140NNR. Often when there is an indoor or outdoor noise complaint, the acoustical engineer or enforcement office arrives at the scene when the noise is gone. The N-140NNR system allows documentation, analysis, and recording of the sound, all done by the complainant. Carried in an unobtrusive back-pack, the system takes seconds to set up. The complainant need only press a button when he/she hears the noise. The analyzer does the rest. It provides an ongoing measurement and analysis of the sound level and a solid-state recording of the sound itself, along with the exact date and time of the occurrence. You have a calibrated measurement with proof of the event. Now there is no need for an expert to be present when the sound occurs. Contact: PeppinR@ScantekInc.com

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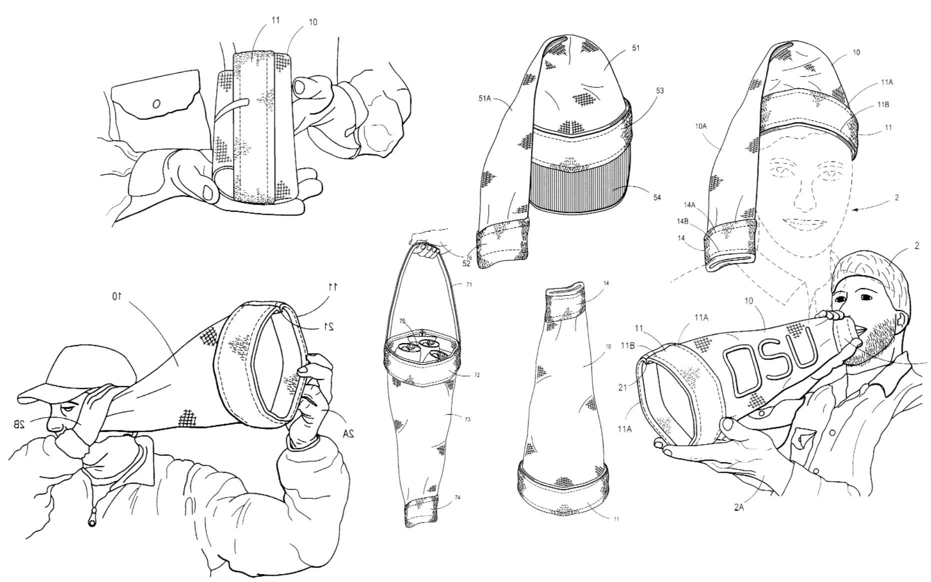
6,568,504

43.38.Ja MULTI PURPOSE HEADGEAR

John H. Cowgill and Charles W. Elroy, Jr., assignors to Sportniks, Incorporated

27 May 2003 .Class 181Õ178.; filed 26 November 2001



A collapsible watch cap can be extended and used as a megaphone. The illustration shows a man literally talking through his hat.—GLA
Clockwise from upper left—folded headgear, hat with brim, hat without brim, megaphone, traffic cone, tote, hearing aid.—Editor

Passings

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

Joseph Pope

1950-2008

Joe was born on December 20, 1950 in New York City growing up in nearby Scarsdale. He graduated with a bachelor's degree in mechanical engineering from Massachusetts Institute of Technology (MIT) where his senior project was on lawn-mower noise control under Dr. Allan Pierce. He obtained a Ph.D. at Stanford University with a pioneering dissertation on the transfer of tire and road noise to vehicle occupants.

Known for his modest, gentle approach Joseph Pope helped to make significant contributions in the field of sound-intensity measurement. He worked initially at the General Motors Research Laboratories (GM) at a time when, due to the Noise Control Act of 1972 and the establishment of the Office of Noise Abatement and Control (ONAC) at the Environmental Protection Agency, GM was very concerned about vehicle noise. At the same time, the newly available two-channel analyzers became an integral part of noise research at GM, by Joe and others. Through his mathematical and experimental ability Joe helped to develop the well-known cross-spectral formulation for measuring sound intensity using two microphones. He was the first to measure the sound power of a truck using sound intensity and collaborated in measuring the sound power of engines and locomotives. The work at GM came to an end when ONAC was abolished in 1981. Subsequently acoustical instrument companies, universities and other institutions carried on the work in this field. As a result, in 1982 Joe began working at Bruel & Kjær as an expert on sound-intensity measurement. He continued at B&K in Boston until 1991 when he founded his own acoustical consultancy, Pope Engineering. He maintained his association with B&K for a number of years conducting seminars in noise control with an emphasis on sound intensity. Joe was an ASA fellow and active on the Technical Committee on Noise. He was a board-certified member of the Institute of Noise Control Engineering (INCE) and a member of the National Council of Acoustical Consultants (NCAC).

Robert Hickling

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

J. M. Harrison

Jacek Jarzynski

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.

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Ad Submission: E-mail: Christine DiPasca at cdipasca@aip.org; tel.: (516) 576-2434. You will be invoiced upon publication of issue. If anonymity is requested, ASA will assign box numbers. Replies to box numbers will be forwarded twice a week. Acoustics Today reserves the right to accept or reject ads at our discretion. Cancellations cannot be honored after deadline date.

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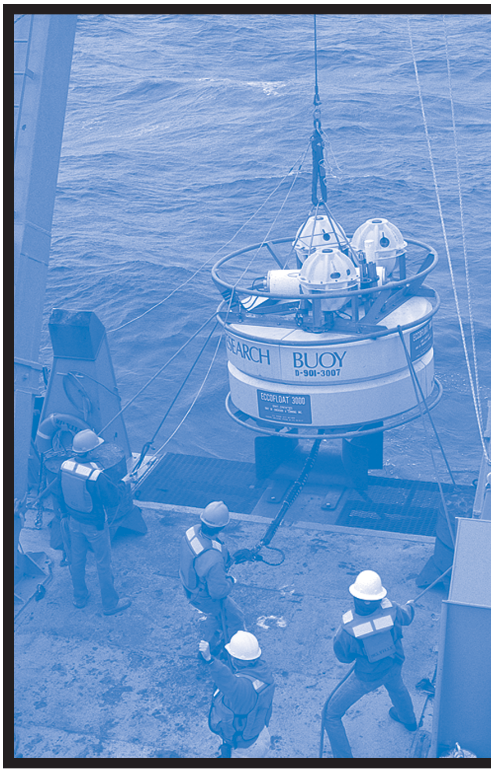

Acoustics Today

Classified Advertising

Whether you're seeking the most qualified candidate for an open position, or looking to make a position change yourself, *Acoustics Today* offers you Classified Advertising where your ad will be seen by over 10,000 readers in the acoustics community. For more information, see Recruiting and Informational Classified Advertisements below.

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2. **Classified Line Advertisements:**
   RATES: Positions Available/Desired and Informational advertisements—
   One-column ad, $30.00 per line or fractions thereof (44 characters per line), $150.00 minimum, maximum length, 40 lines;
   Two-column ad, $40.00 per line or fractions thereof (88 characters per line), $280.00 minimum, maximum length, 60 lines.
   (*Positions Desired ONLY—ads from individual members of the Acoustical Society of America receive a 50% discount.*)

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RIDING THE WAVES

A life in Sound, Science and Industry
A Memoir: Leo Beranek

Emily Thompson, Professor of History, Princeton
Leo Beranek's memoir engagingly describes a life that exemplifies the best possibilities of twentieth-century America. Through peacetime and war, Beranek has played a significant and often foundational role in the academic and corporate fields of acoustics, electronics, and communications. His personal account of that role will be of interest to all students of American history and technology."

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Spring 2008, 312 pp., 24 b&w photos, 3 illus., cloth covered, 978-0-262-02629-1

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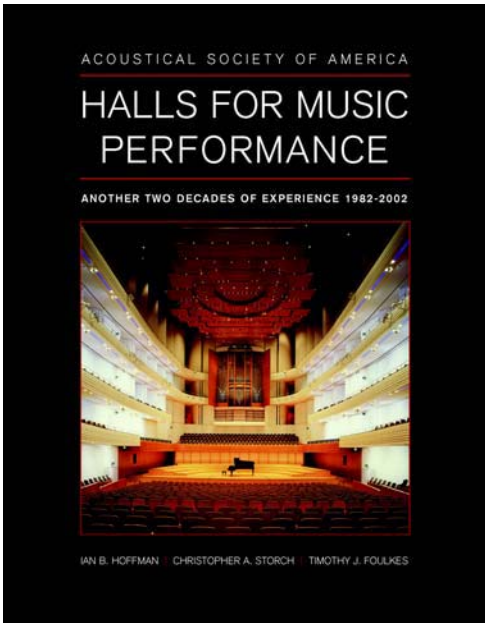

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