NASA JOHNSON SPACE CENTER ORAL HISTORY PROJECT
ORAL HISTORY TRANSCRIPT

BONNIE J. DUNBAR
INTERVIEWED BY JENNIFER ROSS-NAZZAL
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ROSS-NAZZAL: Today is December 22nd, 2004. This oral history with Dr. Bonnie Dunbar is being conducted for the Johnson Space Center Oral History Project in Houston, Texas. Jennifer Ross-Nazzal is the interviewer, and she is assisted by Sandra Johnson.

Thank you for joining us this morning.

DUNBAR: Thank you.

ROSS-NAZZAL: Thank you. I'd like to begin by asking you about your interest in becoming an astronaut. I've read that in the third grade you decided that you wanted to become an astronaut. Why did you make that decision at that point?

DUNBAR: Well, you know, it's very difficult to reconstruct all of the events, but when I was first asked to think about that, I think maybe one of the first classes I went to talk to, maybe a primary school or something, it caused me to kind of reflect on where you come up with that idea when you're nine years old. I was in the third grade, but it wasn't out of class. It was very much separated from what I was studying in school.

When I thought about it, I thought, well, I have to reflect on my family and growing up on a ranch in eastern Washington state, where this all came from, and I think it had to do a lot with just some of the philosophies of my family. My grandparents had emigrated from Scotland

and homesteaded in Oregon, and so I had a grandfather that I knew till he was ninety-two, who always used to talk about the horizons; why he emigrated to the United States so he could own his own soil; was a great kind of adventuring mind, and education was the key to the world, and you should learn to read and do as much as you can in terms of learning.

My parents homesteaded in Washington state in 1948. I was born in '49. I was the oldest of four kids, and it was expected that I would go to school and study hard. They didn't have any expectations about what I would be, but homework was mandatory. Good grades were mandatory. Reading was mandatory. The first set of books my mother ever bought was this set of encyclopedias, and they were in the living room, and when we finally got a TV, and I was about eight, I think, if there was any question about what we were seeing, we would look it up in the encyclopedia. Or if I asked my parents a question, they'd say, "Well, we don't know, but look it up in the encyclopedia." Not only did you have to look it up, you had to read it to the rest of the family, and it was fun. So reading was mandatory to be able to participate in this game.

One of those early shows that I used to come home from school and watch was *Flash Gordon*, and Flash Gordon was exploring the universe. There was no special effects. If you look at these programs today, I think you can even see the wires holding the little spaceships as they fly through space.

But then actually when I was eight, *Sputnik* was launched, and I remember that my parents took me out and we looked for *Sputnik*. I'm pretty sure we saw it, because eastern Washington has clear night skies, especially in that time of year, October. The Milky Way, when I was growing up, was a band of white across the night sky. I mean, you knew that was the Milky Way. And I just became completely engrossed in space and stars and H. G. Wells and Jules Verne, and any book about space I found in our very small rural school, I read.

So it was kind of natural for me. It was what sparked my interest. It was exciting, and the questions were unbounded. What was out there? What did these places look like? Even though I finally learned in high school that people thought we were the only solar system in the universe that had planets, I personally didn't believe it, and so it was no surprise to me that in I think it was '96, '97, we started discovering other planets in other solar systems.

So that's sort of the genesis of it, and it propelled me through engineering. It never occurred to me not to want to do it or to be discouraged by those who thought that I shouldn't do it, because I came from my own family culture that said, "This is the United States of America." My father used to say—he was a Marine in World War II in the South Pacific—"I fought for my sons and my daughters to be able to become what they want to become if they wanted to work hard enough to do it." So in my mind, that was the American ideal, and in my mind, what I wanted to do, where I felt my place in the world was, was helping to explore space.

ROSS-NAZZAL: So even though astronauts at that point were male test pilots, that didn't deter you?

DUNBAR: No, it didn't, because my parents made me believe that I was equal. My father—being the oldest child—was one of my strongest mentors. We raised Hereford cattle, and I wanted to show cattle. Actually, my father asked my brother and I—my brother was sixteen months younger—if we wanted to show cattle. He was very proud of his registered Herefords. It turned out that FFA [Future Farmers of America] at that time was not open to girls. So my father started a 4-H Club—I was nine years old—so that I could show cattle. I showed cattle for nine years, till I was eighteen years old, in 4-H.

ROSS-NAZZAL: Do you ever miss that lifestyle, living on a farm?

DUNBAR: Well, my parents are still there, so I miss it, but I get a chance to visit it frequently.

ROSS-NAZZAL: You came to this decision fairly early in your life. How did you prepare for this future career through elementary school, junior high, and high school?

DUNBAR: Very accidentally. [Laughs] The early books I read said that—you know, about NASA. Of course, NASA was starting to bloom when I—about this age. The Space Act was signed in ’58, so I guess I was nine years old at that time. Then Alan [B.] Shepard [Jr.] flew, John [H.] Glenn [Jr.], and as I was coming through school, and this school I went to, Outlook Grade School [Sunnyside, Washington] it was called—it’s Outlook Elementary now, I think—went to eighth grade; that was it. There was twenty-two in my class; pretty much twenty-two from first to eighth grade. Then we graduated, and then we had to take another bus into Sunnyside High School [Sunnyside, Washington]. But as I was graduating from eighth grade, our principal asked me what I wanted to do or become, because we had to pick electives in high school. I was a little embarrassed to tell him I wanted to be an astronaut, so I just told him I wanted to build spaceships, design spaceships.

He said, “Well, you’ll have to know algebra.”

And I said, “What’s that?”

He said, “Well, trust me.”

So I signed up for algebra in the ninth grade, and went on to—of course, that's the key. Algebra, geometry, trig [trigonometry], math analysis, calculus, chemistry, physics. If you don't have algebra, you don't have the rest of the train. High school for me was wonderful, because I had access to all this wonderful learning and books. The library was bigger. And then I did all the other things. I was in athletics and Debate Club and Speech Club, and I was a cheerleader for three years, and so I was marching on, getting good grades, and I was reading these books.

The books said that astronauts went to MIT [Massachusetts Institute of Technology, Cambridge, Massachusetts] and Purdue [University, West Lafayette, Indiana] and Caltech [California Institute of Technology, Pasadena, California], and so as I prepared to apply to college, I asked around and applied to all of these places, and was accepted at the University of Washington [Seattle, Washington]. I couldn't afford MIT, because we were ranching and farming, but ranching and farming was not a big, profitable business; wonderful lifestyle, but not real profitable. I was going to have to find my own funding to college. Caltech turned me down because they didn't accept women. This is fine; my high school counselor didn't even know that. But the University of Washington not only accepted me, but they offered me what was called a National Defense Loan at that time—Grant and Loan—which enabled many, many young people in my position to go to universities to study science and engineering.

So I brought the paperwork in to my physics teacher, because it asked me to pick a college, and I thought I'd picked one. I picked the University of Washington. [Laughs] And so my parents looked at it, and they didn't quite understand it, either, so I remember going in and talking to Mr. Anderson, and I said, "Well, here I'm supposed to pick a college, and I don't understand this."

He said, "Well, it's within the university, there are these different colleges."

I said, "You mean I can't just take classes in everything?" Because I was also very interested in the Romantic poets at that time as well, [Lord George G.N.] Byron, [Percy B.] Shelley, and [John] Keats, and I wanted to continue reading in that vein in literature.

He looked through it, and he said, "Well, I think you ought to check the block on engineering."

And I said, "But what is that?"

And again I got this statement, "Well, trust me." He said, "You know, I think this is where you'll do well," he says, "if this is—," because I'd told him I wanted to build spaceships.

By that time, 1967, things were really starting to look real, because we eventually landed on the Moon in '69. And that's how I became an engineer. I was very, very fortunate. People gave me good advice at the right time. I had a very supportive family. So by the time I was eighteen and a freshman in engineering at the University of Washington, there was no doubt in my mind that even though there were only men flying in space at that time, that this was the United States of America—my parents had told me that—and eventually, if you're qualified and work hard enough, do well, that those doors are going to open.

I met a dean there in ceramic engineering, Dr. James I. Mueller, who had a NASA grant to work on the thermal protection system for the Shuttle, who convinced me that I should change my major from aeronautics into materials engineering or ceramic engineering, and I did. I talked to him about what I wanted to do. He was extremely supportive, and every time the NASA review team came to assess how well the department was progressing in this research, he introduced me to them. That's how I met Dr. John [D.] Buckley from Langley [Research Center Hampton, Virginia], Dr. Howard [E.] Goldstein from Ames Research Center [Moffett Field, California], Jim Gangler from NASA Headquarters [Washington, D.C.], all part of the team reviewing research that was instrumental for developing the thermal protection system for the Space Shuttle. That then put me on a course of becoming more involved in the real parts of space.

ROSS-NAZZAL: At this point were you actually working on the tiles with your mentor?

DUNBAR: Yes, they had summer positions open, and so one of the summer positions at the University of Washington was doing X-ray diffraction research on some of the fibers that NASA was considering. Silicon dioxide is what we finally selected, silica fibers, but we were actually looking at different forms of it, cristobalite, other compositions, and we would heat them up and see whether or not they went from a glassy state to a crystalline state. That's called devitrification, and the reason that's important is because when that happens, they change volume as well. So you don't want a tile that's exposed to 2300 degrees Fahrenheit on reentry suddenly changing volume, changing shape. You lose the integrity of the protection system. So you start at the very smallest test, taking individual—well, actually almost powder is what it is, powdered X-ray diffraction—determining whether there was a face change when it was exposed to these temperatures. We compiled all that data and supplied it to NASA.

ROSS-NAZZAL: Let me ask you, while you were in college, Apollo 11 was the first flight to land on the Moon. What are your memories of that mission?

DUNBAR: I remember it very much. I was between, let's see, that would have been my sophomore and junior years. It was the summer, July 20th, 1969. I was visiting in Kennewick, Washington, with one of my high school friends who was also in engineering with me, so we arranged to watch it at his parents' house. We were sitting down, but I don't think I could have stood up. It was the most exciting moment, I think, of all of our lives, just to see those pictures.

ROSS-NAZZAL: I can imagine. After you finished your degree at the University of Washington, you went out and you were working for Boeing [Airplane Company], but you came back and were working on your master's degree, and you actually were working on a NASA research grant. Can you tell us about that work?

DUNBAR: I was working as an engineer at Boeing, and I received a call from Dr. Mueller, saying, "Have you considered coming back to graduate school?"

And I said, "No, actually." I said, "I'm finally making a salary."

He said, "Well," he says, "we've got a NASA grant coming in, several, and I'd like you to apply for graduate school." And so I applied, and of course the faculty has a vote, and they vote you in.

Then I had to pick an advisor, one of the projects, and I actually picked my advisor sight unseen, because he was still coming in, I think from the University of Cairo [Cairo, Egypt], but his grant had to do with high energy density battery materials called beta alumina, and what we were trying to determine is how sodium was transported through this material. It was a powder that was compacted, and in order to help the battery process, part of that transport was that sodium had to diffuse through it. So I was looking at diffusion coefficients for sodium beta alumina. But Dr. Suren Sarian was my advisor on that, and so I picked the project, and then he showed up, I think, a couple of months later, because I started earlier in the summer, to pick up some classes. I had to pick up quantum mechanics, and I wanted to be able to focus on that. Then so the fall of 1974 is when I started working under him.

ROSS-NAZZAL: Were you working on this project for a specific NASA Center?

DUNBAR: I think it was actually administered out of Headquarters, but if I were to guess which Center probably had oversight, I would probably think it was maybe, at that time, Lewis Research Center [Cleveland, Ohio]. Maybe Langley, but possibly Lewis.

ROSS-NAZZAL: Were you advised by NASA as to what your research would be used for in the future?

DUNBAR: I received that information, actually, through Dr. Mueller and Dr. Sarian. Yes, high energy density batteries were to be used for spaceflight. We were looking, you know, low mass and more energy. When they say high energy density, more power for the unit volume of mass that would come out of that. There was a lot of other work, similar work being done, actually, in the automotive industry. After I finally received my master's degree, I was invited to give a lecture to the Ford Motor Company in Dearborn [Michigan], who was also doing similar research.

ROSS-NAZZAL: What was the reaction of the auto industry to your research?

DUNBAR: We all were working on little pieces, so I didn't win a Nobel prize for what I was doing. I was actually looking at the diffusion coefficients, but diffusion coefficients as a function of the alignment of grain boundaries. What we had found in hot-pressing these sodium beta alumina samples is that they were not isotropic. They were anisotropic, so it did matter how you aligned this material to the electrodes. So I had very painstakingly done this research with gamma emitters, with radioisotopes, to measure this difference. It was very subtle. The tracers I had had half-lives of about sixteen hours, so any one experiment would take twenty-four hours. I'd be up for twenty-four hours. So I did this over two years. I had a wealth of data, and it was very meticulous, but—so it provided one number.

But that's what research is all about. Sometimes it's like watching grass grow, but you can't rush it. But it's very instrumental to getting to the final answer. And it's as we all produce these single numbers, each one of those numbers has to have integrity. Otherwise the final assumption is incorrect. So what my number had was integrity, and I was very proud of what I produced. We actually, I think, got three papers out of that.

One of the most illuminating moments for me as a graduate student was to spend a weekend and come out with one of those numbers, which I knew had to be wrong, and I knew it had to be wrong because in my literature search I had pulled up a paper from a very renowned researcher at Stanford [University, Stanford, California], who had come up with another value. I wasn't repeating his research; he'd found it by a different method, but my procedure was different, new, so I remember going through all the math and the calibration of my scintillation counter and so forth, and finally, I couldn't find my error.

I went up to Dr. Sarian, I think when he came in on Monday, and I had been up a long time, and I said, "I can't find what I did wrong." And I said, "This number is not coming out right."

He looked at it, and he says, "Now, why don't you think it's right?" And I showed him. I won't name the author of the paper, because I have met him; he's very well known. Sarian looked it over, and then he looked at me, and he says, "Now, why do you think you're wrong?"

And I says, "Well, because it isn't the same number."

He says, "I don't see anything wrong with your data." He says, "At some point you're going to have to recognize that you can be right, that you might have something that's better or known."

Gave me a tremendous amount of confidence, that day. So you still have to do your homework. You have to be sure about what you know, but when you do know it, then you have to have the confidence to stand behind it. Then we published our data.

ROSS-NAZZAL: What ultimately happened with this project, do you know?

DUNBAR: We don't have a lot of sodium beta high energy density batteries out there, because in the automotive industry at the time, oil was still cheap. I think we're going to start seeing the cost-benefit curves cross, and it may not be the sodium beta alumina battery. That was thirty years ago so you're going to see other materials, but you're going to see more battery-driven cars, automobiles.

Now, on the space side of it, there may have been other technologies. As we start exploring, I don't know if this battery technology has any applications. I've been away from it too long. But we're also looking at nuclear. Thirty years ago, the thought of putting nuclear in space at that time for the kind of applications we're talking about was pretty much limited to radioisotopes for some of the deep space robotic explorers in very low power levels. So the times have changed. I don't know, there might be an application in the future. But the data's still real. The data's in the library.

I was reminded about how important it is to publish and keep that data, and the length of time it might take to use it, by an experiment that we did on one of my flights that proved the theory of an Italian physicist that had lived a hundred years ago. But he couldn't go to space to prove it. It had to do with surface tension. So he had published his theories. He had run through all the math. He'd done what he could on some limited 1-G Earth experiments, but it wasn't until we got up into the Spacelab and actually were able to do the experiment that we were able to verify his theory. So someday in the future that data may be useful.

ROSS-NAZZAL: Yes, we'll be revisiting that, I suppose. After you finished your master's degree, you actually went over to England to do summer research. Can you talk about that?

DUNBAR: Yes. Master's degrees are normally one year, maybe a year and a half. I took two years. I knew that Dr. Sarian was rigorous, and I kept producing data. Then I built a machine to do my own hot-pressing. I wasn't happy with the one they had. As you start into research, and you realize, "Well, gee, that doesn't do quite what I want to do," you start designing your own stuff. So we built up what we called a hot lab [laboratory]. I had the only radioactive tracer lab in engineering. It was in the basement; had a lead glass window that was about that big.

[Demonstrates]. If people wanted to come see me, they'd kind of wave at the window, and then I would close up inside and come out.

At the end of two years, the faculty committee looked at my research and said, well, six more months of I think it was—they actually wanted me to take a couple more classes, and they said, "We'll give you a Ph.D."

I said, "I'm broke." I didn't have any more grant money, and at that point, Dr. Sarian had arranged for me to do a visiting scientist position at Harwell Laboratories, AERE [Atomic Energy Research Establishment], in Oxford, England, in May of '76. I was so shortsighted. This is one of my few regrets, was that I really didn't stay the six months and finish the Ph.D., because at that time I thought, "Well, I've got a really good master's, I've got three papers, and I've got this really fun job coming up in England." So I went to Oxford, and it was a great experience, great experience.

But before I left, I actually had been accepted to Rockwell International [Corporation] to start in October of '76. So I couldn't have done the six-months Ph.D., anyway. I had interviewed with the job and hadn't heard and hadn't heard, and all of a sudden they came back with a job offer, and I asked them if they could delay till October so I could do the England tour. They said great. I went and did it, and then came back and immediately started working for Rockwell.

ROSS-NAZZAL: At this point you're a well-established engineer in a field that's dominated by men. Can you talk to us a little bit about that, what it was like for you?

DUNBAR: Well-established might have been kind of broad. I was in my twenties still. It is true that when I was an undergraduate, there weren't very many women engineers, and not all the faculty were particularly receptive to that. But they were the minority. I had a department chair that was absolutely supportive. The nice thing about engineering, unlike maybe an essay in—I took some what we called upper classes, literature courses in Shakespeare and so forth—if you write an essay and it's graded, it's very subjective about how you might be graded. You take an exam in statics, and you're either right or wrong. So it doesn't matter what gender you are. If you got the right answer, you've got the right answer.

So my response to any negative attitudes was to ace the class. It was really quite an inspiring—for me that was just like competing with my brothers. My brothers and I were very close, but we would always one-upsmanship, whether it be in athletics or anything. It was a healthy, friendly competition, but it made me a better person, I think. So I looked at that kind of negative attitude in the same way, as if, "Well, I'm not going to argue with you, but I will perform it to diffuse it."

So I actually also had great support, wonderful faculty people. Dr. Irene [C.] Peden, who was in electrical engineering, also mentored a small group of us. We were in what was called the Society of Women Engineers, the student section, and the society, SWE, is a national organization. It's over fifty years old, and so you'd find professional women engineers helping to kind of provide some support to the young women. They were wonderful to me, but I had great male faculty members supporting me as well, and a great number of friends, student friends. So I didn't find it, as an undergraduate, a particularly bad problem, or as a graduate student, quite frankly.

Industry was a little bit different in the beginning. Boeing, I think, was still, when I worked for them, having some growing pains, but Rockwell—when you come in with a unique skill, and I had worked tiles, they only had two of us, and so our Space Division president, George [W.] Jeffs, was just a wonderful person. Our vice president, Joe [Joseph W.] Cuzzupoli, our division chief, Stan Yoshino [phonetic], right down the line, were absolutely supportive, and I got a wonderful opportunity very early to take on responsibilities that pushed me. I was sent to Palmdale [California] as part of production operations to help provide support and oversight to the startup of the tile production facility there, as an engineer with that background, and so I knew what the end product was supposed to look like and how it was supposed to perform.

Then I already had a network set up. I had the NASA network. I knew Howard at Ames and Jim at Headquarters and John Buckley at Langley, and I knew the universities involved, and so if I had questions, I could pick up the phone. So it was a wonderful experience.

ROSS-NAZZAL: Did you serve as a mentor to any students in California while you were working for Rockwell?

DUNBAR: Not directly, but I did join the Speakers Bureau when we were building the Shuttle, and I did quite a bit of speaking, including at the universities and out into the schools. What I tried to do was encourage all young kids to be engineers. Engineering is the foundation of the modern world, and I personally believe it's not only the foundation of quality of life—the fact that we've got buildings around us and cameras and cell phones and refrigerators and electricity and flight—but because engineers or engineering are also responsible for the way we communicate, I think it's one of the fundamental threads of a democracy, for keeping us together. And it's creative. So I went out and tried to give information to young people that I didn't get. As I said, my entry into engineering was very shotgun. I knew where I wanted to be, but I was very lucky along the way, and I've tried throughout my career to make it a little easier for young people to make that choice.

ROSS-NAZZAL: Let me ask you about working with the thermal protection system. That was a pacing item for the Orbiter. The tiles were fairly brittle, and they were difficult to keep on the Orbiter itself. Can you talk about some of the challenges that you faced?

DUNBAR: First of all, tiles are a ceramic material, so by definition they're brittle. But the reason they have an advantage over metals is that they don't expand ten times over their thermal exposure range. It's called the coefficient of thermal expansion. Also, they are an insulator; they don't conduct heat. We looked at metals, or what they call refractory metal skins, and there are two disadvantages. You still have to insulate behind them, because metals conduct heat. The other is that when you go from room temperature, let's say 75 degrees Fahrenheit, to 2,300, you have a large growth. It's like your cookie pans, I guess, in the oven. So the airframe would distort.

The ceramic materials are very small thermal coefficients of expansion, 10^{-6}, so you're not going to see a lot of deformation. Also you could, on a very low density tile, expose the surface to 2,300 degrees Fahrenheit, and the backface, three inches deep, would not see even close to that, less than a couple hundred degrees, till after you're on the ground. It's a very slow coefficient of thermal expansion and heat transfer. So ceramics had a definite advantage. We knew that from the work we'd done in the sixties, and in fact, ceramics were already being used as the heat shields on nose cones for missiles and so forth.

So the next big challenge was to put them in a low-density, lightweight form that could be applied to the outside of a vehicle. Apollo vehicles, Gemini, Mercury, were all covered by ablators, which meant that they burned up on the reentry to the Earth's atmosphere and could not be reused. The tiles were meant to be reusable. They didn't deform. They didn't change their chemistry. We had to, though, shape them so that they were the shape of an airplane, so we had all the aerodynamic features there, so we sort of did a little reverse engineering, in that we said, "Okay, here's what the Shuttle looks like; got to maintain that shape. Here's how hot it gets from the nose to the tail. Most of the heat's at the nose, on the nose cone, and the leading edges of the wings. We want to make sure the aluminum substructure doesn't get over 350 degrees Fahrenheit; that's when it starts to change shape. So how thick does the tile have to be?"

So we use all those limits and constraints. Then you'd use the computer, which really made the Shuttle a vehicle, to calculate how thick each tile had to be. Then we started looking at, well, okay, how big should each tile have to be. Could I just put large sheets of tile on there? Well, we started looking at what the structure does during launch, and now we're getting to something called vibroacoustics. There's a lot of force pressure on the vehicle, a lot of noise, if you will, generated into the structure, and it vibrates. We calculated that if we put a foot-by-foot piece of tile on there, that the vibration would actually break it up into six-by-six-inch pieces. We said, "Well, we'll design it six by six." So you'll see most tiles are six by six.

Now how close do you put them? We thought, "Well, you can't get them too close, because during that vibration they'll beat each other to death," because they're covered with a glaze. You've got silicon dioxide fibers that are made into very low-mass tiles, nine pounds per cubic feet, or twenty-two pounds, and to ensure they don't erode in the airstream when you reenter, they're covered with a ceramic glaze. So that's also brittle, so you can't get them too close or they'll break the glaze. You can't get them too far apart or, during reentry, the plasma flow will penetrate down in those gaps and could melt the aluminum. So that's called gap or plasma intrusion. So that then constrained what we called the gap.

Then from tile to tile, how high one was compared to the next one, we called step. That became important because if you had too large a step towards the leading edge of the wing, that would disturb the boundary layer, and you would go up the plasma, and instead of having smooth layers, it would start to transition to turbulent, from laminar to turbulent, and turbulent results in higher heating. So that controlled the step. So gap and step were very important to that as well.

Those were all challenges. We depended on advances in computerized machining capabilities, wind tunnel work with models to help us determine the requirements on step, the manufacturing, just everything. Firing a tile, a certain temperature and time was important to maintaining its geometry. All the challenges, never done before. It's, I think, a real tribute to the program that if you look at follow-on programs, even in NASA but also in Japan or in Europe or even the Russians, who built the Buran [Soviet Shuttle], you'll find that the system on the surface is very similar to the Shuttle tile system. It was a good solution.

ROSS-NAZZAL: Did you have the opportunity to work on the densification process that they ultimately came up with to keep the tiles on the Orbiter?

DUNBAR: Not to work on it, but I talked to the people involved in it. The reason we did densification is that, when I was on the contractor side, we had run some calculations about what the bonding strength needed to be for a tile on the Orbiter, but we were supposed to fly the Shuttle, as you recall, in about 1978, and then there were budget pressures from Washington, D.C., that went to NASA and, of course, went out to the contractors. We had to defer some analysis. As I recall, one of the analytical tests that we were supposed to perform was to look again at both vibroacoustical as well as other pressures on the bonding force, and by the time we were able to run that, we realized that what we called three sigma, the outer bounds, might present some problems for all the tiles we'd already put on.

The only way we were going to increase that bonding force or bonding strength was to increase the surface area, because remember, the tile is about ninety percent air, so there's a lot of void where that tile bonded to the strain isolation pad that bonds to the Shuttle. So if we densified it, filled up those voids, then we provided more surface area for that bond. So that's why we went back and then densified all of those tiles, so we could increase the bond strength and make sure that we were going to have enough strength in what we called the three-sigma dispersions.

ROSS-NAZZAL: Could you tell us a little bit about the tile production facility that you managed?

DUNBAR: I didn't manage the tile production facility. We had a group up there who set it up with managers and techs [technicians]. I was their technical overseer, if you will, because I was the only person in the group that actually had a materials science or ceramic engineering background, so I could look at the tunnel kiln and the certification for it—we ran tiles through it—and determine whether or not that was correct. I helped them understand how to calibrate it, how to use the optical pyrometers, how many test samples we had to send through to be statistically significant. So I did a few things. I hold, I guess, one of the tech awards for how to coat a tile with RCG [Reaction-Cured Glass].

We were having a problem in that we were hand-spraying this RCG, Reaction-Cured Glass, which was patented by Howard Goldstein at Ames, onto the tile. The tile was put on a little rotating metal base, and we used the equivalent of like a spray gun to put this ceramic glaze on. The operator had to be calibrated, because they had to do so many passes to get the right thickness. Too thin, and it didn't form a glassy barrier. Too thick, and it would tend to craze or crack or even curl. The other thing we noticed is that you didn't want to spray all the way to the bottom. You had to leave some room there for the tile to breathe and also to be bonded to the SIP [Strain Isolation Pad]. So they'd put a little mask around the bottom of the tiles, and they'd spray the glaze on.

What they didn't realize, is when they were pulling the little mask off, they were actually separating the glaze just a little bit from the tiles, so that when they fired it in the kiln, it curled up. Well, that's all going to crack off. So I was watching them do this one-day, and I asked them, "Is it necessary for you to put the mask right on the tile? What would happen if you backed it off like an eighth of an inch and then just kind of sprayed over it?" It would kind of then bevel the concentration or the thickness of the spray down as well. We said, "How are we going to do that, because what is it going to stick to?"

I happened to look up at our scheduling board. Back in the seventies we had what are called war rooms or scheduling rooms, and they had all these magnetic blue strips and black strips and red strips on it, and I said, "Well, why don't we take two of those magnetic strips, and we'll make a little elbow, and then we can just move it around the platform as we want. We'll back it off from the tile about an eighth of an inch." So we went into the war room. We got some that stuff. We cut it up, and we did it; sprayed the tile, had the techs spray the tile. Ran it through the kiln, and it worked perfectly. So we got a little tech thing out of that.

So I did a few little things like that in working the process, but our group back in Downey [California] was responsible for that production facility, and so in that respect, I was kind of the envoy to make certain it was operating. Then when we briefed NASA, I did quite a few classes for the folks up there on what a ceramic was, what devitrification was, why you shouldn't touch the tiles with your hands, what salt will do to it, and everything from A to Z on it, so that they understood when NASA management came through they could respond intelligently to the questions, but also could do the operation properly.

ROSS-NAZZAL: At that point, were there any astronauts coming out who were working with you on the tile?

DUNBAR: No, because I was there 1976 through '78. I did see astronauts. They were flying ALT, the Approach and Landing Tests, and that's how I met Dick [Richard H.] Truly and Joe Henry Engle when they came out to Rockwell. But I didn't meet any other astronauts. I think tiles, I know John [W.] Young was very interested in them, but it was such a new technology, I don't know; from my end of it, it wasn't visible to me who in the Astronaut Office was following it.

ROSS-NAZZAL: You actually received the Engineer of the Year award for your work on the thermal protection system. Can you talk about that award?

DUNBAR: It was a little bit surprising to me. I was having so much fun. I loved problems. I kept hoping for little ones to come up every day so that we could go solve them. We wanted to make sure we had a good production line there. But this was brand-new, challenging work, and it just was a great opportunity.

I did have a call one day. We were supposed to waterproof these tiles, and they had brought in the prototype unit to Downey, and the techs had set it up, and they'd put some tiles in it. They'd run per the manufacturer's procedure on this waterproofing; silane, they called it. The test for whether or not the tile was waterproofed was to turn it upside down, where you had the white fibers exposed, put a water drop on it, and it's just like waterproofing a coat or your car, if it's waterproofed the water stays beaded up on it. If it's not, it just soaks in like a sponge.

Well, nothing was passing, and so I was asked to go take a look at it. So I said, "Well, let's just break it down into its component parts first." So we did a tabletop drawing of the whole system, where all the valves were, all the heaters were, the electronic components. Then we got the chemical and looked at the directions for how it ought to be applied, the temperatures, pressures, and so forth.

To make a long story short, what was happening was that the temperature—they had to heat this stuff up. It was a two-component, as I believe, waterproofer. They had to heat it up to a certain temperature before it could be introduced to the chamber, and this was like a big oven with a big door on it.

Well, thermodynamics is really kind of an interesting subject. What was happening was that they were heating the liquid up to a certain temperature, and as soon as they opened the valve, this stuff all vaporizes into a big chamber, and at the same time, it cools, and so it's not penetrating the tiles. That was really easy to see when I went into the chamber, because I looked around the orifices where this stuff is interjected into the chamber, and there are all these little crystals. So what the vapor was doing was coming in, rapidly cooling, and crystallizing right at the chamber inlet, and none of it was really getting into where the tiles were.

So what we did was we back-designed into kind of a superheating condition. We heated the oven for a longer period of time. Now I'm trying to remember the full procedure, so that we weren't ever introducing it into a cold oven. We put the tiles in. We brought the tiles all up to a temperature, and then I believe that we also preheated or overheated the chamber where the silane liquid was, so that when we introduced it, everything was still at the same temperature. It would stay a vapor and not go back into a liquid phase.

Once we got it fixed there in Downey, then we exported the process up to Palmdale. And we took two days to do that. I know there were some people kept saying "Well it was a miracle." I said, "No, it wasn't." We just sat down and very methodically went through the process.

ROSS-NAZZAL: What was morale like working for Rockwell? You had mentioned there had been some budget cuts when you were—

DUNBAR: Oh, exciting. Yes, there were some budget cuts, but this was the next-generation vehicle. Not only was it next-generation, it was transformational is the word we use now. If you think about it, everything to that point was one use only. Couldn't bring any mass back. We sent a lot of things into orbit that we had to test and leave there, and it became a shooting star, coming back to Earth. So this transformed our ability to do research. It's why we have a Space Station now. We not only learned from Skylab, but we flew, I think, twelve or thirteen flights of Spacelab, countless research projects that we could bring back to Earth, get the results out, diagnose problems with equipment. I think it saved the government billions of dollars, because we didn't throw it away each time.

So it was exciting, and we knew what it could do. New technology. It was leading-edge on not only the thermal protection systems, but it was the first fully fly-by-wire vehicle, in terms of the computers and the flight control system. The main engines were also a pathfinder as well, and so it was exciting, even if it delayed till '81. If you think about it, we baselined it to the contractor, to Rockwell, in 1972, I believe. So nine years later we have a vehicle, a reusable vehicle, flying.

ROSS-NAZZAL: You mentioned that you actually got to meet some of the ALT astronauts. Did you get a chance to go out and witness some of the ALT tests themselves?

DUNBAR: Yes. In fact, because the Palmdale facility was right there at Edwards [Air Force Base, California], what I would do is catch the Rockwell plane out of Long Beach [California] very early in the morning; I don't remember, six, six-thirty in the morning. I was driving in from Huntington Beach [California] where I lived. Then we'd fly out to Palmdale; we'd land maybe seven in the morning and work there till four. We started out in a Rockwell Commander, and then we graduated to a very old DC-3 tail-dragger that would go in the morning. So we were there every day, and the ALT flights were going on.

ROSS-NAZZAL: What are your memories of some of those flights?

DUNBAR: I remember it's exciting. You think about it, too, it was pretty dicey, too, putting the Shuttle on top of a 747. Of course, that's how we transport it now all the time. And then releasing the two, because now you've got two aerodynamic problems, as well. You've got the Shuttle, which you're testing, and you've got all these separation dynamics from the 747.

ROSS-NAZZAL: I think this would be a good place for us to stop and change the tape. This is all very interesting.

[Tape change]

ROSS-NAZZAL: So in '78 you actually submitted an application for the first class of Space Shuttle astronauts. Can you talk about how you found out that they were accepting applications?

DUNBAR: I knew that the Shuttle Program would be open to both men and women actually when I was still an undergraduate, and I learned that from John Buckley at Langley, the NASA engineer who was overseeing our project, because we were working on the Shuttle. The department chairman, Jim Mueller, one day told him that I wanted to be an astronaut someday.

John, who's been a great friend even since his retirement, said he had heard that they were going to open up the program to women for Shuttle, and that if he heard anything, he'd let me know.

I received a call from several people. But they started taking the applications or doing the interviews in '77 for the '78 class, so somewhere around '76, '77, I heard that the process was going to happen fairly soon. I learned about it while I was at Rockwell, and applied and was selected as a finalist. I had great support from the company. They did a nice story in the company newspaper. Flew down to Houston in I think it was maybe October of '77, in the fall there. Went through the interviews, the physicals, and then flew back to Downey and then waited for the outcome. And then got a call—I think it was in the spring of '78—saying that I had not been selected, but would I interview for some positions at JSC.

I went to see I think it was our division chief at that time, Stan Yoshino. I said, "Look, I've gotten a call from NASA."

He says, "Well, why don't you go talk to Joe Cuzzupoli?" who was the vice president of production and operations at that time.

I went to talk to Joe, and I says, "You know, I would like to be an astronaut someday. I've loved my work here, but what should I do about this opportunity?"

He said, "Well, why don't you go talk to them, and if something works out, that's great, and if you don't like it there, if it doesn't work out, come back to Rockwell." I was at that time the youngest in my group by a good, fair amount, maybe even—I don't know—ten, fifteen, twenty years, and so my opportunities for career growth were going to be limited for a while if I wanted to stay in the Space Division, which I did. Although they had put me in a program called PACE, Professional and Company Executive Development, I think that's what it was. We would stay for lectures after work on management and that type of thing, and it was going to be a steppingstone to do rotations around the company. So I'd already kind of started another development program within the Space Division when I went to JSC to do the interviews.

So I was there on business, in any case, and I spoke to two different groups. One was Classical Flight Control. I talked to, I think, the ECLS people, if I'm not mistaken, Environmental Control and Life Support. Then I talked to John [T.] Cox, who was in Payload Operations, which was a brand-new group. Of course, both of these at that time were under Flight Operations, and that Directorate was led by Mr. George [W. S.] Abbey.

So I remember a conversation I had with the ECLS Lead Flight Controller, who was there during Apollo. I was, I think, twenty-nine at the time. He was a nice guy, but he didn't know me, and he says, "Well, you know, everybody starts at the bottom."

I said, "Okay, I'm willing to do that."

He said, "You have to start by doing systems-level drawings, interface drawings."

And I said, "Okay," and then I said, "and where do you go from there?"

And he says, "Well, where would you like to go?"

And I says, "Well, I'd like be a Flight Director someday. I mean, if that's where I'm going to go."

And he says, "Well, then you start in the back room, and you spend this much time there. Then you work your way up to the front room, and then if you do well there, then you may work your way up to Flight Director."

I asked him how much time you'd have to spend on any one of these things, and I added it all up and it looked like I was going to be forty-some years old before I really made it to Flight Director or to the front room, even. So I asked that. I says, "How old were you when you were in the front room?" I think he was front room, Gemini and early Apollo.

He kind of looked at me, and he said, "Twenty-six." So I decided that that was interesting work, but probably not the most productive use of my time. Great people, and we became good friends when I finally came into NASA.

But then I went to Payload Operations, and that was about what we're putting in the back of the Shuttle, and working with the customers. Doing interface drawings, but also helping to define requirements and then sitting on console during the mission, in the Payload Operations console, which at that time was right next to the CapCom, the crew member Capsule Communicator. So I said, "You know, if you're serious about this, I will come into this group." It's new; we were helping to define it; it was exciting. And that's what I did.

So in July of 1978, I came to Johnson Space Center and started, was given a couple of payloads, and then all of a sudden Skylab reentry was there. They needed people, so I volunteered and was trained as a Guidance and Navigation Controller [GNC] for Skylab and sat on console for nine months until we brought it in in July of 1979.

ROSS-NAZZAL: Can you talk to us about that reentry mission itself?

DUNBAR: Oh, that was fun. I had no background in GNC, so it was all on-the-job training, and it was by the people that actually performed that work during the mission, and we had no manuals, but see, there was a vehicle up there. We were getting live data.

We didn't have TDRS [Tracking and Data Relay] Satellites. We were back in that era when we sent commands up to the vehicle. We read them off to ground stations around the world in I think it was either octal or hexadecimal code, and I was talking to Controllers in Santiago [Chile] and Madrid [Spain], just around the world. Then they would send the command up. We would then verify that the command was executed. It would come back down, of course, during our downlink. So we'd read it up. We verified it; they'd read it back to us. Then we actually had another person online, usually at Marshall [Space Flight Center, Huntsville, Alabama], who would also back up what was read up, and in GNC, that was very important, because we were reading up the code for attitude control.

We had no method of actively deorbiting Skylab, no retrograde engines, so we had to manage drag. By managing drag, we would then propagate the probability of where it would reenter and impact the Earth. Of course, you're propagating out months at a time, and you've got solar flare activity changing the atmosphere all the time. But we did that every day, drag management, so it was very important to do that.

ROSS-NAZZAL: There were some discussions at that point that Skylab might fall on North America and damage property. Were you ever afraid that that might happen?

DUNBAR: You know, I think back on that, and I was young, excited, doing my job, and NASA was the smartest group around, and I figured they knew exactly what they were doing. It was my job just to execute the commands.

The actual calculations were all done at Marshall. We had a very primitive—I look back on it now—kind of very primitive computer interface to Marshall sitting there in Building 30, and we would get drag information from them, which we then had to convert. I'm trying to remember which way or the other; we had binary, octal, and hexadecimal commands, and we had to convert one to the other. It was very laborious handwork.

But we would get the attitude control information in from Marshall, based on all the models that they were running. We would convert that into uplink commands that we would read, you know, like one, zeros, whatever, to the remote sites and send up. And I just had a lot of faith that that was happening on a daily basis, and they were watching the orbits, and they knew what was happening.

ROSS-NAZZAL: What kind of schedule were you working at this point when you were working in this position?

DUNBAR: It was very bizarre. We were seven days on, two days off, and a progressively rotating schedule, so every seven or nine days, we'd rotate eight hours forward. So I remember putting aluminum foil over my bedroom windows in El Lago [Texas], so I could sleep during the day when I was on at night. You just really didn't know what time the outside world was on.

I remember waking up; it was dark. I looked at the clock, but my clock didn't say a.m. or p.m., and so I didn't know whether I had overslept, or I had awakened in my night. For a moment there, it's a little confusing; no digital clocks. So I called the operator, and she must have thought I was absolutely crazy. I said, "Could you tell me whether it's eight a.m. or eight p.m.?" And she told me, and I just had awakened in the middle of my sleep period, and so I went back to bed.

But, yes, it was our life. In fact, by the time Skylab reentered, and I was on console so I was watching my data disappear, it was—you know, you connect to a spacecraft like that. It's hard to explain. I know it's an inanimate object, but it really was like watching something die. It had lasted much longer in a lower altitude than we ever expected, so data was still coming in well beyond the point at which it should have broken up, and it would just kind of gradually disappear.

ROSS-NAZZAL: After some of the successful flights of Apollo and then after the Shuttle missions, there's usually a party. Did you have any sort of celebration, or wake, perhaps?

DUNBAR: Well, we actually had a very famous "splatdown" party. We had black T-shirts made. It was called "Skylab Splatdown." It was a pool party, as I recall, because I remember a lot of people went into the pool.

ROSS-NAZZAL: Can you tell us about the team that worked on this reentry? For instance, were there any other women who were working on the team?

DUNBAR: Oh yes. Let's see; Cindy [Cynthia N.] Majors was on that team. She was on another—we had, I think, three flight control teams, maybe three or four, and she was a GNC on one of the other teams. Debbie [T.] Dingell at that time. There weren't that many women. There were probably three or four women in mission control that I remember at that time.

ROSS-NAZZAL: Did you get a chance to work with Gene [Eugene F.] Kranz and some of the other old Flight Controllers?

DUNBAR: After the Skylab reentered, then, of course, I went back into my Payload Officer job, and we started preparing for STS-1. Now, STS-1 had payloads, but they were really instrumentation test payloads. They were called ASEP, and ASEP really was a computer in the lower payload bay that integrated sensors from all over the vehicle, thermal sensors, for example, and eventually aerodynamic sensors. But it still was not part of the actual vehicle. It was put in payloads, so my first job was to put together the systems integration drawings for that, and I was assigned to the front room as a Payload Officer.

The first set of sims [simulations] that I went through, my Flight Director was Gene Kranz. It was absolutely great. He was super, I remember, and of course, sitting in the back row there very frequently was Dr. [Christopher C.] Kraft [Jr.], as the Center Director.

For me, it was like watching TV. It was the most exciting time of my life at that point, and frightening, because I knew full well that if you did not perform or do your job, you were gone, and it was in front of everybody, because once we finished a sim, we debriefed live on the open mike [microphone], and we went through our training team. We'd go down through the scenario and they would then talk about everybody's mistakes, including the crew's, and the Flight Controller's, and so it was a time in my life I was really very focused on doing the right thing and doing the best job I could. But I was working with the best, and I couldn't have asked for more.

ROSS-NAZZAL: When you accepted this position at JSC, were you given any hints that you might be selected for the next astronaut selection if you came down?

DUNBAR: No. No, not at all. In fact, it was a double-edged sword about whether or not I would be selected, if you want to look at that way. If you looked at the '78 class, I don't think anybody that had worked at JSC was selected. So if you didn't perform, they were going to see that.

[Laughs] But at the same time, I looked at it as a win-win. If I had to stay in mission control and could eventually be a Flight Director, that was a win, and if I got selected as an astronaut, that was a win.

ROSS-NAZZAL: You actually were selected as an astronaut. Can you tell us about that telephone call you received?

DUNBAR: Oh yes. Well, when I wasn't selected as an astronaut, the call that I received was from Dr. Carolyn [L.] Huntoon. So everybody knew that if Mr. Abbey called you, you were selected. If Dr. Huntoon called you, you weren't. So when I was at Rockwell and that call came, it was from Dr. Huntoon, and I just knew. The secretary said who it was, and I said, "Well, I know what this is about."

But when they selected the '80 class, as a Payload Officer, I shared the same floor as the astronauts, the third floor, Building 4. There weren't that many astronauts, and they were all on one side of Building 4. The Payload Officers were all on the other side. So I received a call from Mr. Abbey, but that wasn't unusual, because he was also the coach of our coed softball team, and I would get calls anyway, telling me what field to be at, at what time.

In fact, when I first showed up to NASA—to go back to my interview, in 1977—they asked, "What sports do you play?" Well, having grown up where I did, I was always a baseball player. Not a softball player, but a real baseball player, and I played on coed teams, because we were a small community. We didn't have enough to really field an all-boys or an all-girls team. I played two positions. I played first base, and I played catcher. So during my interview, they asked everybody, "What sports do you play?"

I said, "I play baseball," and we talked about the positions. So my first day at work at JSC, there's a little yellow phone message pads similar to what I think we still use—I don't know, maybe we've changed them—and all it says—it's from Mr. Abbey—"Field 3, six o'clock, be there," or something like that. I hadn't even signed up for the team yet. [Laughter]

ROSS-NAZZAL: I guess that was a hint.

DUNBAR: That was a hint. So I showed up. So it was not unusual to get these calls about what time the team was going to meet, and so the day that they made the announcements, I get a message from Mr. Abbey, and I called back, not knowing which way it's going to go, and he said, "How would you like to move your office down the hall?"

I knew immediately what that meant, and I said, "Yes, sir, that sounds like a good move." And that's how I found out.

ROSS-NAZZAL: When you told your family, what was their reaction?

DUNBAR: Very excited. Very excited. My parents have been supportive of everything I've done. They were supportive of all of us. They just wanted us to turn out to be good citizens, to do the best job we could, and be productive. So the fact that I was able to do something I wanted to do was exciting to them. They've always been supportive.

ROSS-NAZZAL: Was there any sort of interest in your small Washington town over the fact that you were selected as an astronaut?

DUNBAR: Oh yes. Oh yes. There was a lot of press interest, but I didn't really go back there in any kind of official capacity until after my first flight, and then I got to lead a parade. [Laughs]

ROSS-NAZZAL: That's pretty big.

DUNBAR: It's a small town, you know, so it's one street up and one street down. It didn't take very long.

ROSS-NAZZAL: Can you tell us a little bit about the training that you underwent during your AsCan [Astronaut Candidate] days?

DUNBAR: I think the AsCan training is very similar today, but probably longer because of the combined Shuttle-Station curriculum. We had academics, but we had something I think was advantageous for us, even over the current classes. When we received our subsystem briefings, we received them from the subsystem manager, and it was, of course, Shuttle-focused. So when we got our briefing on the main engines, we got it from either the Managing Engineer or the Lead Engineer or the Design Engineer. It hadn't filtered down through two or three people. And we asked questions that could get answered. How many times do you have that opportunity? It was outstanding. So we had our briefings on all of the systems.

Then we toured all of the NASA facilities, the Centers, many of the contractors, and that's beneficial both ways. It's for us to learn and to kind of network, because we're going to work with these people as crew support or leads throughout our flying career, but also, I was on the other side of that fence as a Rockwell contractor. It's important for us to see the people that are going to be flying it, or to know that they have time to pay attention to us. So I always was very conscious of the fact about how important it was to go out and spend time with the people building your vehicle.

ROSS-NAZZAL: Let me go back and ask you a couple of questions. You were selected as part of the second group of Space Shuttle astronauts that included women. I wonder if, at that point, did you realize that you were going to be serving as a role model for girls and young women who, much like you at age nine, might be interested in being an astronaut someday?

DUNBAR: Well, role model has always been a word that's troubled me. It's not something you choose, and it can be a double-edged sword. First of all, I do feel a tremendous amount of responsibility in my job, male or female, that we represent the government, that we have to hold ourselves to a higher standard. That has to be there. So you hope you're a role model for both young boys and young girls. If we're a role model for young girls because the girls think it's not possible because they're being told by the boys that it's not possible, that's the double-edged sword.

My role model was not female. My role model was John Glenn. It was Alan Shepard. It was some mythical character in a book. But I was taught that it was not what you looked like on the outside, but what you did on the inside that was important, so the external packaging was not as important. So I didn't look at my role models by how they were packaged. So it concerns me these days that instead of uniting, we're separating. We're categorizing, and I think in some ways we make it harder, not easier.

So I still have a real sense of responsibility in the classical sense of a role model that young girls see that it's possible for them to do things. I'm still troubled that we have to have that. I always felt that this country really was a new platform. It's called "The Grand Experiment," and that grand experiment is still evolving. Women got the vote in 1920. They're over fifty percent of the population. It's a tremendous amount of talent to help us maintain this democracy, and we shouldn't be worrying about the packaging. We should be worrying about the talent and the capability to do the job.

ROSS-NAZZAL: I have one more question related to women's issues. When we interviewed Mary [L.] Cleave, she had mentioned that male and female astronauts were treated equally around the office, but she recognized that there were some differences. What are your memories of that, when you came to JSC and then started working in the Astronaut Office?

DUNBAR: I remember that Mr. Abbey had an absolute firm commitment, along with Dr. Kraft and Dr. Huntoon, who was the only woman on the selection committee, that we would all be treated the same, that we were all qualified when we were selected. That commitment manifested in a number of ways.

One of the most significant ways for me that it manifested it was in the design of the vehicle and the equipment. When I was a Rockwell engineer, it was made very clear to me as we were designing the vehicle—I wasn't responsible for the inside, but I was around all those engineers, and most of the Apollo astronauts were relatively small on the male scale—but that we were going to design this vehicle to fifth percentile Japanese female, which may be Japanese-American, or American-Japanese; to ninety-fifth percentile Caucasian male, or maybe even

African-American male; but the largest span we could of the American population. And the management at Johnson Space Center supported and confirmed that.

One of the first instances of that, that occurred to me, was my first flight, which was STS 61-A, D-1, *Deutschland eins*, that was bought and paid for by West Germany. In fact, I think they paid NASA about sixty, seventy million dollars for that flight. Well, they supplied three of the eight crew members, two German crew members and a Dutchman, and we had five Americans; two Mission Specialists. And since it was a Spacelab flight, it was about an eighteen-month training flow, and Guy [Guion S.] Bluford [Jr.] and I were the two Mission Specialists, and we were sent over early to start our training in [West] Germany.

When I showed up—I had been studying German, but there was a lot of discussion about both of us, but one, with respect to me, they were very concerned that I had been assigned to the flight, because their medical experiment wasn't intended to include female blood. They thought that would ruin their statistics. They would have an "N of one" and all these male things, and I was actually told in front of my face—and I have to first of all qualify that I've become very good friends with all these people; but any time you're at the point of the pathfinder, there's going to be things happening. I was told that maybe NASA had done this intentionally to offend the Germans by assigning a woman.

So we started to work through that, and then we started to realize there were some experiments on board, like the vestibular sled, that didn't fit me, and so again in [West] Germany I was hearing the discussion, "Well, you don't fit our experiments. We really need somebody else."

And I was thinking, "What do I do with this information? They're discussing it around me, and this is my first flight." So at that time Dr. Joe [Joseph P.] Kerwin was head of Space and Life Sciences. I think I went back through Mr. Abbey. He actually wrote a memo for the record and to DFVLR [Deutsche Forschungs Versuchsanstat fur Luft und Raumfahrt, German Aerospace Research Establishment] stating that all equipment should be designed to this percentile spread. So they stood by it.

I say that now, because I think we're eroding that requirement in today's environment, and if we're not very careful, we're going to get back to only flying cookie-cutter astronauts, and that's not the direction the country ought to be going. The country ought to be opening space for everyone, so absolutely in '78, '80, early eighties, this agency was committed to women, and it was a very equal environment.

ROSS-NAZZAL: Once you had finished your training, what were some of your first assignments in the Astronaut Office?

DUNBAR: Very first assignment was to SAIL, Shuttle Avionics Integration Lab, and that was to check out the software, Building 15, both Mission Specialist and CDR [Commander]. I got to fly a lot of launches and entries. Flew the heads-up display when it first came on board. Checked out the RMS, Remote Manipulator System software. It also was very regular hours, because we came in as teams, and that allowed me in my off-time to finish my Ph.D. research, which I was doing over in Building 37.

ROSS-NAZZAL: Let's talk about your dissertation. Actually, you were now an astronaut, and then you were working on your dissertation, and as I understand it, Carolyn Huntoon was sort of the head of your research.

DUNBAR: She was on my dissertation committee. My chair was actually Dr. Bob [Robert M.] Nerem at the University of Houston. When I came here in ’78, first of all I looked at who was selected in the ’78 class, and all the Mission Specialists had Ph.D.s. That’s the point at which I regretted not going that extra six months. But only a little while, because I’m not sure I would have had my job at Rockwell; who knows? But I thought, “Okay, well, if that’s what it takes, I’ll go back to school.”

So I shopped around, and I had a meeting with Dr. Bob Nerem, who was chairman of mechanical engineering, materials engineering, at the University of Houston. I had a project in mind. At that time, all Mission Specialists had some research money to maintain currency that they could apply for through Dr. Huntoon, who was kind of the overseer of the Mission Specialists. So I put a proposal together. I started taking classes. I took two years of classes, from ’78 to ’80, as part of the Ph.D. process. Put a proposal together, which was accepted by the committee, and started my research. So I finished my research after I’d been selected. But I didn’t have a life for three years.

Every weekend, every evening, I was over in Building 37, because I was looking at the effects of simulated weightlessness—which, in the animal world, is limb suspension—on the strength of bone. I was using a rat model that had been developed at the Ames Research Center by Dr. Emily Holton, called the hind leg suspension model; was running those over in Building 37. We had an animal lab over there, actually, doing what’s called whole body metabolic balance as well.

So I’d suspend them for thirty days; eventually dissect the femurs to see what was happening to the bone; measure the strength over in Building 13 in their Instron machines.

Because it was a metabolic balance, I controlled everything they ate, and then we had chemical assays of all the waste materials as well, and that's when we could also assure ourselves that the loss of calcium through the body was being replicated, similar to what we'd seen on Skylab. So that was the bulk of my research for about three years.

ROSS-NAZZAL: What impact do you think that your research had on NASA?

DUNBAR: It was part of the collective work that said that hind leg suspension could simulate weightlessness. Also, I was looking at bone strength, or bone characteristics, using fracture mechanics, which had never done before. We'd always wondered, is the strength reduction due to the fact that we just lost a cross-sectional area, or is it due to the fact that we've intrinsically changed the material properties? My data suggested that we intrinsically changed the material properties, so it's not just cross-sectional area. In fact, bone is a living organism that's made up of collagen and hydroxyapatite crystals and so forth. Those are the two main components. If we're changing the material properties, that does not show up in an X-ray, does not show up necessarily in a bone scan.

There is also some data that led on to a follow-on piece of work that suggested there's a change in bone blood flow, and that's one I'm actually pursuing again right now in discussions with NASA Headquarters, because there's been, really, even in the intervening twenty-five-some years, no work beyond what we had looked at. So bone blood flow may be also an important factor in spaceflight. We'll be looking into that.

ROSS-NAZZAL: While you were also going to graduate school and working as an astronaut, STS-1 launched. Did you have any duties for that flight, as an astronaut?

DUNBAR: Yes, I did. I had a very fun duty. I was actually sent to the Cape [Canaveral, Florida]. The first flight, I was watching it from John Young's office. I was following some TPS [Thermal Protection System] for the office, although Dan [Daniel C.] Brandenstein was kind of the lead for it, but I didn't have specific duties. But on STS-2, I was sent to the Cape and supported CBS [Columbia Broadcasting System, Inc.] on the launch with Walter Cronkite, which was a really outstanding experience.

ROSS-NAZZAL: Can you tell us a little bit about that?

DUNBAR: You know, I'm thinking back. I know I supported landing for STS-1, because I had to go to New York [New York]. So I did; I supported the landing from New York, because I recall getting into the taxi from the studios to go back to my hotel, and the taxi driver already had a paper that said "The Dream Is Alive" or something. It was a very famous headline. So anyway, what was your question again?

ROSS-NAZZAL: I was just curious if you could tell us about your work with Walter Cronkite. What sort of questions would he ask?

DUNBAR: First of all, he's a very supportive person. But I was technical, so I was on camera, but he might have a question. He says, "Now, what exactly do the tile do?" Well, I had that in spades. Maybe that's why they sent me to cover landing, I don't know. But it was mostly technical; every network had an astronaut, and I happened to have CBS. Then when I think did STS-3, the same thing. Then it was with Dan Rather at that time.

Dan Rather, I really enjoyed working with him, because he wanted to make sure—he felt he was, I think, stepping in some fairly big shoes of Walter Cronkite, and he wanted to ask the right questions, so he'd hand me the question on a three-by-five card, and he'd say, "Now, tell me if it's just stupid or not." [Laughs] He always asked; none of his questions are stupid. But I had it there so I could think about it, so when he turned around and asked me the question, then I could give a shorter answer and more direct.

ROSS-NAZZAL: Any special anecdotes from any of those missions that you supported?

DUNBAR: Oh, that I want on the record? [Laughs] Oh, gee. I remember Dan Rather, as I was sitting there and we were getting ready to go on our first camera segment, said, "Now, I don't want you to get nervous. There's only about a million people watching." [Laughs] He was actually very nice.

ROSS-NAZZAL: Why don't we talk for a brief time—we might continue this next time—about your first flight. When did you find out that you were selected for your first mission?

DUNBAR: I found out in February of '84 that I was going to be leaving for—I have to make sure I've got these times all right—I think it was February of '84 that I was going to be leaving for [West] Germany in three weeks, I think it was, to fly the D-1 mission. Actually, maybe I'd heard informally a little bit before that, that I was being considered, because I was asked to support kind of that mission. I'm trying to remember. I think it was Bill [William B.] Lenoir who was running the payloads or the missions for the office, and he'd call me and he says, "I'd like you to just kind of start following the D-1 mission." In those days, when you're asked to start following something, it kind of implied a little bit, before the announcement. But then they actually called me in and asked me to go to [West] Germany, and that Guy Bluford would be the other Mission Specialist, but he had to follow up on something else. He was going to follow me by about two weeks, I guess it was. So that's how it happened.

ROSS-NAZZAL: In that three-week period, did you start studying German? You had mentioned you had been studying German before you went over there.

DUNBAR: Yes, you know, I've got to think about all the lead-up to that. Yes, we got a Berlitz instructor in. We started studying German, although the mission was conducted in English from Oberpfaffenhofen, because they had kind of an international control center there. We started the German so we could live there, because the street signs were in German and so forth. Of course, I had a household. I was living by myself. I had to find people who would pay my bills. I was going to be gone for seven weeks on that first tour. Altogether we spent about seven months in [West] Germany, training, in an eighteen-month training flow.

ROSS-NAZZAL: Can you talk to us about working in [West] Germany, working with the PIs [Principal Investigators]? You've given us some indication what it was like working with them, but just an overall summary.

DUNBAR: Well, what was fun to see was we had worked with [West] Germany to develop Spacelab. That was their entry into man-rated vehicles. That had happened in the seventies. That was a partnership that is not very visible, but the Spacelab module itself was built by, at that time, MBB-ERNO [Messerschmitt-Bölkow-Blohm-Entwicklungts Ring Nord Organization, Spacelab contractors] up in Bremen. We sent a corps of engineers over there to work with them so that we could man-rate it for safety, and the agreement was, is that they would supply the first Spacelab, and we'd purchase the second. In fact, the one we purchased, the second one we purchased, is the one, I believe, we flew on D-1, because the first one flew on STS-9, which was in 1983 with John Young.

When I went over there, it was a very exciting time for them, because it was purchased by West Germany, although they had European, ESA, [European Space Agency] involvement in it. The *Bundestag* had become involved in this, which is their legislative government. At that time the seat of government in [West] Germany was in Bonn, and we're training in Bonn/Cologne, you know we're actually Cologne Airfield there. So it wasn't unusual for our two German astronauts, Ernst Messerschmid and Reinhard Furrer, to have lunch with what we'd call a senator. There was just a lot of interest. The mission manager at that time told me that they hoped to use this mission not only to advance their science and human spaceflight, but to inspire a generation of young people in [West] Germany that really hadn't had inspiration since the war, and they lost the war. So this had very much a policy, political flavor to it, not just a scientific flavor to it.

Now, the researchers themselves came from all over Europe, so we flew to Paris [France] to train. We were in the Netherlands and other parts of [West] Germany, and we had other researchers come in, some from Scotland, some from Italy. Then there were also U.S. researchers there as well. MIT, they were co-researchers on the vestibular sled and vestibular studies.

So most of the time was training—I found that really fun—and translating that training into procedures, which is something that I had learned to do fairly well as an engineer. How do you capture the intent of a researcher and translate that into an operational procedure that several crew members with many different backgrounds have to be able to read, and come out of the other end of that with the right scientific result? Or, in that process, be able to use human judgment to determine if something is not following the way you thought it was going to follow, and know then that you have to contact the investigator on the ground or the representative. So that was not just a one-way flow of data in this training. It was very much working as part of the team with the investigators.

ROSS-NAZZAL: Could you compare and contrast the training at JSC versus training over in Europe?

DUNBAR: It's two different communities. You can't compare them. What we do to train here is we train on known systems, and we train on safety of flight systems, and so we've matured them. We train the Shuttle, the Station. Most of the training we did in Europe, back in Shuttle, was on the research. Just like when I flew USML [United States Microgravity Laboratory]-1, which was a Spacelab flight, I had the core training here. I had Spacelab systems training at Marshall. But the research, while some of it was done both places, we traveled a lot to the research site. I went to the University of Wisconsin [Madison, Wisconsin] to train on the plant growth. I went to the

University of Alabama, Birmingham [Alabama], to train on protein crystal growth, that type of thing.

ROSS-NAZZAL: What was it like training with these European astronauts, who you mentioned were having lunch with senators, and there's a great deal of interest and attention in the flight? What was it like working with people who were, I don't want to say superstars, but famous?

DUNBAR: Oh, they're great people. Actually, it was fun to talk to them, because in [West] Germany they very much occupied an original seven status, and so it was always interesting to hear from their perspective—and see what they were doing—how the program was being received, and we helped them. It's changing now, but there's still a lot of dichotomy, even in Germany, about the value of human spaceflight, even though they're a major partner in ESA and in the Space Station, because the mission managers there at DFVLR would very candidly say, "We're working very hard on our human spaceflight program. We need your help." Because there would be one or two ministers that would vocally try to kill the program, and so we were interested in working with them and helping them.

Of course, they were able to get a second mission, D-2, and they're building the Columbus module for the international space station, and they very well—you know, this new Aurora Program in Europe, Germany would be a key partner in as well. I think it's important that globally we get more and more countries into space, just from a humanity point of view. So I've always been interested in that part of it, and so I enjoyed talking with Reinhard and Ernst.

Also, Reinhard was a well-known physicist from [West] Berlin, and I had a chance to go visit his university at one time and talk to his friends. He was a professor. That's a very well esteemed position in Germany. It's better than being president of the company if you're *Herr Professor*. So being with him allowed me to see a great deal of research on things I might not have seen, so I thought it was a good dimension of the mission.

ROSS-NAZZAL: What was the press interest like in this mission?

DUNBAR: It was very high, but not for always the right reasons. [Laughs] We always try to promote the research we do in space, but press in any country, depending on how articulate they are, don't always understand that aspect of it, so they then focus on the other sides, the personal part of it, and of course, the personalities of the German crew members were very much in the news and so forth. I'll never forget my first crew press conference, and probably some of those crew members remember it as well. I had an interviewer, a reporter in [West] Germany, ask me what I thought of *Dallas*, and I said, "Well, you know, I've only visited once or twice, but I hear it's a pretty city." Well, I did not know that the most popular show in [West] Germany in 1984 was *Dallas* with what's-his-name, T. J., whatever.

ROSS-NAZZAL: I just remember J. R. Ewing.

DUNBAR: J. R. Ewing. So he looks at me. He says, "No, no, I mean the TV show."

And I said, "I've never seen it." And he couldn't believe that, coming from America, I had never watched *Dallas* with J. R. Ewing. But, you know, I was busy. [Laughs]

ROSS-NAZZAL: Busy traveling all over Europe.

DUNBAR: Right.

ROSS-NAZZAL: Well, I'm wondering, would you like to talk a little bit about the mission, or should we wait to talk about the mission till next time?

DUNBAR: Why don't we go ahead and wait, just because my voice is getting a little—

ROSS-NAZZAL: Sure. Sure. Well, thank you for coming by today.

DUNBAR: Thank you.

ROSS-NAZZAL: I've really enjoyed it.

[End of interview]