Oral History Interview
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HUBBARD: ...But this effort that results in that result is a combination of the efforts of people who don't normally work together. You've got NASA and the Department of Defense and the FAA as kind of one group. You've got the universities as another group. You've got the aircraft companies. All of them working together in a fashion that would produce a result like this is what I think is fantastic.

CONWAY: You think pulling together, getting those different organizations to work together was a major, difficult part of it.

HUBBARD: Yes. Because the companies are usually fearful of people who regulate what they do. They have to be willing to put it on the table, as it were. And actually at the start of this effort, there was no accepted way to measure noise and it's effects. All of that went into it. Then the process of applying that to the design and operation of commercial aircraft, there were profits involved.

CONWAY: You think the industry resisted being regulated insofar as noise.

HUBBARD: They always do. The implication is that the bottom line will affect their profit margin, which is true. I had the privilege, you'd say, of being in on some of the
early things that happened in air transport noise. Jets were coming into places like New York City. Do you remember Mr. Garret?

CONWAY: No.

HUBBARD: He was a division chief here early. He was my division chief at the time. A number of us and some headquarters people went up to meet a citizen's group off LaGuardia airport in that area. It really opened my eyes. They were really incensed that airplanes would make that much noise in their communities. It really affected their way of life. That's up on this end of the chart.

CONWAY: Right, with the 707-320.

HUBBARD: The 707 and it's derivatives were doing that to the people. It was really a tragedy. There's no question but they were really doing it to them. The real exciting thing is that this curve has the shape it has for the reason that a lot of different groups made contributions. And all of this time, the airplane is getting bigger and carrying more people and more this and that. You might think the two are inconsistent, but because of the effectiveness of these combined efforts, the picture looks like that and it's a terrific picture.

CONWAY: Let's go back to the New York City area stuff. That's a major part of the focus on what I'm doing, the campaigns around the New York City airports and the Port
HUBBARD: I'm not familiar with what it is. I've been away from it for twenty some years. The numbers may have changed. But back when this effort was started the effort of defining PNdB and what the levels ought to be was being kicked around by a lot of different groups. I forgot to mention the technical societies were in on this too.


HUBBARD: The acoustical society, the SAE, ASME, AIAA, all had interests and sponsored special sessions and things like that.

CONWAY: I interviewed Geoffrey Lilley a while back. Believe it or not he's here for the summer.

HUBBARD: He's a long time friend of mine. I've known him since the early 1950s.

CONWAY: That's what I wanted to bring up. You guys had essentially a very similar experiment running on both sides of the pond. You were working with an air jet to figure out the sources of jet noise. Could you explain how you came to do that?

HUBBARD: When I first came here the interest in acoustics was for small personal owner type airplanes. That was the first assignment I had was to work on a project
where we were trying to make propeller noise less offensive, because after World War II, the idea was with all these people trained as pilots, there'd be a big rush toward what we call general aviation. It really never happened for a lot of reasons. There was a motivation for us to figure out how to make them quiet. That's where the slow speed multi-blade propellers came from. It spilled over now. You see the results of that in some of these commuter airplanes. It never got lost. But on the other hand, it wasn't as exciting as a lot of other things that came later. That led to a structural study, because one of the things that was on the horizon was airplanes like the B-36 where the propellers were close to the structure and they create fluctuating loads on the structure. That was one of the things after the multi-blade propeller, the big thing was being able to design structures near the propellers so that you could fly the airplane without losing it. Then the next thing was the jet noise business. There was a school of thought around here that the commercial airplane, which was mainly a propeller airplane at that time, would go into a transition of a turbo propeller airplane and then maybe a jet airplane later on. Things happened a lot different than that and the jet airplane came on the picture quickly. What we were trying to do was to figure out where the noise came from in the jet and what you could do to alleviate the noise.

CONWAY: You thought the noise from the jets would be so bad that somehow you would have to deal with it?

HUBBARD: Yes. You only had to listen to a few of them to decide that. Jets in those days weren't like they are now. They were very high velocity jets. There was no
bypass. It was 100 percent jet. We borrowed an airplane from the Air Force and did quite a lot of initial survey work to get a feel for where the jet was coming from and where the noise was coming from. At the same time we were doing that, Jeff was working at one of the government labs over in England with some small scale devices. We pretty much later, after we got to where we could compare our activities, we kind of made the same conclusions. He has a particular interest in the analytical side of a problem and after some initial experiments, he has devoted his whole career to the mathematics movement.

CONWAY: But you’re an experimentalist.

HUBBARD: Yes. Primarily. Some people like to do one thing and some like to do another. The way I look at it, the final proof of the pudding is if you have a real good experiment and show an effect. Because if you do it analytically, you may have left out something. Eventually the two come together and one is not very useful without the other. I’m a firm believer you have to have both and work them one against the other. But my interests are in measurements.

CONWAY: I forgot to start off by asking you my usual biographical question. Who are you? What was your education? How did you come here? That sort of thing.

HUBBARD: I’m an engineering graduate from the University of Vermont in electrical engineering. You might think that’s kind of foreign to what I’ve been doing. But actually
electrical engineering and acoustics are very closely related. I had no problem there. I spent time in the service after I got my degree. I came here pretty much as a result of drawing a number out of a hat. I was in a foreign military post and there was a chance for one person to come back on R&R and we all put our names in a hat and mine got drawn out. I came to Atlantic City where the Air Force had a big hotel arrangement with people rotating around. There was a fellow named Smith who was a recruiter from Langley up there. He was interviewing people. To make a long story short, the war in Europe ended while I was there, so my assignment got changed. Draper Smith was the guy. He interviewed me for a temporary position down here while I was waiting. We all had numbers in those days and my number wasn't high enough to get immediate separation so I was looking for a way around that and he had just the thing. I could come here and work and meanwhile the numbers would play out and I could get separated. I came here and spent about a year while I was still in the service. It turned out later, I found out, that I was the only one that he ever hired from up there. He spent I don't know how many months. I figured there was something unique about that.

That's about it. The first thing I did after I came here, after a few days was this quiet airplane. The objective there was to fly a quiet airplane. They did that for one of the annual early inspections. I forget the date. It was around 1946 or 1947.

CONWAY: This is one of Fred Weick's programs?

HUBBARD: I don't remember that name. There was a propeller and an engine muffler program, a two phase program to put on an L-5 military airplane. They flew it around
for all the people who were assembled here. It was a pretty effective demonstration.

CONWAY: You were talking about the experimental work you were doing on the problem of what causes jet noise. And you and Jeff Lilley and a theoretician by the name of the Lighthill all wound up having a conference in England about this in 1953.

HUBBARD: That's about right. I visited Lighthill. He was a big guy.

CONWAY: I've never seen him.

HUBBARD: I don't mean physically. Intellectually he was big. He took me into his office. We had lunch together. He knew I had been working on jet noise and he'd been working on jet noise. He gets credit for one of the real early papers and everybody references that. He said that he did the work and then he put the paper in his desk for a year and didn't touch it, then he took it out and published it. It turned out while his paper was in his desk, Bill Lassiter and I, who had been working here at Langley on jet experiments, had written a paper summarizing what we had done. We weren't quite sure we wanted to publish it then. We were thinking of doing some more experiments. We put that paper in our desk and our paper was in the desk at the same time his was. They both got published about the same time. We didn't know what he had done, and he didn't know what we had done. We didn't know what Jeff Lilley was doing at the time. But it's always fun and really exciting to work in an area where nobody has really published much, so you really don't know what the answers are. That's the real thrill of
doing research is not knowing what the answer is. In this day and time, it's harder to find problems that haven't been worked somewhere. In those days it was easy. All the Acoustics problems were available pretty much.

CONWAY: Following the 1953 conference, I understand you had largely achieved some sort of consensus over the sources of jet noise amongst the three separate bunches you've told me about. Is that right?

HUBBARD: Yes, I think that's about right. In that time period, 1953, somewhere in here, the 707, there was effort going on to develop some kind of suppressor. Jeff Lilley had done some small scale work on that. I think he had friends at Rolls Royce that were working on a larger scale. We had a tremendous effort here going at the Boeing company on it. You don't want to quote me on numbers, but I think it was something like a $25 million effort for the company. The numbers may not be right, but it was a big effort.

CONWAY: I've seen numbers as high as $50 million industry wide. I have no way of verifying them.

HUBBARD: You'll never verify those. It's just hearsay.

CONWAY: But it's sufficient to know that it was a really big effort, which means that the company must have been afraid that cities might ban the thing.
HUBBARD: Yes. Or not necessarily ban, but restrict the operations so much that it
would be not practical, not economically feasible. There are many places in the world
where there are still some restraints.

CONWAY: There are night restrictions and various sundry things.

HUBBARD: And time of day restrictions.

CONWAY: One document I found in the NACA committee records was a comment by
Bob Withington at Boeing that the city of Seattle wouldn't let Boeing fly jets at night.

HUBBARD: I guess at one time that probably was true.

CONWAY: That was in 1952 which suggested to me that the company may have had
a very direct interest in noise reduction.

HUBBARD: At one time I heard a paper that was given probably in the literature
somewhere about flight restrictions. I seem to remember that about 100 cities around
the world had some kind of restrictions, some a lot more serious than others. That
shows you the magnitude of the problem. And it's the reason why a whole lot of people
in a whole lot of organizations came together and forgot their differences and worked
together to get somewhere. That's behind all that.
CONWAY: Let's talk a little bit about the suppressor effort that was going on. There's a bunch of publications that I've pulled out of various files showing multi tube suppressor, some that were circular and some that were rectangular. Can you tell me about how that stuff came about?

HUBBARD: You don't have to work with jets very much to learn that almost anything you can do to destroy the symmetry helps. The jet comes out and mixes with the air. So outside of the nozzle, anything you can do would be helpful. In fact the mechanic I worked with used to stick a screw driver in there. It did wonders. It doesn't take much if you destroy the symmetry in the right way without hurting the thrust efficiency. But almost everything that was tried, particularly in that Boeing program resulted in big hardware and heavy hardware and safety concerns, weight concerns, efficiency concerns and my recollection. . . . I wasn't involved in the performance end of it. My recollection is that the effort wasn't that successful. It seemed there should have been better ways to do it, which of course led to the bypass engine. And that was really the significant development.

CONWAY: I understand. So the suppressors added lots of weight and they reduced the thrust efficiency, and really that forced you to address the jet engine itself and reengineer the engine to be quieter, instead of trying to suppress it after the fact. Is that about right?

HUBBARD: Yes, that's nicely stated. And of course there was a big so called quiet
engine program at the Lewis Lab.

CONWAY:  Wasn't that later? Wasn't that in the sixties, or was it going on even in the fifties?

HUBBARD:  I don't know when it started. I'm pretty hazy. I'm sure you can do better on dates that I can.

CONWAY:  It's not a problem. How involved were you with the development of measurements standards?

HUBBARD:  There are two things working here that you have to sort out. One is that when you start going into a bypass engine, then you've got turbo machinery involved. And you've got tones that are generated. You have to figure out two things. One is how you can get rid of the tones. The other is if you do have any tones left that you can't get rid of, how can you measure the effects. It turns out that tones are normally deleterious, that you want to get rid of them if you possibly can, because it's very difficult to just have them and live with them. The project that I was most concerned with at that time was this quiet airplane. I forget what the name of it was. It was flying engines that had been treated in the nacelle with acoustic treatment to keep the tone noise from radiating out.

CONWAY:  This pub.
HUBBARD: That represents a $50 million investment, what's in there. That's pretty well confirmed.

CONWAY: The NASA SP-189. This is the sixties program that came out.

HUBBARD: That was the first results. They were pretty encouraging. Then the rest of this curve is pretty much a refinement of the stuff that was started there, better materials, later materials, better ways of installing. The bypass ratio went up, so the geometries change. You had more space to work in there. A lot of good things happened here to bring that curve down.

CONWAY: And how much do you think of that improvement is due to aerodynamic refinement of the plane, not related to the engines?

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**Fig. 1** - Progress in noise reduction.

- Normalized to 445 KN thrust
- Noise levels are for airplane/engine configurations at time of initial service

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CONWAY: That's what I thought. It's not the quiet engine program, because the quiet engine program is later on, but how did NASA put together this program in the early sixties?

HUBBARD: We got some special money from headquarters I think. We made a proposition. "Here's potentially a good thing, but we haven't flown any of these things yet and it's costly to do it." And we wanted to do it on an airplane that had some relevance, so we could demonstrate it. There are always critics. We needed to have some real good experiments and data to show that at least we were on a track that had some payoff. Where the money came from I'm not sure. But Langley had two separate contracts that are traceable back to this time period somewhere in here.


HUBBARD: For the Boeing Company to make a modification on their airplane, for the Douglas Company to make some modifications on one of theirs. I think the results there were pretty encouraging. It set the stage for this whole development of increasing the bypass ratio.

CONWAY: So this came out of a program that Langley sold to headquarters to help improve the situation.

HUBBARD: That's my recollection. There may have been some other players. I just
don't. That's quite a ways back.

CONWAY: That's a long time ago. I wasn't even born yet.

HUBBARD: I'd be a little hesitant as to where or how the thing exactly got started. There aren't many people left who probably know that.

CONWAY: There really aren't.

HUBBARD: Let me say something else.

CONWAY: Sure. You have a list of things to tell me there.

HUBBARD: As a background to all this activity, there was the activity in the technical societies. And the SAE played a big role in this. Because they had what they called the A21 committee. You may run into that in your reading. That was a committee that was in place for a good many years. I don't know how long, but probably forty or fifty years. That's stretching it. Thirty years maybe, forty.

CONWAY: I ran into that in Leo Beranek's notes.

HUBBARD: The A21 committee represented the aircraft companies, and not only American but foreign too. That brought another player into the picture, which makes
this all the more remarkable, because they were players. All of these companies were fighting for their existence really. They took it seriously. There was this committee that met once or twice a year and one of the things that they took on was this business of a measurement unit of the noise. That's the PNDB stuff. It was largely given a home there in that committee, because you had all the players there. You had the university people. You had one other group. There were the acoustical consultants, like BBN [Bolt, Beranek, and Newmann] and they had a lot of expertise and they were anxious to get contracts and to work on problems that were current. And they were a very useful group. Karl Kryter was a name that we knew real well. He essentially devoted this career to this subject. Leo Beranek, whom I greatly admire, never really got involved in the psychoacoustics part. He was physical acoustics. But Karl was psychoacoustics, and a number of other people in the organization.

CONWAY: So the SAE A21 committee is the aircraft companies. Was Bill Littlewood the chair of this for a long time? I can't remember who it was.

HUBBARD: I think he chaired it for a little and got it started. Then there was another guy from American Airlines. Who was that guy? He had it for a long time. In fact he died at one of the meetings in New York I think it was.

CONWAY: I remember reading about that too. It was Frank Kolk, their chief engineer.
HUBBARD: Frank devoted a lot of time, I would say fifteen years or more. I think he recognized the idea that people had to work together or they were going to hang separately. He was the driving force. At about that time, maybe a little later, the lab here at Langley opened up in the late sixties.

CONWAY: They started building it around 1968 and finished in 1970.

HUBBARD: That had provision for doing laboratory tests to sharpen up these measurement schemes. And it has until just recently, they are still doing it. As you read through the literature I'm sure you've done a lot of this, a new research item pops up and people start working on it. It usually goes pretty hot for about a decade, sometimes two decades. But some of these things have been going for three decades, like the stuff that Jeff Lilley talked to you about. I dare say some of that is in the fourth decade. A lot of people have gotten a living out of doing it. I guess what it shows is that it's a pretty tough problem. The first group makes a pass through it and they learn something. Then the next group comes along and they've got better instruments and better mathematical techniques, so they sweep through it and they make more progress. Then the same thing happens for the next group. Each new decade, and instrumentation is one thing that has just blossomed. During the time of this curve, back here, when I was doing some of this first work on jets, the instrument research at Langley's first high freq noise division made our analyzer for us. That shows you how crude things were.

CONWAY: There had never been any reason to measure noise at that intensity and
frequency before.

HUBBARD: The frequency was out of the range that people were interested in around here. And even to this day, the aerodynamicists largely draw a straight line through the data and the acoustics guys are worried about all the hash that is on the line.

CONWAY: All the noise. So instrumentation just didn't exist when you started. That also means that your margins of error in the measurements were pretty big too.

HUBBARD: Yes. And now we've progressed to where everything's got a computer in it and margins of error are a lot smaller and you can do a lot more different things with the data. It opens it up more to analysis.

CONWAY: I want to talk a little more about the A21 committee. I read some fragmentary stuff in Leo Beranek's papers about that committee and the resistance on the committee to the adoption of a community noise standard, as opposed to sideline which they seemed to have favored. Do you remember that at all?

HUBBARD: That was kicked around for years. I guess I was on the committee during much of that time. But I don't know from what angle he is making those remarks.

CONWAY: He's not really. What I found is a series of correspondence done at the time. What his thinking was, was that the aircraft companies and especially the airlines
didn't want a community standard because it would make it easier to sue them. 
Whereas they were happy with the sideline noise standard because sideline noise is 
on-airport primarily. It's the controversy, whether there was in fact a major controversy 
over this or whether it is a flash in a pan, is what I'm trying to get at.

HUBBARD: I think there was a lot of controversy on that committee. I think it's a 
testament to Frank Kolk to have kept the group together and kept them talking. 
Because there were divergent views right along. It was a hard problem to work. There 
is another group of people, the people who represent the community. They were in the 
act too. The A21 committee had one or two of them. I forget who they were. But 
surely the technical societies have that kind of person, the acoustical society is full of 
people who are worried about the community. ASME, AIAA, they all have that element. 
Their voice was in the discussion.

CONWAY: There was a national level noise committee too that the Johnson 
administration started. Was there a lot of interaction between the professional society 
committees and the political level committees?

HUBBARD: Well the EPA I believe was represented on the committee.

CONWAY: That would be after 1968 or 1969. The EPA is founded one of those 
dates.
HUBBARD: I'm certain they were on the committee for a time.

CONWAY: I was going to ask if there was NASA representation, but you were on it, so of course there was.

HUBBARD: There were a couple of us. I think there was a Lewis representative. I was on it for a few years. Dave Stevens was on it more recently. Have you talked to Dave at all?

CONWAY: No.

HUBBARD: Yes, he was the division chief in acoustics here at Langley and was on the A21 committee in this period down here, probably 1980. I think he was on the committee down in here. My tenure was up in here. There was a lot of controversy on the committee. It wasn't a committee where people sat down and everybody was cozy. There were a lot of arguments because of the conflict of interest.

CONWAY: What sorts of controversy were there? Were there controversies over measurements standards, or of rather how to measure, or were they controversies between manufacturers over whose airplanes were quieter? What kind of controversies are we talking about?

HUBBARD: I would say how to measure and where to measure. Because some
airplanes make more noise out the side and some make more noise out the back. Different kinds of airplanes. Where you measure and how you measure are both important.

CONWAY: Controversies over essentially the construction of what eventually would become the part 36 regulations is what it amounts to.

HUBBARD: Yes. And the FAA played a big role in that because they were going to be the administrators of it. A fellow named Bill Sperry, who now is dead, devoted a large part of his career to both how and where to measure.

CONWAY: It took the FAA a long time to get regulations on aircraft noise out. Do you have any insight into why that might be?

HUBBARD: Of course they advertise and have hearings and I guess I lived through that time. I even went to some of the hearings. It's quite a lengthy process. You have hundreds of people who testify, then there's a digestion period after that to figure out what all that means, and then some decisions are made and regulations are put forward. I'm not sure I know all the ins and outs of it, but the idea I guess is to get the general public in on it, as well as the technicians. They went through all the steps and I suspect there was some unhappiness somewhere at that time, there usually is. They deserve a lot of credit for having the courage to push it and get something on the books. If you don't have something on the books it's hard to improve it.
CONWAY: They drew a great deal of criticism with the first standard things that only affected future aircraft and not current ones.

HUBBARD: Yes, well, for obvious reasons I guess. It would have bankrupted the whole industry if they made it retroactive. It's hard to make anything retroactive especially where aircraft design is involved. It's hopeless, I guess.

CONWAY: It's enormously expensive to go back and fix it after the fact.

HUBBARD: Although having said that, some of the early airplanes were retrofitted with hush kits with limited success, enough to meet whatever criteria they were trying to meet. That one thing we can say is that the technology is such that you can design to a certain number. There are methods, which means that the whole technology has grown up and that it has evolved into workable applications.

CONWAY: Since you brought up hush kits, there were actually several NASA problems after about 1968 to develop modifications for engines. There was the quiet engine program, and there was another one, the refan program. How involved with those were you?

HUBBARD: Very little. They had their separate channels of input into this process. That was a different group of people, but I think a lot of the ideas that were developed back there have probably now shown up in some of these. There was a lot of work
done on how you put absorptive materials and interactive materials into the cells safely. A lot of thought was given to that. There are some design rules established. But that was outside of the things that I was involved with. And a lot of it has happened since I retired.

CONWAY: I think there's been a great deal of work that hasn't found its way onto new airplanes. It seems to me there isn't a new standard yet. They're just starting to fight over a new standard.

HUBBARD: Probably so. I don't know what the situation is on the new engines, whether they've run out of technology or whether they've got some in the bank yet. I don't know who. I guess you'd need to talk to some company people.

CONWAY: I know that GE's in-house publication last year was bragging that they had the stuff to do another 50 percent noise reduction in their next new engine start designs. I don't know how seriously I want to take 50 percent, but it sounds like they have some substantial things left to do, at least they think they do. That's the future. You were working on the SAE A21 committee in the sixties. And what else were you working on noise related at the time around here?

HUBBARD: One of the most exciting things that I was involved in was the sonic boom research.
CONWAY: I was going to bring that up.

HUBBARD: This research here as I told you before I think is a substantial contribution. If you didn't have this, you wouldn't have the world wide air systems that we have. They wouldn't exist.

CONWAY: I agree. The communities would have shut it down.

HUBBARD: Right. So there was a need for it. People got together, different groups got together, developed the technology and applied it. And the rules have been published and there are those who are policing the rules. So it's a whole continuum of activities that have led to a very desirable result. And all this time the airplanes are getting bigger, carrying more people, but not going faster.

CONWAY: But they're getting a lot more fuel efficient.

HUBBARD: Yes, more efficient. And essentially making less noise. They've probably got a little ways to go. But when you look at any other industry, that hasn't happened. But in the aircraft industry, if you're looking for an example of noise reduction, aircraft industry has got it all. Hardly any other industry has got all the pieces. A little bit here, a little bit there, no rules to go by, nobody to police. Maybe they don't have the technology, although I think in a lot of cases they've got the technology, they just haven't been forced to apply it. But I think you've got that picture. Looking back on a
career if you had a part in this you could feel good about it.

The SST project had its real exciting moments and its disappointments. But the sonic boom was one of the most exciting things I've ever done.

CONWAY: When did you start getting involved in this sonic boom work?

HUBBARD: The late fifties I think it was.

CONWAY: That's what I expected. It's something like 1952 or 1953 before somebody even reports the bang.

HUBBARD: I think there was one serious measurement made by somebody somewhere before we got into the act here. And the thing that was exciting, several things, John Stack who is a big name here had that under his wing.

CONWAY: He loved the SST.

HUBBARD: He loved the SST and he loved anybody who had any ideas for research that he could sell. He sold the SST research. He was a good salesman. I hope you won't print this. I worked a long time for Mr. Gilruth. Mr. Gilruth is a famous guy who did a lot of good things. You make some kind of a proposal to him for doing something and he'd put it on a pile of stuff on his desk and probably wouldn't look at it, certainly anytime soon. You never could get a yes or a no out of him. He'd say, "Let me think
about it." When you went to Stack with an idea, before you got out of his office, you had a decision. He liked action. We were right there at the right time. We got Air Force support and that was substantial. We got FAA support. The EPA was interested. And of course the companies were very cooperative. They were interested too, although I don't think they put much money into it. We had mostly federal funds. At one time, up to a few years ago, I had the planning role in just about every flight that was ever made for research purposes in sonic booms. And we were trying to measure the wave patterns around the airplane. We were trying to measure how the waves propagated, how if you operated the aircraft differently what you got on the ground, how important that was, the effects, the effects on people, what it did to structures, to animals and all that stuff was part of the program. There was a while there where every month I would gather up what we'd learn and went up to the executive office building in Washington. There was a big committee up there and they'd review it and give us ideas. There was so much interest in the program that people were tying in with you monthly. I'd get calls from, not the director of the agency or the administrator, but people second or third in command up in headquarters. They'd call down and talk to me about progress. I couldn't hardly believe it. We had the university participation. We had some of the companies helping us, the other government agencies and the technical societies were very interested. We had special sessions and conferences and things like that. The results, somebody like Stack was hoping that the results would be very optimistic, but they weren't. We had to relay that to a lot of different people.
CONWAY: A lot of bad news.

HUBBARD: A lot of bad news. The interesting piece of it was that it was a project that if you needed something you got it, within reason. If you had a reason for wanting to do something and you had a way to do it, you got to do it, which is very unusual in research. Usually you're scraping the barrel in all directions. Am I using too much tape?

CONWAY: No, I just need to keep track. These run out after 74 minutes, so I'm just making sure that we're not about to run out of recording space. Keep going.

HUBBARD: Of course there were foreign interests involved, and a lot of community interest. People were worried about breaking windows and scaring pheasants and a lot of things that we researched during that time. But most of the news was bad. Animals apparently adapt, like deer herds aren't spooked. Cattle grazing in the fields, horses. There was concern out of Edward's Air Force Base. There was a pheasant farm out there that had twenty or thirty thousand pheasants. That's a sight to see. They're all caged up. The farmers were so afraid that they're going to be scared. If they're scared, they run and they get into the corner of the cage and they pile up and kill each other. So they've got to be happy all the time. Turkeys are the same way. These pheasants had little glasses on their noses. They pinched them on. They weren't glasses, but opaque lenses. They couldn't see forward, they could see sideways. We did things like flew airplanes over at a specified time and took pictures of the flock.
CONWAY:  To find out whether they were afraid of it. That's a bit I hadn't heard of. There is a big mink test.

HUBBARD:  A lot of mink problems were complained about. I guess there was something to it. The Air Force paid a few bills. We did a lot of structural tests on elements of buildings, like windows mainly. But we measured the wall vibrations, because not only would you have a potential structural problem, but you'd have a psychological environment that would disturb people. If you're inside a room and you're excited with a boom, a lot of things happen. If the walls move, then you get pictures moving. You get furniture moving if it's against the wall. You've got things falling off shelves if the shelves move. So a lot of different things can happen. Some of these houses have a friction pull on a light, like a spring-loaded shaft with the lights on it that go from floor to ceiling. If you move the ceiling then the light falls over. We did a number of studies and had engineers go out and investigate damage. The damage was real, but very superficial in the category of plaster cracks and window cracks. And in real severe cases, maybe a whole ceiling would fall, because the ceiling was excited or the plaster was not cured. There was usually contributing factors to large damage items. Most of the items were superficial.

But one of the plus things that came out of it, I'd guess you'd say was that we learned how to operate the airplane to place the booms in a certain place. The Concord is using that all the time now. You've got a fore and aft location problem and you've got a transverse location problem. The transverse one has given them some trouble. The longitudinal one I think they've got right on the barrelhead. The effects of
weather is another thing that we pinned down very nicely. In fact the late Jack Reeder worked with us here locally on some things where we pretty much defined what it took for the wave to come from the airplane down to the ground. And there is a very simple relationship there. If the airplane's speed is less than the speed of sound at the ground, you don't have any transmission.

CONWAY: There's no transmission, right.

HUBBARD: That's a very neat thing to know and to use if you're flying airplanes.

CONWAY: Which means that up to mach 1.4 you can actually make a boomless plane.

HUBBARD: 1.14. You don't have a whole lot to work with, but you do have some. And there is what they used to call a super boom. When you accelerate the airplane, there is a little local area where the waves pile up and accelerate as you're going from subsonic to supersonic. You can located those super booms very accurately within a mile. If you've got good weather information you can do it better than that. The sideways boom is something that is very interesting, but not very controllable.

CONWAY: Especially in a turn, is that right?

HUBBARD: A maneuver is something else. Let's come back to that. If I'm flying
supersonically here, maybe I can show you a picture of it that will save some time. I know it's in here.

[begin tape 2]

HUBBARD: This sonic boom thing was exciting because so many people were interested in it, so many players. We couldn't get the information fast enough. As a result we were travelling most of the time and hardly doing any writing. We got way behind in our documentation. Only recently has that been caught up. Dominic Maglieri, a fellow who used to work with me and now works at Eagle Engineering has done a lot. Do you know Dominic?

CONWAY: I've talked to him on the phone, but I couldn't get him to consent to being interviewed, unfortunately.

HUBBARD: He's a very knowledgeable guy especially in the sonic boom stuff.

CONWAY: Everyone tells me that he's the expert.

HUBBARD: I'm kind of surprised that he wouldn't do it. He could do it. He's a very talented guy.

CONWAY: I'll try again. I'm trying to interview Neil Driver again too.
HUBBARD: Tell him you talked to me and that I thought he ought to talk to you.

CONWAY: Alright. The sonic boom theory that Maglieri and a few others come up with in the late fifties don't include a weight and volume aspect to the formula. Is that right?

HUBBARD: Some of the early theory did not include the lift element.

CONWAY: The lift component.

HUBBARD: I think the theory is in pretty good shape.

CONWAY: I wanted to look at the historical development of the theory and the lift effect is not included. Do you think it's because the airplanes were too small to notice it in the fifties?

HUBBARD: Dominic would be somebody to ask about that. He's got the largest sonic boom library in the world. He's got more stuff than you can get from this library here. He's got personal communications of a lot of things. I'm serious about that. A lot of people worked on the theory. That again is not one of my big things. I would defer questions like that to somebody else. But certainly in this day and time the theory is very useful. It's in good shape as far as I know and is being used all the time.
CONWAY: So what you were involved in with the sonic boom was in measurement of the effects.

HUBBARD: Measurement and effects and generation and airplane operational effects and weather effects. And the effects on structures and animals. We had veterinarians working and all that. All we did was arrange things so they could get their data. Even had fish experiments and bird egg experiments and a lot of things that were important to some people. They needed to either feel bad or feel good about some of those things.

CONWAY: How was the National Academy of Sciences committee involved in all this?

HUBBARD: I'm not sure there was one at this time. Over the years we've worked with the National Academy a lot.

CONWAY: Through the CHABA?

HUBBARD: I don't remember. Things were happening so fast here. I don't think they had a chance to get organized. It usually took a year or two for them. They had a lot of talent. But they would meet on a problem and study it and write a report. I certainly don't want to short change them because they've always done a good thing for NASA, especially in the airport noise problem area. But I can't remember how they interacted
CONWAY: I've been through their records and I know what the reports they were generating say. I was wondering if they had a coordinating role.

HUBBARD: No, I don't think so. They're a very slow moving group. They're talented and got a lot of information, but to run a research program involving airplanes, forget it.

CONWAY: The operating agencies had to do it. You told me you got a lot of interest out of the Air Force on this. Why was that?

HUBBARD: They were paying bills right and left for damage.

CONWAY: Damage claim bills.

HUBBARD: That was one of their interests. The other interest was people just didn’t like hearing the booms. It impacted Air Force operations. The Air Force and to a limited extent the Navy have these supersonic operating ranges around some over land, some over water, and some a combination. They're off the east coast, off the Gulf coast, in Texas, some places in the west, over land, and so they're sensitive to any kind of adverse impact on people living there. There was one other interest that they had and that was whether the sonic boom could be used for any benefit in their operations.
CONWAY: As a weapon.

HUBBARD: I don't know what the current status is, but for the airplanes that we had to work with back in, I don't know what time period it was, I could get it out. It was like F-104s, 105s, things like that, we could do some damage with them. But it didn't seem to have a lot of potential. The concept was, you could take a city like Boston and you could buzz Boston with conceivably an airplane or even a missile, something that would generate a wave. You could go through and take out most of the windows. Windows are windows. It's nice to have them in cold weather, but it isn't that big a deal. Would it be worthwhile? You'd probably have to design an airplane to make a big wave. Maybe you'd fly it remotely. There were some thinking like that, but I don't believe it went too far.

CONWAY: As soon as you found you've got to generate a really large pressure wave in order to do real structural damage.

HUBBARD: During World War II the Germans put a lot of effort into evaluating acoustics as a weapon against people. You can find that stuff in the literature. It's very interesting reading. I think about the only thing I remember from what I read was if you put the right kind of a fur coat on a person and excited him with the right frequency, you could kill him because you could increase his body temperature beyond safe limits. But for battle field type stuff, you couldn't.
CONWAY: They weren't very successful. That's just bizarre. But they did all sort of bizarre research during the war.

HUBBARD: One of the recent things I did and it was really neat, was this wind turbine study. And that's a little different, although all this stuff we've been talking that relates to airplanes also related to wind turbines. It's always interesting to get in early on a research area where you don't know the answer. After I retired I got doing some of this. The problem was, is there a problem and how do you alleviate it. I think our attack on it was very efficient, because we already had the airplane experience and could relate it directly to these big rotating blade systems. One of the things that had been observed and the surrounding communities didn't like it was the low frequency noise generated by some of these big structures. Some of the blades were three hundred feet in diameter. It was like a wing of a 747.

CONWAY: Going around in a circle.

HUBBARD: We made some measurements as far as 20 kilometers, the blade passage frequency.

CONWAY: This is in the eighties that you were doing this?

HUBBARD: Yes, the late eighties.
CONWAY: The idea was to make the noise of the wind turbines more acceptable.

HUBBARD: The wind turbine is an interesting piece of equipment. Because if the wind is blowing you want to keep it operating. In some places of the world the wind blows for days and days and through the night and day. Maybe for weeks. Like an example is the trade wind area of Hawaii. Once the winds start blowing they just keep going. You've got a different exposure pattern. It's not like an airplane landing or taking off over your house. You get a few minutes of that. But these last for days all day long and all night. It's a different exposure problem. And a different frequency range. You've got these frequencies that move the house, move the windows. So all of that is in it. But the real neat part of all this was that we had a pretty good chance when the study was over to document it. It's probably better documented than anything I've been involved in.

On documentation this is...

CONWAY: Aeroacoustics of flight vehicles that you edited.

HUBBARD: The AIAA did that, got me to do that.


HUBBARD: This is the third printing. They've printed 2,300 copies.
CONWAY: They've got to have this in our library here.

HUBBARD: The reason for doing this as it was explained to me, and this is one of the AIAA committees, you get to a point in time where you've completed one of these research cycles and so you've got a decade or two decades of work and the people who did the work are leaving the area, because they are dying, they're going into other work, they're getting promoted. So you have to capture them before they forget all they know about it.

CONWAY: And it helps the next generation. It gives them a place to start. We've pulled it all together into one nice two volume piece.

HUBBARD: Like if I was a new employee at the Boeing Company, they'd give me one of these and I'd get a running start.

CONWAY: They'd say, "Sit down and read this." I'll dig that up out of the library. It looks like a couple of good articles.

HUBBARD: This is written from the perspective that you kind of gather together what you know about a subject and you don't have all the derivation of equations. That's in somebody else's book.

CONWAY: I'm a historian. I can't deal with equations. I draw the line at charts.
HUBBARD: This is a chapter I did with John Houbolt on vibrations induced by acoustic waves. We did a chapter for this shock and vibration handbook.


HUBBARD: Creed is dead. Harris is still writing books. If after you think about, if you have some questions I could work on those. My memory straight off isn't that great anymore, but I've got enough notes around the house I could go back and reconstruct a few things if you need to.

CONWAY: I've been through part of the noise files that the Langley lab generated. They're all up in storage in Philadelphia now. I built myself a data base. I have to admit the whole thing seems to me has been reasonably straight forward from the NACA/NASA end of things. And as you say, it's been obviously a very successful piece of work. I haven't had that many detailed questions to ask you because it's fairly clear.

HUBBARD: It's one of the key enabling technologies for airplanes. Without it you don't have much.

CONWAY: One thing we didn't get into is structural acoustics. I know for example that the Lockheed Electra had big problems with pieces being shaken off by the props.

HUBBARD: That's covered in here.
CONWAY: That's covered in the Harris and Creed book.

HUBBARD: One of the things that came out of these studies is the detailed design of components of the airplane. What you've got to do is get rid of stress concentrations. And you do it by getting rid of angle turns and rivet holes and things like that if you can. That's why bonding has been very effective. No rivets at all in this.

CONWAY: So that's partly coming from acoustics.

HUBBARD: It's all acoustics essentially. If you didn't have the jet noise pounding on it or the boundary layer noise pounding on it, you wouldn't have these problems, or the engine noise radiating out to the flaps and the tail section and the aft fuselage and places like that.

CONWAY: I see.

HUBBARD: It's a noise loading. The B-36 had fluctuating loads from the propellers. It was a pusher airplane and it loaded up the wings and the flaps on the flap areas. One of the British airplanes, was it the Comet? No I don't think it was the Comet. It was later than the Comet, had an aft end fuselage structure problem that was very difficult. They had to work real hard on it. The B-52, one of the data points if you will, the B-52 was a spare one they had that they weren't going to use anymore. They anchored it down and ran the engines full blast for about two hours. At the end of that time the
airplane was essentially a piece of junk. It was just destroyed because of the noise load.

CONWAY: And because the airplane couldn't flex in response to it because you'd anchored it?

HUBBARD: No. That would imply large motions. These are the panel structures, the flap structures, that sort of thing, not the spars.

CONWAY: Then the early B-52s couldn't operate at full power for very long.

HUBBARD: They had a lot of problems with structural problems. Their maintenance problems were substantial. But they were on top of them and they were able to . . .

CONWAY: They were able to overcome them by changing the ways they made the parts.

HUBBARD: That's one thing and stringent maintenance.

CONWAY: That clearly fed into the 707 and so on, because it's the same engine on the early 707s.

HUBBARD: I think every airplane is a little heavier than it would be if you didn't have
this problem.

CONWAY: If you didn't have the acoustics loading.

HUBBARD: In the aft part of the airplane you've got the separated flow along the fuselage and so you've got a fluctuating loads situation there and it shows on the tail. But most of the designs, I really don't know what affects the design say on a 747. I think acoustics is in on it in some places, but like the tail section is completely designed by someone other requirement.

CONWAY: I understand. I don't have any more questions for you at least not at the moment. Do you have anything else you think I should now before we wrap up?

HUBBARD: I guess I'm interested in what happens to all this.

CONWAY: I always tell everybody that. What I'm going to do is I copy the disks over on to cassette tapes and I send them off to a transcriptionist. She will turn the interview into a stack of paper. Then what happens is when I get the transcription back from her, I edit it and I send it to you so you can edit it to make sure it accurately reflects what you said and the names are all spelled right. Once you've signed off on the transcription, we sign a legal type cover letter that puts access limitations on it. You can make it open to the public, open to only people with your written permission, or closed until your death and then the transcript winds up in this office and up at the
NASA headquarters history office. That's what happens to all of it.

HUBBARD: So it's not a formal history. It's just a write up for the archives?

CONWAY: What I will do is I will use it in what I'm doing is a history of supersonic transport research for NASA. What will happen is that all of these interviews I'm doing with wind up as source material for that book. And because the transcription is retained permanently, then other people can use it for other books if they should happen to be interested. It will eventually wind up as a book, but my manuscript is due in two years, to be finished. I'm giving a paper on aircraft noise abatement next month at a conference in Prague, and I'll be turning that eventually into an article for one of the history journals. So they'll all eventually be written up into published products, but the transcript itself doesn't get published. It stays around here. That all makes sense to you?

HUBBARD: I guess. I've never been involved that way before.

CONWAY: History works a little bit differently than engineering, but not a lot differently. We still have to publish things.

[end of interview]