Prof. Peter Westervelt
WHOI Ocean Acoustics
Nov. 15, 2006

PART 1

Intro-This is a weekly gathering of the Ocean Acoustics Laboratory; this is a part of the Department Applied Ocean Physics and Engineering here at the Institution. Of course this is a very special occasion; I'm very pleased to welcome you to our Institution.

Glad to be here. Don't recognize it but I was here very early on, forty years ago, when they dedicated one of the labs.

Intro-This is the first and the oldest of the buildings, we have of the order of sixty buildings at the Institution, but Bigelow Laboratory is the first, built in 1930 and apparently the donors, the Rockefeller Brothers, were later asked about the donation to the Institution and they expressed surprise, they didn't recall it, they didn't know why they were asked! The influence of Brown University has been genuinely profound in many ways, it continues to be and there was a celebration of Brown University Physics at the Acoustical Society of America meeting in Providence in June, quite a turn out. Of course the Physics Department is also a profound personal influence for several of us and many colleges that we work with also. Your work has already been described to the group. But, its actually been very enlightening to take a ramble through some of the literature you're responsible for concerned with scattering with sound by sound and parametric acoustic array, absorption of sound by sound. A favorite later theme of course was non-scattering of sound by sound. But also analogies, the power of analogies. That you solve a problem in non-linear acoustics, you're also solving a problem in elasto dynamics, general relativity; the connections are quite explicit. So also I've mentioned some of your work on national committees, sonic boom.

Somehow I got myself on the committee at the National Academy looking at sonic booms and I was sent out with my family to the headquarters of the Bowing Company which was attending the field there of super sonic aircrafts and sent them up to the top of Crystal Mountain for skiing while I went down to attend meetings to determine if there was a future for the super sonic transport and we decided there wasn't and I think my uncle, who lived with Bill Bowing, and founded the company, the first plane was a Bowing and Westerville believe it or not, must have turned over in his grave when we reached the conclusion that they were not going to build a super sonic transport, for obvious reasons because of the sonic boom. Many of you are accusations here, everyone.

Q-I don't know if you and Alan ever crossed paths in those years, with the sonic boom work.

Alan-I though it would be a great thing to get into, so I started working on it and then I read the newspaper and Congress was taking some vote, and it was dead. This, I learned, was a common pattern, everything you work on gets eventually scrapped by the government, they move on to something else, you have to be flexible.

Leo Libra (sic) Bernetich (sic) was on that committee with me, amongst with others.

Q- I recall you describing a problem involved with use of ultra sound for imaging fetuses, which has come back. You told me about that, 1970, some of your work on one of the committees- National Academy of Sciences.

That was a National Research Council Committee. I wrote a short paper on the acoustics of the sack where the embryo is supposed to stand and suggested an experiment be performed, mimicking the uterus by water filled balloons. I don't know if anyone ever carried out the experiment. We were concerned about the impact of aircraft noise on the fetus and it turns out the transmission, from air to fluid, is so low that it practically doesn't exist.

Q- One actually experienced sonic boom. It was on the Cillies (sic), west of the British Isles. By that time the planes from Ethra (sic) were up to speed and there was a visceral effect. So it wasn't unreasonable for you to be looking at the effect of fetuses.

Yes, we were not so concerned about the proximity to a jet operating pulley. The jet noise that goes with the eighth power and the exhaust velocity, that's what we were concerned about.

Q-The problem is still open, there's work being done today. There's a lot of concern about sound exposure during these routine ultra sonic medical examinations

Definitely, you can perform auditory tests on the fetus; it appears you can predict the outcome of the person's hearing.

Q-The starting part for a lot of your work, the wave equation, is expressed in terms of Lighthill's formulation. I believe you also knew Lighthill.

I had visited Lighthill on several occasions when I was in England, 1951-1952. My first assignment upon joining the faculty at Brown University was to go over with Ed David and I went over to spend two or three weeks in England looking into anti-submarine warfare. We both ended up spending nearly a year and a half over there. During that time I had the opportunity to visit Lighthill and start the pre-print of his classic paper on the exact equations of the moment of sound extension generation. But also, I was asked if I could visit a chap by the name of Captain Round, whose famous for having invented the heterodyne radio and also co-inventor of frequency modulation. He was an older man then who'd been asked to help in the development of the magneto stretch in the underwater sound generator and the people at the Embassy said he would much appreciate it if I went up to visit him with a bowl of kidney stew to go. So I said yes indeed, I'd love to do that, this was the end of 1951. So I went up with his beloved kidney stew, which was much appreciated, and he had a magneto stretch generator that he was testing for the Admiralty, it was about this size, in air generating about 15 kHz and it was firing across the room to a microphone, the amplifier was feeding the generator, it was fed with raw AC. So needless to say, that beam was modulated at twice the frequency of the electrical system and as I walked across the beam I got this fabulously powerful low frequency sound, I said—uh-oh what's going on here— and went back to think about it and it was either one of two possibilities—the beam demodulated through the anomalies of my ear, three possibilities, or the radiation pressure was actuating in my ear, those were the only two I thought of at the time, but when I went back I said—something else must be going on. It was too highly directive and ultimately of course it was the parametric array being generated in air, believe it or not, that was causing this strong low frequency I was listening to. So I figured the genesis of the parametric array probably dates back to that occasion and observation in 1951.

Q-What was producing the different frequency then? I think of the parametric array as two frequencies that are fairly close.

I know, that's right. But you can also modulate the beam and get the same effect. It's as if you had two frequencies and the difference between the frequencies is equal to the modulation frequency, there's basically very little difference there. Now the parametric array has been patented by several people of course. There's one on display at the Science Museum in Boston and people are working on it to various applications in museums to focus on the viewer of a painting, to give them the information about the paintings, and in the navy to pick someone up on a carrier, talk to him without interference of other people.

Q-This was sort of at the top of my list of questions, the origin of the parametric array. You were publishing scattering of sound by sound in the late 1950s, but really without suggestion that there was this practical application.

True, the first article I wrote on it appeared in 1960 or 1961, but I'd had it written and didn't submit it for at least a year, because I had a visitor from Russia by the name of Constantine Abonet (sic). He spent a year with us and at the time it was thought we should probably keep this information away from him. So it was a year before it was submitted and in the meantime Belong (sic) and I had actually performed the first experiment in water. Belong (sic) was Beyer's student who didn't quite make it to the PHD, we gave him a masters on that experiment and the paper was eventually published. At that time, Constantine Abonet (sic) visited our farm, seven miles from Providence, where he was quite taken by my wife on the tractor, mowing the hay. One day I said we'll break the rules and regulations and drive you to Boston because we were limited to a twenty-five mile radius out of which we couldn't go because of so called security. So I took him aboard and started driving to Boson and I said—hey would you like to take the wheel—and he said—ohh yes—and he took it. We saw a hitchhiker on the road and we stopped and picked him up and he said—who's driving—and I said—a Russian—and he was a little ratty driving, he almost said—let me out please—. Anyway, he had a good time, and I don't know if I've seen him since then, but I gather he's got a job in Boulder. Well he wasn't there when I went out there to see some head of the Aero dynamical Department who wanted me to give a talk there because we provided them with one our assistant professors whose still there I guess. I went, and before the talk he said—let's climb Green Mountain—which is directly behind the university. But not only did we climb up it, we ran up it, and ran down. I was so out of breath and when I got up to give the lecture, well before I gave the lecture, for the first time in my life, frightful cramps up my legs. I learned later that he was an Indian and this was his traditional trick to prepare people to give lectures—knock them out one way or another, and he sure did.

Q-Speaking of swimming, Lighthill died at sea while swimming?

That's right, and Longdow (sic) died mountain climbing, I've got to keep them separate because they're both my heros- Longdow (sic), Longdown (sic), Liscious (sic), and Sir James Lighthill. Lighthill was in charge of Farnburow (sic) after a while and I visited, Farnburow (sic) is the place where they tested all their aircrafts and so forth. It was exciting, seeing all these jets going by and I asked and was given a list of pictures, which I sent home to my sister in Vermont, but they slipped out of the envelope in the Post Office and the FBI got after it. I only learned this indirectly; my sister never received the pictures. But word got around, and I learned of it from a guy named Singer, S. Fred Singer.

Q- With the ??? did you propose to buy her, or try to observe this experimentally, or had he already decided?

No, what happened was, as I mentioned, Bellon and I actually performed the experiment. Bellon was Buyer's student and Bellon continued to refine the experiment and that's what happened. Much to my horror, they got a much narrower directional pattern than theory predicted and I tried to get them to correct that because if that was the combined function of, not only the parametric array, but the super imposed radiation pressure that was impinging on the receiver. That's my way of thinking on the experiment; its essence had already been performed ten years earlier in air by Captain Round, without him knowing it.

Q- But there still are some issues connected with the parametric array in air, according to some authorities, work going on in Texas perhaps still?

Well, I think it's still going on in several places, these multiplicand of inventers are all trying to promote the device as a feasible and useful gadget. I don't know if Texas is still doing anything of that sort, could be. I'm enjoying retirement; I'm a couch potato and not really paying too much attention to what's going on today's ??? group.

Q-Murray Corman (sic) is using nonlinear effects in soils in an attempt to detect lines.

Right, and I think the Russians are doing some dirt bugging stuff. They were, some time ago, relying on their knowledge of the properties of the Earth to discover the location of petroleum and things of that sort, but I don't know about the lines.

Q- They're certainly being used in the world of gas exploration industry. But a beam can be formed in water, and at that point it's very directional and low frequency without needing additional momanarity (sic). Sometimes the commercial parametric arrays operate in water of thousands of meters depth to go into the bottom, that's the beginning, its fully formed, but they're able to make measurements to quite some remarkable depths.

At the other extreme, you have people in Holland who are trying to use this in water that has a depth of half a meter to do mapping of the sediment structure for civil engineering purposes.

You, of course, did a classic paper on the behavior of the parametric array and why bend noise, is there a problem, and you published that in Draser (sic), what a thing to do. Never received very much tension.

Q- You actually asked me for several years when I was going to publish that and it sort of ended up in proceedings, a paper at a meeting, but it's incomplete. I recall another paper of yours on oseen forces. I was wondering if you were interested in elaborating, I think there's an oceanographic connection there. But I'd like to here your explanation.

That was essentially my PHD thesis, which, in essence, was really never published because I got mad at my mentors.

Q-Who was your mentor?

Richard H. Bolt (drawing on white board)—the force (F), part two(F_2) a linear component with a viscosity component(N_v), and the velocity(V). Well at higher altitudes you add a term which is nonlinear, so it's a constant (C), times the velocity(V) and the magnitude of the velocity(V). Then again, if you super impose, if your velocity(V), composed of two sonisonal (sic) frequencies, sign one omega t(Sinwt) plus sign two omega t(Sin2wt). Depending on the phase between the two omega, you have a high peak and a low and if you throw this into this equation (F_2 N_vV + C V V)you get a steady force in one direction. If the phase is reversed, you get the peak on the other direction and the force will be reversed. A force on what? Well, we made experiments where we took a ten micron ball in a tube and sent the wave through. For one phase, the strong force would make the ball go forward and for the other phase it would make it go backwards. It was very strong forces, ours is a magnitude above radiation pressure. So that's what the oseen force did for you. And we made lots of experiments and got published and I had a fat thesis that a lot of people seemed to resent because there are obvious applications of this sort of thing. It also works if you put these kind of waves through an aurtofitz (sic). We did that experiment too. We had a aurofitzies (sic) of various sizes and what would happen is you would get a strong uni-directional flow in one direction or the other, depending on the phase relation between fundamental and the second harmonic. A suggestion was made at the end that this might have applications for membranes, semi-conducting membranes for forcing drugs across the skin and stuff like that. We tried a little experiment in the chemical department, MIT never went for it, but I still think it's has great future for possible applications to semi-permiable membranes because you can develop a uni-directional force across these membranes.

Q-Is this related to tidal rectification? Which I believe is the secondary flows in the ocean related to tidal drag, bottom drag, which looks like V modulates. You set up secondary flows.

Of course, the forces make it develop when it happens over obstacles. That's right.

Q-With respect to sedimentation, you've worked out the particle size dependence of the force.

Well, this action only takes place if the article displacement amplitude is greater than essentially the radius of the obstacle to get the true nonlinear effect. So the particle can't be entrained in the sound wave, its sufficiently small and sufficiently light, it will be entrained, and it won't work. But that's the condition of the displacement amplitude, it must equal or exceed the dimensions of the sphere or the cylinder or the object in general.

Q-This had nothing to do with compressibility?

No, it's strictly a hydro-dynamic phenomenon. Then INGAR (sic) of course used the oseen approximation to solve the problem of streaming about an obstacle. If you have a powerful sound wave hitting an obstacle, the secondary flow is set up where the steady flow comes in here. Even karameters (sic), the oseen approximation solved that problem, that turned out to be a terrible mistake because, it turns out, the complete solution for the problem the steady flow is equal to the solution plus the velocity transform, which is a thing that has to be added, the displacement dot duv (sic). This is a non-linear term, the displacement brought in to the grata (sic) of the velocity. But, if you use the oseen solution, there's two parts to this, there's the oseen part, and then if you add this term(displacement dot duv(sic)), which you have to in order to get the correct solution, they exactly cancel each other out. You get a big zero. That was one of my short papers. They forgot to realize that this had to be added (displacement dot duv(sic)) and it's the exact solution to the oseen problem. This is true for any shaped object what so ever, which is interesting. So if you go to an awful lot of trouble to get the oseen solution, all sort of complicated integrals and such even for a simple sphere, but you really don't need to because this is the first order, displacement, the first order, velocity, you calculate directly and it's exactly equal to the negative of the oseen solution. This acoustic streaming, I don't know why it has had so much publication; I don't know what its importance is, other than, as you mentioned the hydrographic applications.

Q-If you had a fluid with particles in suspension, and the particles were very small, but had a wide size distribution, there would seem like there was a differential effect driving the smaller ones into the proximity of the larger ones, which would make possible agglutination.

Yes, if the particles were stationary in first order so the flow past them is adequate to bring in the non-linear terms, but only then I guess. Then one can make a detailed calculation of that.

Q-Something that has occurred to me, there could be advanced sedimentation rates as a result of this. There could be applications in chemical engineering and the use of ultrasound to promote chemical reactions

There has been a lot of literature on the first order effect, this agglutination effect. When some particles are more massive then others you get the relative velocity between the two, you use the relative dynamic velocity not the steady states.

Q-I'm not that into it, but I was on a thesis committee once with Penn State and they had ??? from the Department of Energy and the sensitive ???, smokestacks and they were going to put ultra-side radiators on the sides and the smoke went up with all the stuff in it that they were, somehow with these little dust particles qualigate (sic) and when they get big enough they'd settle because of the gravity. If they were too small, you wouldn't care, because they wouldn't kill you, but there was a certain size and they were really bad, and they hoped to get rid of that. It's another one of those things that the government had interest in for a short while and then stopped.

Q-Brayton Point Power Plant, which supplies ten percent of the electricity in New England, is undergoing a major upgrade in the cleaning of its exhaust. It's a hundred million dollar project. But I don't think with any use of acoustics.

Q-The fellow who's ??? is at Penn State is a guy named Ritof (sic), I don't know if Peter knows him, his name was Gared (sic) Dreheart(sic) Ritof(sic), he was a mechanical engineer.

Q-As a society of course we just kind of look the other way when it comes to particulate emissions, diesel engines being notorious in that category. Separation in fluids is quite an important thing.

Q- There really is a lot of interest; I remember when it was acid rain, now I really hear nothing about it. Nobody cares.

??? the same legion (sic) of all of our fish, is that on solid ground. That just came out in <u>*Science*</u> recently, this tremendous experiment that covered all parts of the universe. Are you aware of that?

Q- This is the sorriest part of this whole business, I have to tell you, doing sound scattering by biological organisms and that's to find out how stocks are mismanaged and over-fished. It's actually been known by the community, that is the community of scientists, for quite a long time and the trends are unmistakable, indisputable.

Q-Ken, why do you believe that that the fishermen allow themselves to basically shorten their own careers by over fishing? Reel in their own lively hood, it happens world wide, over and over again.

Q-For the same reason that we would drive trucks.

Q-You can still fish there, that's the argument, and it's not gone. It's still there, I mean, there friend caught a lot of fish the week before, so it's unfortunate. I like to add in that the aquifers in the Midwest are just going away.

Q- But I hear that fishermen report that there are plenty of fish and that the scientists don't know what they're talking about and the government doesn't know what they're talking about. But they're focused on going to the places where the fish are, and they're experts at finding fish, they're biased.

Q- It's actually quite a deep subject, but the climatists have been calling it the tragedy of the commons for quite a long time, that says a lot.

Q-Wasn't there a professor at MIT who was throwing iron dust in the ocean in order to feed and overgrow these fish?

Q-No, there are iron enriching experiments, because iron is a limiting nutrient. There have been large consortions (sic) of scientists doing a couple of big programs. One in the

Antarctic area, the polar area, studying phytoplankton and so forth. But iron is a basic limiting nutrient in much of the world's ocean.

You don't relate it to the transit (sic) Earth of Mars across the sun.

Q-Well the transit (sic) of Mercury. Well, it's overcast throughout New England. Otherwise I think Jim and I would have used it.

We did some general relativity; I told my students there was no future in that. Therefore, go into mechanics, hydrodynamics, so forth and so on. But the relationship between general relativity and fluid dynamics is so close. Maybe I can show you a little bit about that. The famous Lighthill equations can all be reduced to a simple equation involving the valembration (sic) of the pressure($\Box P$) proportional to the double divergence($d^2/dx_i dx_j$) of the ui uj, this is a stress tenser (sic) plus P minus 0C squared, delta ij. Well this is similar to the crazy tensor for general relativity R uu to the curvature tensor plus this famous cosmological constant times delta uu (sic) proportional to the constants T uu (sic). This T uu (sic) is related to the ijs, we're swimming over only three parts, these are swimming over four. There's a very similar distinction here, this is the source term, generating all the nonlinear acoustical effects. Well, if you're going to make a comparison, you have to add in the forces of gravity, so you have this term here, the gravitational constant G. g is the gravitational field on earth, times the density plus this term uu. Well if this is only one dimension, then this is going to be g-gravity- times the density plus u squared . The g will have a minus sign in from because it's a force N. So let's say we're in the universe, to have this vanish, you've got to have this term (-gd) equal to that term (u^2) and down here's where the fun begins. So if you make these terms($-gp_u + pu^2$) zero, you say—well what does that amount to—well it's the same thing if you're on Earth and you're throwing up a little piece of material and you ask what's the condition that it equals the escape velocity, that's a classic problem. Then, for that, you say the kinetic energy of the particle going up must equal its potential energy at that point, I'm now developing the definition of what's called, the one of our universe is if you take the potential energy (PE) is equal to the kinetic energy (KE) and the trivials M_1, M_2, now this is the gravitational constant over 2r, that's the potential energy, is 1mv squared over 2($m_1 m_2 G/2r = m_1 v^2/2$). Take that addition and then you find the m_2, the m_1s cancel out. m_2 is equal to the density, and now this is the universe, times the volume of the universe, which is 4/3 pi, radius r cubed, now this is a moveable radius, this is the volume of which ?time is equal to r v squared over 2 times G ($m_2 = p_u V = 4/3 \pi r^3 = rv^2/2G$). Now the velocity, this is in the universe, is equal to the hubble constant times r ($V = hr$). Because the hubble constant is just r-how far away you are from the radius of the universe ($h = r/r_u$). This is all straight forward acoustics. Then if you solve this you find the density, the density of the universe is equal to three times the h-h equals hubble. You find this density of the universe is 3h squared over 8 pi G ($e_u = 3h^2/8$ pi G). This is the correct density for a flat universe, flat meaning no acceleration because we set these two things equal to each other

Q- Whatever the cause for evading the math, it looks likes all these guys are constants. You have to enter the model mass, don't you?

You haven't entered the model mass in essence. According to this simplified theory, it's not infinite because there's a definite limit to the radius of the universe. What we want to show is that we want to calculate the total flux leaving the universe at that optical edge, so the total flux of energy and that will obviously be equal to the energy density times u times the area of the universe(total flux of energy = [pu] u area), the optical edge, which is rouge u. But at the edge, the velocity is the velocity of light. That's seen from this expression, when r equals r at the edge of the universe, this goes to c and so this is c squared times the area of the edge which 4 pi radius r of the universe, squared. Then if you put all these things together, this equals, in effect, c to the fifth, over the gravitational constant. This is an astronomical constant and it figures in the efficiency with which gravitational waves can be generated by moving objects, quadriflow (sic) generation. So let the efficiency of generation would be equal to, in effect, the kinetic energy of the device that's generating the waves, dived by this astronomical constant, that's the total radiation for many devices that has this kinetic energy interchanged. So this is effectively c to the fifth over G which is of the order of 10 to the 52 watts (Efficiency = KE/c5/G). Now that's a really astronomical number. I first worked this out in a little paper in the Physraz (sic) which was published back in 1952 or 3 believe it or not. Well I'm doing this to indicate almost the impossibility of detecting these gravitational waves, we're spending millions of billions of dollars trying to do it, we haven't yet sent it up in space, although a chap by the name of Joe Webber did and I had one of his devices on the moon I don't know whether it self-destructed or not, but it wouldn't have made any difference because it was totally incapable of receiving these waves. Now this term up here (KE), there's no monopole let alone dipole radiation from gravitational waves, it's only the lowest order, quadrapole (sic). The energy radiated by any device is approximately equal to the third derivative of the quadrapole (sic) squared. That is what would be radiated, this term up here divided by this huge term 10 to the 53 watts (KE/10 to the 53), which indicates the almost near probability of not detecting anything gravitationally. Sorry to diverge you on this idiot calculation, but it shows you the connection between acoustics and general relativity.

Q-Well you did develop a linearized theory for general relativity based on these non-linear acoustical equations. You used them to actually quantify the ?fluctuations of sterile light passing by the sun. Also, persection (sic)of the periluion (sic)of Mercury, which is a tie into the transit observations.

Well there's nothing really original in that other than the ???. I would like to explain one simple little thing though, and that is if you admit the photon and receive it and it goes past the sun, you find that this process of admitting and reception sends out a gravitational wave which causes the sun to move in this direction a microscopical amount, it moves in the opposite direction from which the photon is going. Therefore this thing (the photon) will go a little bit further to balance momentum and this results in the famous ?Shapiro time delay due to the passage of a photon past the sun. On the other hand, it will also cause the photon to be deflected in that direction. If you solve the equation of motion to the sun in the presence of the wave, the sun requires a velocity in that direction, which equally balances the momentum of the additional momentum of that direction of the photon. So you can do these little calculations and naturally satisfy the necessary equations of momentum, energy and conservation.

PART 2

Q-I recall that you had worked out your linearized theory for gravitation, but I'm not sure it's ever been published?

No, it hasn't. We did get a letter from ?SERN, it was published as an AEC-at that time it was the Atomic Energy Commission Report, and SERN asked permission for it to be reproduced for their crowd. But it's never been published, that's right. Well bits and parts. Scattering by black holes, that was published in the American Physics Society.

Q-The definition I got by is Lindsey's definition, is waves associated with matter that contracts with electro-magnetic waves. So water waves, are by that definition, the waves of the tide, ?acoustics, and you could say that quanti-mechanical waves sub size their acoustics.

Q-These words remind me of my last few years at Brown, I wasn't there long, but long enough to see you working on the problem of absorption of sound by sound.

Yes, well that would have never seen the light of day, hadn't it have been for a distinguished editor of the Acoustical Society Journal. I submitted that and I was roundly rejected. *passes around paper* Then I met him at IC international something conference in Madrid told him the woes, I had been rejected and he was very nice, he put it in, it got published. But, I insisted that I would not change the date of submission and I would make no corrections whatsoever. It was about two years after it was submitted it saw the light of day.

Q-Was that your last work on the absorption of sound by sound.

No, I think I have a paper on scattering of black holes and fizredi (sic). I didn't bring that.

Q-I'd like to ask you something different now. Of course you were there with Robert Bruce Lindsey, Arthur Williams, Bob Buyer, yourself, and you all left without issue, no survivors, apparently. It just jumped to chemistry is a sense with Jerry D. Bowld (sic) and Humphrey Maris has done some things, and Charles Elba (sic), but more in sort of the materials area.

I think acoustics ceases to exist as a discipline at Brown University now.

Q-Was that a conscious decision of the faculty?

Probably.

Q-Phil Styles was their chair at the time; I don't know what his policies there on replacing people. But, it seems as though a solid physics group was strong and getting stronger.

Q-But, obviously this group here was funding itself, doing good work, why would you lose a group that was thriving? I mean if there's a group and they were absolutely destitute and the University is feeding them hand to mouth. Ok, that's an issue, but obviously that wasn't the case.

Q-There were no issues on lab space. I didn't perceive any inequities; everyone seemed to have equal space, equal offices, equal lab space and so on and so on. I didn't see that, it was just a systematic, quiet non-replacement of people in your faculty.

Well, we've added to the astrophysics crowd, and that was probably to the expense of the acoustics group.

Q-Can I throw out a legend, which you can refute. This came to me, not from a faculty member, but from an alumnus there, that said there was a time, when they had a new department head who said, when you come up for ten year and you submit your credentials, your list of publications we'll red line all your acoustics publications and we'll only look at those that have to deal with real physics. Is that a true story or not?

I don't know.

Q-It seems as though acoustics doesn't have a home because it may reside in the physics department, it may reside in the engineering department, mechanical engineering, or even electrical engineering. I know at one time they started the Institute of Acoustics; Ralph Goodwin (sic) I think was the director. I don't know what's happened to that, it was to recognize acousticians. But still at the university level, it doesn't have a legitimate home because it cuts across multiple disciplines.

Q-Yet the acoustical society is thriving and the meetings are vibrant, and it's so cross-disciplined between human psychology, physiology, music, atmospheric, ocean acoustics. It's unbelievable. It's just that the people come from diverse, academic environments, and commercial and industrial environments coming together. That's why this society is so important because of this issue of what is acoustics, and where does it belong, make your own home.

Go back to the original definition of physics and that natural and experimental philosophy. That's what acoustics belongs in.

Q-Well acoustics is one sub-discipline of physics that everyone is familiar with, except people that can't hear. But most people are ultimately familiar with sound. They think about sound a lot, and they use their ears. I think this familiarity may make it less attractive in an academic environment?

Q- I think A is more equal to 0 and is largely linear and that's what has killed off a lot of a lot of acoustics. It's where physics departments draw the line. Non-linear dynamics fine, but that gets thrown into statistical mechanics and other areas, but classic physics gets thrown out the door in physics departments.

Q-But it's kind of like ray optics, classical optics is in the same category.

Q-But optics now has kind of moved to the engineering department, it's not in the physics department so much either.

Q-But again, we're not without funding, so it seems to be application driven, the Acoustical Society of America, with the musical acousticians, physiological, physiological acoustics, the list just goes on and on, that's our home- our home away from home.

Q-But there's a difference between research, and funding, and teaching, and education of students.

Q-There's a question too, if it has become more of an applied discipline as opposed to basic research. In other words, have we answered all the basic questions about sound, I'm not sure that's true. But on the other hand, a large amount of acoustics is applications.

Q-If the wave equation was derived some time ago, it would not be disputed. But you could say that about a lot of fields. The development of it is yet another trek, and the tricks remain to be had. I mean sophisticated ones, not narrow ones, quite broad and sophisticated ones. It's just not clear where it belongs. This is one good home by the way, fertile ground in the entire floor. I found myself drawn here, realizing that there was no home. I was searching for a home, and got drawn here. It has felt natural ever since because any and all aspects of acoustics are discussed.
Actually after all this discussion of theory, you gave terrific advice on experimentation, which I don't know if you'll admit to being great with experiments, but you said you did the dull (sic) and escrew (sic) and helped advised that.

I got my hands dirty, and I enjoyed it very much. I had great fun with oseen forces, and obscene forces as well.

Q-This particular group here, our activities is one concerned on the development of methodology, being pursued in many directions. But in this institution about eight hundred staff, acoustics is being used almost everywhere. It's a very far reach. People take advantage, when people go out and take measurements of the sea floor, things from which plate tectonics were ultimately derived.

Well it’s nice to know that Brown has provided this group with two super accomplished and excellent researchers.

Q-We’re happy to acknowledge our intellectual antecedents and origins.

OK, let’s not let it go to my head. Thanks very much for inviting me here. I enjoyed it very much!