NASA Johnson Space Center Oral History Project
Oral History Transcript

Donald H. Peterson
Interviewed by Jennifer Ross-Nazzal
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ROSS-NAZZAL: Today is November 14, 2002. This oral history with Donald H. Peterson 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 and Rebecca Wright.

I'd like to thank you for joining us this morning and taking time out of your schedule to meet with us.

PETERSON: I'm glad to be here. I'm essentially retired, so I don't have much of a schedule anymore.

ROSS-NAZZAL: Why don't we begin by getting some background on you. Why don't you tell us about your interest in aviation and aerospace when you were a child, how you developed that interest, maybe what sort of events or people sparked this interest.

PETERSON: Well, it started—I guess actually it started when I was a child, but I don't remember a point in time when I suddenly became interested in it. When I was a kid, I grew up in a very small town in Mississippi, and we didn't have a big university or any high-tech industries or anything. We had a pretty good library, and I did a lot of reading when I was a kid. I read adventure stories. I also read science fiction, and I guess my first interest in space came through science fiction, some of which was absolutely fantasy-type stuff, and some of it was pretty realistic. I read some interpretations of some German science fiction, which was much more realistic than a lot of the other stuff.

Also, I had a neighbor, his name was J.A. Glenn [phonetic], Joe Glenn. He was a P-38 fighter pilot in World War II, and when he'd come on leave, he was kind of the town hero. Since he lived next door, I could go visit with him, and he used to talk about flying and that sort of thing.

Finally, when I got in school, I just kind [of] had a knack for math and physics and science and that sort of stuff, so I was interested in technical things. I don't remember exactly when that happened, but all of that together, I guess, kind of led me to be interested in aviation.

ROSS-NAZZAL: You actually graduated from the U.S. Military Academy [West Point, New York] in '55.

PETERSON: Right.

ROSS-NAZZAL: I notice that you elected to work with the Air Force rather than the Army. Can you tell us about that decision?

PETERSON: Yes. I'm so old that when I graduated at the Military Academy, there was no Air Force Academy [Colorado Springs, Colorado] and the rule then was that one-third of the West Point graduates and one-third of the Annapolis [United States Naval Academy, Annapolis, Maryland] graduates went into the Air Force. So it wasn't like a big individual decision. All assignments out of the Military Academy were based on class standing, but you didn't have to stand very high in the class in order to get your choice. So since a third of the whole class went into the Air Force, there were a lot of us in those days that did.

That's all changed now. With the Air Force Academy, I think now going from one service academy to a different service is pretty rare. They still allow people to do that, but I think it's a very small percentage now.

ROSS-NAZZAL: Why don't you talk to us about your career in the Air Force until you actually entered the MOL [Manned Orbiting Laboratory] program.

PETERSON: Well, let's see. My first real job in the Air Force was as an instructor pilot, and I taught flying for about three and a half, four years. That was a good assignment, actually, because you got a lot of flying time and you do all the different things in an aircraft that are normally done in any kind of flying. I mean, you do acrobatics, and you fly instruments, and you fly formation. So you get a variety of things and you fly with students, which teaches you some other things about flying. I got a lot of flying time, which later on was very important because that was one of the criteria, for example, to get into test pilot school.

Then I served a tour—I actually was asked, when I was leaving that assignment, if I would be interested in a program called the nuclear-powered aircraft, and you may not even remember that. It was a long time ago. They were looking for pilots who were willing to go back to school and get a degree in nuclear engineering to work with an airplane that was going to be powered by a nuclear reactor.

So I went back to school, and I got a master's degree, which took a couple of years at Wright-Patterson [Air Force Base, Ohio] and about six months before I graduated, they cancelled the nuclear-powered aircraft program. So I had a master's degree in nuclear engineering and really no flying assignment where I could use that.

I wound up working in technical intelligence at Wright-Patterson for about another three or four years. I was very lucky. I worked for a colonel named DeGoes, [who] is now deceased. But he knew that I was interested in flying, and so he let me spend one day a week working as an instructor pilot at Wright-Patterson and four days a week on my technical intelligence job. My civilian boss didn't like it very much, so he carried me on his rolls as eight-tenths of a man, because I was out of his office one day a week, which didn't really matter in the long run.

But the technical intelligence, I worked on not nuclear weapons, but nuclear reactor systems. We looked primarily at Russian stuff as best we could figure it out, and a lot of interesting things there. But I guess all of that led eventually back to technical things. Since I was flying one day a week, I flew with most of the senior officers at Wright-Patterson, and in the course of flying, you spend a lot of time talking with these people, and so I picked up a lot of information just from listening. There were at that time about twenty-seven general officers and a whole slew of colonels, and I was a captain. So it was kind of fun to get to hear all of those people.

I finally wound up serving—General [Arthur W.] Cruikshank was the Commander of Foreign Technology Division, and I wound up flying kind of as his personal pilot and got to act as his aide when he traveled, and that was extremely interesting. He was a fascinating character. He flew as a Flying Tiger in World War II, was shot down, killed a couple of Japanese with his bare hands, and walked out, and walked like 180 miles to his own lines in the course of several weeks. Covered himself with mud so his skin would look like theirs, and if anyone questioned him, he'd act like he was insane. He just babbled and walked on, and they'd just let him go.

He, also, after he got out [of the Flying Tigers, he], went to Princeton [University, Princeton, New Jersey] on a Guggenheim fellowship and got a master's degree in one year. So he was not a dummy. A pretty smart guy. I'm sorry, I diverged. But a lot of fascinating characters that I worked with and had the privilege of working with.

ROSS-NAZZAL: Well, how do you think that these type of positions prepared you for the MOL program, which you eventually entered.

PETERSON: Well, I'm not sure how much I can talk about the MOL program. There's a lot of stuff published if you want to—I think you can even go on the web now and get a lot of information on it. But it was a very highly classified program. Essentially it involved a couple of things that I had experience with. One was flying. They wanted pilots. Also, it involved technical intelligence, and I had three or four years of background in technical intelligence. So it was a pretty good fit.

But basically that program died for lack of funding. General [Joseph S.] Bleymaier was the commander, and he finally went to [President Richard M.] Nixon and said, "Either fund this program or kill it, because we're burning time and money and we're not making progress because we don't have enough funds," and Nixon decided to kill it, which I don't know whether that was a good or bad decision, but I thought what Bleymaier did was the right thing to do, because the program was floundering, and we were spending quite a [bit (by Air Force standards), but] not much money by comparison with the NASA programs, by the way. It's amazing. I think the biggest amount of money that program ever spent in one year was $300 million, and that's pretty small by comparison, say, with a Saturn or the lunar program or the Shuttle.

ROSS-NAZZAL: …There were a lot of complaints that the program was essentially following in NASA's footsteps, replicating efforts, and things like that. Were you aware of that when you were in the program?

PETERSON: Not to any great extent. I think that's not true. I think what we were doing was something significantly different than what NASA was doing. It would have used some of the same types of hardware, but some of the precision of the hardware that we had to have was advanced beyond anything NASA was doing at the time.

You can go in *Aviation Week* magazine now and read—in fact, the last issue had pictures made from space, of Soviet facilities that were made thirty years ago, that had a one-foot resolution. That means you could distinguish objects from space as small in size as one foot. So some of the precision of those systems was pretty amazing.

ROSS-NAZZAL: Why don't we go back, and you can tell us a little bit about what prompted you to apply to the MOL program.

PETERSON: I think the fact that they needed people who understood intelligence and understood flying and the fact that there was no nuclear-powered airplane program to go to. So it was an assignment where I could use a lot of the things that I really knew and understood, and a lot of background.

ROSS-NAZZAL: Did anyone encourage you to apply to the program?

PETERSON: No, the Air Force put out, the same way NASA does now, I think, they put out like a public announcement, except within the Air Force it wasn't really public, but it was an announcement to Air Force-rated officers. As I remember it, you had to have a degree in engineering, you had to be within a certain age, and you had to be within a certain grade, that is, captain or—I believe the highest grade they would accept was major. Obviously you had to be healthy and that sort of thing.

But other than that, it was just a standard announcement like a lot of other things. In the Air Force and in most of the services, I think, they put out, I forget what they're called, but they're, like, here's a list of potential assignments and if you're qualified and you want to volunteer, you can do that.

For example, the people that fly the SR-71 had the same kind of program. That's the big Blackbird that operates out of primarily Beale Air Force Base [California]. That's another fascinating program. I just read an article by a guy that flies that, and he said on one of his missions he got to watch the sun rise in the west twice. They fly faster than the Earth rotates. So when the sun would set, they would fly faster enough to catch up with it. Then they'd turn south to pass over some targets and turn back west and caught up with it again. Those kind of programs are fascinating. That's a very difficult program, by the way. Very uncomfortable flying, pressure suits, long, long missions, no space inside the airplane. It's not an easy job.

I'm sorry, I keep diverging, but—

ROSS-NAZZAL: No, these are wonderful stories. Why don't you tell us about the training, whatever you feel comfortable telling us about the training.

PETERSON: About the MOL program?

ROSS-NAZZAL: About the MOL training.

PETERSON: Basically, I can describe in generic terms, but basically what we did was we had couple or three different operations we were supposed to do, and we spent our time the same way NASA spends their time, learning to do the things that you're supposed to do in space. Of course, part of that was, we learned to operate in a pressure suit in case you had to go outside. Well, we really didn't plan to go outside the vehicle.

We learned to operate all the equipment on the vehicle, and we went through all the situations involving launch and reentry. Of course, we were flying a capsule in those days, so we weren't landing on a runway; we were going to land in the water. We had to go through survival training and water survival and all the rest of that. The idea was that you might come down someplace that you hadn't planned to come down.

You could come down almost anywhere. The Earth is two-thirds water. So you've got a lot of places to pick from, and, of course, the military would then come pick you up. But you had to be able to stay afloat and stay alive maybe for several days until they could get to you.

Finding people in those days wasn't nearly as good as it is now. They didn't have the global positioning system and all those things.

ROSS-NAZZAL: Because of that, did you have to participate in, say, desert survival training or jungle survival training?

PETERSON: We did all of it. We did desert and jungle. We did kind of Arctic survival but not—that was the one we didn't do very much of, and the idea was that you were more likely to come down somewhere on a part of the Earth that was not the Arctic, because we didn't spend very much time over the poles. We flew over the poles, but we didn't spend much time there.

Military satellites, a lot of them go pole to pole for probably obvious reasons. I mean, we can talk about that if you're interested. You go pole to pole like this. [Peterson gestures.] The Earth rotates under you, and so in a twenty-four-hour period you get to look at everything. You look at the whole Earth, and you look at it once in daylight and once in darkness. So, polar orbits, especially low orbits, give you a good view of everything, and that's primarily what military satellites do. I mean, I suspect exactly what they do is still classified, but there's tons of material now in the open literature about military satellite operation. You can pick up *Aviation Week* or even *Scientific American* or *Discover* magazine. Periodically they'll have articles in there about the military and what they do.

ROSS-NAZZAL: Well, while you were working with the MOL program, did you ever work with NASA? I know that there was an arrangement between NASA and the MOL program.

PETERSON: I didn't, no. I think those arrangements, though, were primarily engineering arrangements. We were using, for example, the Gemini capsule, but it was modified substantially. Have you talked to any of the other MOL people?

ROSS-NAZZAL: Yes, we talked with [Karol J.] Bobko and [Henry W.] Hartsfield [Jr.] and [C. Gordon] Fullerton.

PETERSON: If I'm repeating stuff, just tell me. There's no point in telling you twice. But they took the seats in the Gemini and tilted them apart, and they put a tunnel that went back through the heat shield into the lab. But that work was all done, and most of that work was done at St. Louis, [Missouri] at the McDonnell [Aircraft Corporation] plant there. Since NASA had bought Gemini capsules and tested them, we dealt with them primarily on that. Some of the other work was done at other facilities and had very little contact with NASA. Remember, this was before, well before Skylab. So NASA didn't have the Skylab experience and that sort of thing at the time.

ROSS-NAZZAL: Did you work with any of the contractors? You mentioned McDonnell [Aircraft Corporation]. Did you work with any of them?

PETERSON: Worked with all of them. We traveled in civilian clothing, and we traveled often with false I.D.'s [identification]. I used to travel with a Black fellow who was killed later, a super guy, named Bob [Robert H.] Lawrence. It was kind of funny, in those days, of course, we were much younger, and we both had crewcuts, and we'd go someplace. Young White and

Black guys together in those days weren't as common as it is today. We found a couple of interesting things. There were restaurants that wouldn't serve him, and there were restaurants that wouldn't serve me. In other words, he was welcome, but I really wasn't. Nobody ever really threw us out or threatened violence, but they'd just ignore us.

The other thing is, we stopped at a service station one time to get gas, and this young attendant came out. We were in trench coats, both of us. It was cold. We were up in the north part of the United States. He came out, looked us all over real good, and came over quietly and said, "F.B.I. [Federal Bureau of Investigation]?"

And I said, "No." I know he'd been watching Bill Cosby and Bob Culp.

He stood around a minute and said, "C.I.A. [Central Intelligence Agency]?"

And I said, "No."

And he said, "Oh, okay," like, "You know, I know you are, but that's all right." But it was really hilarious.

Bob was a super guy. His death was a terrible tragedy, killed at Edwards [Air Force Base, California] in an F-104.

ROSS-NAZZAL: I know that there was a lot of publicity surrounding his appointment to the MOL program, because he was going to be the first African-American astronaut, essentially.

PETERSON: Yes. NASA had selected a Black guy, and I didn't know him, and I probably shouldn't comment. But the story was that he just didn't work out, and I don't know whether they suggested he leave or he decided to leave. But he never flew. I don't know what that was all about. That was long before I came to NASA.

ROSS-NAZZAL: That was during the Apollo Program, or—

PETERSON: I think it was even before that. But I don't really remember that. You probably shouldn't quote that. I just remember that Bob Lawrence was supposed to [be] the first Black American astronaut.

Of course, that really created a problem for us. The rest of us were unknown, and we could travel on false I.D., and nobody knew, had any idea who I was. But they worried because the press learned to recognize him. In other words, they knew him on sight, and it becomes much harder to run a secret program when one of your guys is, like, a high interest to the media, and he really was for a while. He kind of shunned that, obviously to try to shut some of that down. We always worried that we'd show up at some place and somebody would recognize him and make a big to-do about it.

ROSS-NAZZAL: Well, after the program was cancelled in '69, what did you decide to do?

PETERSON: Didn't have a lot of choice. We had some special clearances to work on that program, and you couldn't fly, for example, combat missions, and you couldn't fly certain reconnaissance missions, because you were exposed to being captured by some enemy, particularly the Russians, but I guess we worried about the Chinese and others. You had information that was secret enough that they didn't want that to happen.

So we didn't have much choice, and Hank [Hartsfield] and I went back to school. We were both going to work on a Ph.D. Then NASA changed their minds about when we had to show up, and so that kind of squelched that. Hank, I believe, got a master's degree out of that. But I already had a master's degree, and they kind of said, "Well, you could get another master's degree, but it won't mean much." So it really wasn't worth doing.

The Air Force was very upset, too. They don't like assigning you to a school and having you not complete the course. We finally had to get the Undersecretary of the Air Force to waive that requirement so we could go to NASA.

ROSS-NAZZAL: So actually the program that you attended at the University of Tennessee [Knoxville, Tennessee] was an Air Force program?

PETERSON: The Air Force sends people to civilian schools under a program sponsored by the Air Force Institute of Technology. They send people to study all kinds of things, I mean, standard, the same kind of course any person at school would take. They were trying to give us a generalized course, and I think I was going to get, if I had finished the course, a doctorate in something called engineering science, which is kind of a catch-all. You learn a lot about thermodynamics, and you learn math, and you learn a lot of physics and this, that, and the other.

I don't remember what Hank was going to major in. But the Air Force just didn't want you to drop out of those programs, so I had to get special permission to be a Ph.D. dropout.

ROSS-NAZZAL: Why don't you tell us a little bit about that degree program, what you were studying while you were at the University of Tennessee.

PETERSON: It was a pretty general program. I studied a lot of thermodynamics and aerodynamics, a lot of mathematics, primarily because I like mathematics, but those kinds of courses. That school, by the way, was located at the Arnold Engineering Development Center, [Arnold Air Force Base, Tennessee] and they have access to Arnold's wind tunnels. So a lot of the research was done there, and I would probably have done some kind of aerodynamic research program.

I think Hank's master's program had something to do with lasers, but you'd need to verify with him. It's been a long time ago. I don't really remember very well.

ROSS-NAZZAL: Why don't we talk a little bit about transferring to NASA. Tell us about your visit down here to NASA and then the call from NASA.

PETERSON: Well, that was kind of interesting. You might think that there was a lot of—I mean, a bunch of screening and testing and all that. As far as I know, there was none. There were fourteen people who were crew on the MOL program, and they took the seven youngest people. I'm sure they did that because they figured it would be a while before we'd get a chance to fly, and the other guys had reached either age or rank seniority where they really didn't fit in. A couple of the other guys went on with Air Force careers and did extremely well.

Bob [Robert T.] Herres became Chief of Staff of the Air Force, and Jim [James A.] Abrahamson wound up running the F-16 program and then became an [Associate] Administrator [for Space Transportation Systems] in NASA for several years. So the fact that they didn't come to NASA didn't really hurt their military careers.

ROSS-NAZZAL: How did you feel when you got the call from NASA? What was your initial reaction?

PETERSON: Well, I was happy, because I joined the MOL program because I wanted to fly and do those kinds of things, and I figured that the assignment at NASA would be very similar, and it was, except none of it was classified. I shouldn't say that. There's a couple of little items that NASA usually said are classified. But by and large, the NASA program is wide open, and not only is it open, they advertise things. I mean, they go out of their way to make what they're doing public.

It was just a totally different environment, a lot easier environment to work in, because you didn't have to worry about talking about what you were doing. They sent us out to talk to all kinds of civilian groups about the NASA program, and they wanted people to know what they were doing. Very open organization. By the way, an excellent, I thought and still think, an excellent technical organization. NASA does really good engineering work.

Their management doesn't seem to ever be able to get the budget right, but that's a separate issue. Part of that is because of the way that program started, I think. When the manned space program started in this country, the Cold War was in full swing, and we were scared to death, and there was this feeling that space was the high ground, that is, if you commanded space, you had command of the Earth. Now, it's really not necessarily true, but that was believed by a lot of people in those days, not just civilians, but military and government and everybody else. So the idea that the Russians might be ahead of us was pretty frightening, so there was strong public and government support for the manned space program and essentially an unlimited budget.

There's a story—and I have no idea whether this is true or not—that NASA's original estimate that they were going to ask the government for, for the Apollo Program was $5 billion, and they took it, and I think Mr. [James E.] Webb was the Administrator then, and he said, "Let's double that." Then they went to Congress, and some congressman said, "That's not big enough. You ought to double that." So actually they quadrupled their estimate, and they still spent a third more than the $20 billion quadrupled estimate, and nobody ever questioned that.

The people that worked at NASA were told, "You do whatever needs to be done, and we'll worry about paying for it." You know, under those conditions, you can do a wonderful engineering job, where you're not worried about "What happens if I need to test this one more time?"

What NASA did in those days quite often was, if they wanted a particular type of radio or a pressure suit, they'd build two or three versions and then test them, and they'd pick the best one. The Air Force used to do that, by the way, with airplanes. If they wanted a fighter airplane, they'd build two versions, and they'd have what they called a fly-off, a test, and then they'd picked the one that performed the best. It's so expensive now that nobody can really do that anymore. [There was a recent partial exception; two prototypes of the plane did fly before one was selected, but they did not compete one-on-one in a mission environment.]

But the NASA people came along in that environment, and in the early years they never had to worry about money. Now they do have to worry about money, but they're still oriented very strongly toward perfection in the engineering, and sometimes they just overrun their budgets, and they really don't get all that much concerned about it. Maybe you can't have both. I mean, maybe you can't just force people to live on a budget and expect them to do superb engineering all the time.

I thought it was sad that NASA overran the Space Station Program by a bunch of money, and it turned out their own bookkeeping didn't [provide adequate records]. The auditors couldn't even find out where the money went, and NASA couldn't tell them, and the outfit that was working with NASA as their auditor was Arthur Anderson, who at that time were deeply embroiled in the Enron mess, and the whole thing looked worse than it was. I think NASA just wasn't much concerned about rigid accounting for the money. They were spending it on things that needed to be done, and they didn't worry about it, which doesn't work very well in today's fiscal environment.

ROSS-NAZZAL: Well, you described a very interesting culture [at] NASA in comparison with the Air Force. I'm wondering if you can tell us when you first arrived at NASA what the mood was like.

PETERSON: Things were very upbeat at NASA. People that worked at NASA, well, imagine that you want to study thermodynamics or aerodynamics. You want to work on some challenging, advanced project, and somebody says, "Fine. Here's your desk, and your boss is this guy, but he won't bother you very much. You just kind of do what you think is right, and don't worry about the money." How much better can it get? It's like a teenager with a car and an unlimited budget, you know. You just do what you enjoy, and those people enjoyed what they were doing. So when they were out there working, it wasn't like going to work; it was coming out there to do things they really enjoyed. It was a superb and still is an excellent workforce, I think, in terms of what they do and the way they go about doing it. Very dedicated people.

I remember on Apollo 16 a fellow named Dave [A.] Ballard and I went out to the pad, and the vehicle was, I don't know, two or three days from launch. The batteries had expired on some of those [crew flashlights], because [the launch] had slipped, and we were going to replace the batteries. We did that, and the equipment was in the lunar module, and when we got out, they couldn't close the hatch. Something went wrong with it. So they needed to fix it, obviously.

A fellow named [Rocco] Petrone, great big Italian fellow, was the director of the program at that time. Most of the Grumman [Aircraft Engineering Corporation] people, a lot of the Grumman people were Italian, and they loved him. I mean, they thought he was wonderful. He asked for volunteers, and everybody in Grumman volunteered. He went with them. He took a team of guys. He went out on the pad, and they lived out there for, like, about twenty-five hours, twenty-six hours. They fixed the thing, but they fueled the vehicle while they were on the pad, which was considered an extremely hazardous operation. But, you know, the guy said, "Yeah, we'll do that," and he stayed with [them]. I thought that was pretty impressive, see.… And they got the thing fixed and got it ready to fly and launched right on time.

I think there's still that kind of dedication with some of the people. I think what's happened, though, is the program has become much, much more safety-conscious and much, much more money-conscious, and there's just an extreme reluctance now to take those kinds of risks, mainly because if anything goes wrong, the media and everybody else jumps on you immediately. You do 500 really challenging things and you do them all right, and you do one wrong and that's all anybody ever hears about. That's a very tough environment to work in. Of course, Congress, they back you as long as things are going well, and as soon as things go badly, they sort of act like they don't know who you are, and that really doesn't help either.

A lot of the money expenditures, by the way, when NASA contractors bid on a program, they want some piece of hardware, like the rescue vehicle, and I think the bids now are, what, $750,000 or something like that, well, I think it's going to cost more than that, and I think the contractors know that, and I think NASA knows that, and I think Congress knows that. But if you went in there and said, "It's going to cost a billion and a half dollars," the program probably wouldn't be approved.

So Congress, they want the money to come here, and I just saw in today's paper that Mr. [George W.] Bush is moving some funds to the Johnson Space Center budget so they can go build that vehicle. Well, the chances are very good that they'll overrun the cost, and I think everybody knows that from day one. But if you came out and said, "This is how much it's really going to cost," everybody would say, "Oh, don't do that."

So Congress doesn't mind that. Of course, when they overrun, then Congress turns around and says, "Those guys, spendthrifts, they don't know what they're doing. They don't keep books right," and blah, blah, blah. But they really don't punish NASA for that. They just kind of try to back away from the whole thing so they don't look responsible. So it's kind of a game in that sense, and the money side always has been a game.

But the same thing happens in the military, and the same thing happens in a lot of other places. NASA is certainly not the only place that underestimates costs and overruns budgets. A lot of outfits do that. Right now the military's probably going to do that and get pretty much a blank check because of all the terrorist activity and the thing in Iraq and the rest of that. People are not very critical of them right now, just like it was with NASA in the early days. We were in a Cold War with the Russians.

I remember when [Yuri] Gagarin flew and circled the Earth broadcasting, "I am eagle. I am eagle," over and over and over. You think the people in this country weren't terribly concerned about that? People had visions of a whole fleet of atomic weapons in orbit. In fact, for a while we were afraid the Russians had done just that. It was a scary time, and so whatever you needed to do to protect yourself, people thought, "We need to go and do that," and they weren't much worried that it cost a bunch of money.

I'm sorry, I keep diverging off your list of questions here.

ROSS-NAZZAL: That's all right. This is your oral history.

You had mentioned Apollo 16. You were actually on the support crew, and you were a CapCom [Capsule Communicator] for Apollo 16. Was that your first assignment when you came to NASA?

PETERSON: You know, it's been so long. I think I was actually assigned to work the Shuttle Program pretty much from the start. But then when, like, the Apollo 16 flight came along, they would pull people off other jobs and say, "Go work this for a while." The idea was, they wanted you to get some experience with the operational side. In other words, they wanted you to work with the flight controllers, and they wanted you to work with flight crews, and they wanted you to go the Cape [Canaveral, Florida] and see the types of operations.

Very different operation at the Cape than the operation here or at [NASA] Marshall [Space Flight Center, Huntsville, Alabama]. Marshall and [NASA] Johnson [Space Center, Houston, Texas] in those days were the design and planning Centers and that sort of thing. But actually getting that hardware ready to fly was all done at the Cape, and that's a very different environment. The analogy I used to use when I was talking to folks on the road was, it's like these teams that build these high-powered race cars. The owner and the engineers, they carefully plan how to make this car this way and make the tires better and the springs better and the chassis better, but when race day comes, nobody gives a damn. It's "Will this car run fast enough, long enough to win the race?" That's what the driver cares about, and that's what the pit crew cares about.

That's kind of the attitude at the Cape, is, "We've got to make this thing fly, and it's got to go to the Moon and come back," or it's got to go to orbit and come back, or whatever, and that's a whole different attitude than the guys who plan and design the systems.

The only really operational people at the Johnson Space Center are the flight control teams. They are concerned about operations. But most of the rest of the people there are planners and designers and engineers and that sort of thing. And I'm not belittling that. That's where this hardware all comes from. But it's just a different type of operation.

ROSS-NAZZAL: Before you worked on Apollo 16, did you have to undergo any sort of astronaut training program when you arrived at the Johnson Space Center?

PETERSON: Remember, there were only seven of us in the group that came in at that time, and I think that they felt that the best way to train us was what's called on-the-job training. We were assigned to work with senior astronauts. We worked with [James A.] Lovell [Jr.] and [Edwin E. "Buzz"] Aldrin and Jack [John L.] Swigert [Jr.] and one or two other people who had flown and were much senior to us and knew the ins and outs of how NASA worked and the contracts and the systems and all the rest of that. So you really learned on the job, and with only a few people, that's a fine way to do that, because if you had a question, people had time to sit down and talk with you.

There was another thing that was available that really isn't available anymore. The Astronaut Office had a—I forget what it was called, but it was a technical support organization, in the same building that the astronauts were housed in. And if you had any kind of question about anything, you could always pick up the phone and call one of those guys and you'd either go to their office or they'd come to your office, and they'd brief you, teach you whatever you needed to know.

And literally, those guys, each one had a specialty, and in their specialty they were top of the line. They knew everything there was to know about their particular system. So it was a wonderful way to learn, because essentially it was like having a couple of hundred guys who would tutor you on whatever you needed to know. Of course, that also is part of the cost of running a program like that, because you pay all those guys. But that sort of guaranteed the quality of those programs, and maybe that's the only way to really guarantee that kind of quality.

ROSS-NAZZAL: Well, let's talk about your work as a support crew member on Apollo 16. That was when you thought you were working on Shuttle, and you were pulled to work on the crew. What were some of your duties as a support crew member?

PETERSON: Basically what support crews do is, in the course of getting ready to fly, anytime there's anything being done with a piece of hardware or with an operational procedure, the people who are doing it want somebody from the flight crew to come meet with them and get briefed on it. Well, the flight crew can't just—I mean, on Apollo there were three guys on the flight crew, and there was a backup crew. That's a total of six people. Well, in a given day there might be twenty-five different meetings going on, and they just couldn't cover all that.

So what we did, as one of my co-workers said, we did everything the flight crew didn't want to do, or didn't have time to do, really, is the right answer. But we went to meetings [tests, and simulations]. I remember one of the big concerns was when the lunar module came up off the Moon, it had to re-rendezvous with the command module, and it used radar to do that, and it used something called a Kalman filter, which I ain't going to try to explain here. But whenever you went to anybody and said, "How do you know when the trajectory is correct?" and they said, "Oh, the Kalman filter," well, I figured everybody knows what a Kalman filter is except me. So I've got to find out. I started asking people, and I find out 80 percent of the people that were throwing that term around had no idea what a Kalman filter was or did.

The Software Directorate at that time was under Bill [Howard W.] Tindall. I said, "I want to learn about Kalman filters," and this guy taught me all about Kalman filters.

But we found out, interestingly enough, that if the frame that the radar [antenna] was mounted on got bent—and what they were concerned about was if you made a hard landing on the Moon and this big heavy radar [antenna] bent the little framework it was hanging on, what would it do? We found out the Kalman filter won't fix that. In fact, it will converge to the wrong answer.

So that was the kind of thing. But, I mean, there was a lot of little things like that, which every time you did one of those little things, you learned something, and, of course, what they did was, they said, "Okay, we now know that's a problem. So now we'll figure out a way to have a countermeasure if we think that's happening." They could watch from the ground, and they could also watch from the command module, and they could back that up. But those were the kind of things we did.

Some of them were fairly simple. I mean, some of them were things like, "Okay, go get in the lunar module, and we're going to do this test, and all we want you to do is throw the switches when we tell you." But they wanted somebody, a crew representative, to do that, so that person could go back to the crew and say, "Look. I went through that whole procedure step by step, and everything worked." It wasn't that they didn't trust the engineers; it's just that they wanted somebody from the crew to be there. But those are the kind of things we did.

ROSS-NAZZAL: How familiar were you with the experiments?

PETERSON: Not very. I worked primarily on the lunar module itself, and I knew some things, and it's been so long ago, I don't remember much of that. But I knew how the computers worked and how the thrusters worked and how the radar worked and how the life support system worked and those kinds of things. But there were other people who worked—I think Tony [Anthony W.] England was the guy who was the CapCom for the lunar surface operations, and so he was the guy who learned all about the lunar surface experiments.

ROSS-NAZZAL: You also served as CapCom on the mission. Why don't you tell us a little bit about your duties as CapCom.

PETERSON: Basically what the CapCom does is communicate between the crew and the flight director, and the idea is, again, they want somebody who understands the vehicle and who understands flying to, like, be the crew's representative on the ground control team. You sit there in a roomful of people, and I forget how many there were, but thirty-some-odd people, and each one has a different specialty, and they're watching the vehicle. They get a lot of telemetry data back, and they're all looking at that.

Well, as a CapCom, you learn to listen sometimes on two or three [communication] loops at the same time. So you were listening to two or three different conversations, and you were also listening for the flight crew, for the guys in space. You learn to pick up [keywords and phrases]. You'd hear some conversation going on, and you'd realize, okay, that sounds like a minor problem, and so you'd just turn that off and go to some other loop and listen there. But you also listened to the flight director, and, of course, the flight director would then say, "Hey, we've got a problem. We need to do thus and so."

Then what your job was, was to make sure that, first of all, you couldn't let thirty people talk to the crew, okay, because that would just be a hodgepodge. So what they did was, the thirty people talked to the CapCom and the flight director. Then the flight director said, "Okay, here's what we think we ought to do. What's the best way to tell the crew? How should we go about doing this?"

Having gone through some of the simulations and followed the guys around while they were doing simulations, you got a feel for how much time they had and what the crew knew and didn't know. In other words, probably nobody on the crew, for example, understood the Kalman filter; didn't have to. I suspect I was one of the very few astronauts that ever made the effort to learn that, and I wouldn't have if we hadn't had a radar problem. You know what I mean?

So you had a good feeling for what the crew would understand and what they wouldn't understand, and also for how they would react to certain things. You tried to winnow all this vast amount of information down to bite-size stuff that you could pass up to them and they could understand, because there were three people up there and they were getting information not just from the thirty-five guys in the control center, but from hundreds of guys in the back rooms and thousands of guys out in various contractor facilities, who were all feeding information in constantly.

There were always people that said, "They need to check the batteries in the such-and-so radio." Well, he said, "Hey, that's the radio. We ain't gonna use that radio unless the other radios fail, and the guys are really busy right now. We can't do that now." So that would go on your list of things that maybe next Sunday, when they're not busy, we'll tell them about that.

But that's kind of the way the job was. Again, very seldom is there disagreement or any rancor in that group. Once in a while a guy will think—especially some of the scientists who wanted some piece of data really badly and the guy had spent his entire life working as a professor at some university, knew nothing about operations, and his little experiment wasn't performing well, and he wanted everything else in the whole world to stop until that was fixed, and once in a while we'd have a problem with a guy like that.

But the guys that worked for NASA understood that you have to prioritize this. It does no good to fix the radio in one of the lunar surface experiments if you lose the spacecraft. You've got to have a sense of where does all this fit. And, frankly, NASA's view of science was that most of it was nice to do, but if we couldn't do it, you didn't take chances in order to try to do science. The big goal was to get people to the Moon, do what you could on the surface, and get them back, and that's kind of the way that worked.

By the way, there was one interesting scientific thing I did. I went on a survey where they were teaching the crews how to do a geological survey, and they took us all out near Taos, New Mexico. Pretty country out there, very rugged. There were two teams. The prime crew went with one geology training team, and the backup crew went with another one. I got to listen to both debriefings, and I was, frankly, amazed, because the guys did exactly the same traverse. One team started thirty or forty minutes before the other, and they went to these nine different places, and they took notes and they analyzed stuff.

The two geology training teams, which were made up, by the way, of very well-known geologists from all around the United States and maybe Europe and other places, in the two debriefings, the geology teams told these two different crews two entirely different interpretations of the terrain. I thought, makes you wonder how much of a rigid science geology really is, because you could obviously interpret a lot of that stuff more than one way.

The crews' attitude was, "Maybe we really shouldn't try to do so much interpretation. Maybe we just gather data. We just gather facts and pictures and samples and that kind of thing. We bring that all back, and then the geologists can spend the next two years or five years or whatever analyzing and discussing." But it was interesting that some of the science training was not as scientific as you might have thought it would be, as far as I thought it would be.

Of course, then you run into the same thing in the military. If you listen to two different intelligence groups brief you on some enemy operation, you're very likely to get two very different versions.

ROSS-NAZZAL: Yes, people's perceptions often vary.

PETERSON: Yes, and, remember, you know, geology and military intelligence share some traits. You're not getting complete sets of information. You're getting bits and pieces, and you're trying to put together a whole picture from that, and you can misinterpret that pretty easily.

ROSS-NAZZAL: You mentioned a couple of things that I'd like to go back to. You mentioned there were a couple of times that you had to deal with a scientist who might get upset because they wanted their experiment to run and get fixed. You talked about it just a little bit, but I'd like for you to talk about it in a little bit more detail, balancing the request of the scientists versus the time constraints of the astronauts on the lunar surface or in the command module.

PETERSON: I probably can't really do justice to that in a few minutes. But basically there's a hierarchy of things. Safety is obviously one of the paramount, because if you kill the crew or destroy the spacecraft, all the rest of the stuff doesn't mean anything anyway. So, obviously, maintaining the vehicle in operational condition and maintaining the health and well-being of the crew take priority over everything else.

From there you work down. Some systems on the spacecraft are critical, and some of them aren't. For example, if you've landed on the Moon and you find out that in the landing you've bent one of the legs on the landing part of the vehicle, unless that's going to affect the liftoff from the Moon, which it might because you're now maybe not sitting level, but if it's not going to affect that, then don't worry about it.

Now, there's some fellow who was responsible for designing that vehicle and designing that leg, and he's extremely concerned about that, and he wants 400 pictures and some measurements, and he wants to know where did it bend and were there cracks or were there little splintery things up and down the legs or did it just break cleanly, because he wants to go back and figure out how to make the next one where that can't possibly happen. But that takes a lower priority, because you've got other things you need to do on the lunar surface and you've only get so much time.

The CapCom, by the way, didn't make those decisions. The flight director actually makes those kind of decisions. In other words, he looks at all that and says, "Okay. I know you want all this information, but we don't have time for that. If we get a chance, we'll get you some pictures, okay? But you're just going to have to be patient and wait, because we've got two guys on the lunar surface. They're out 300 yards from the vehicle, and they're now covered in dust, and they're trying to pick up rocks, and they're doing this. We've got to focus on that."

Some of the problems were pretty severe. That lunar dust was a terrible problem. When we first started, nobody knew what that stuff would do. They didn't know whether that stuff would harm a human being. The problem was, when the guys—as long as you were in the pressure suit, you were fine. But when you came back inside the vehicle, that stuff was all over the suits, and you brought it back inside with you, and we didn't really have any good way to clean that off. So when you took those suits off, you were inside this little tiny cabin, closed in there with all the stuff that you'd brought back from the lunar surface.

I guess, in general, the scientists weren't terribly worried about that because the lunar surface is a very hostile place. It's either extremely hot or extremely cold all the time, and it's airless and no water. So they figured there can't be a whole lot there that would hurt you, but they didn't want to take any chances either. That's why, for example, when the lunar crews came back, they quarantined them for a while. They wanted to be sure that they hadn't brought back some strange malady.

But, yes, there was concern about that sort of thing, which would be given a much higher priority than minor damage to a lander vehicle. But the flight director had to look at all that and decide, "Yes, I'm going to do this and I'm not going to do that," or, "I'm not going to do it now." I think what happens is, unfortunately maybe, but science experiments, it's like I remember one of the flight directors said, "If every science experiment on the Apollo failed, we'd still go to the Moon and come back as long as we don't lose the vehicles and the guys, and that would still be considered a reasonably successful mission."

So if some guy's experiment didn't work, especially if it was a flaw built into the experiment itself, NASA wasn't very sympathetic about "Let's go see if we can't repair his experiment." It's, like, "You know, you had two years to get this ready. You supposedly tested it 500 times, and if it doesn't work, that's really kind of your responsibility." If we could fix something, we did.

But a lot of guys, they were used to working in a lab at a university, and if things broke there, you'd call in the technicians and you'd take the equipment apart and you'd check all the wiring. Some of them wanted to do that sort of stuff, and we said, "No, we can't do that. You're talking about a two-day job. We don't have that much time."

Those were the kind of things that—and most of the scientists were mature enough to realize that you take whatever you can get and you hope it all works, and if it doesn't, if they can help you, they will, and if they can't, you'd just have to accept that. But there are one or two guys always who, you know, they just couldn't accept the fact that their equipment wasn't the most important thing in the world, because in their world, to them, it probably was the most important thing. Being able to send equipment to the Moon and take science data was a big deal for a guy who'd spent five years or ten years working on something, and here was this chance to prove it or experiment with it, and then it got on the surface and didn't work. It was like his whole career was just crushed.

I could understand that, but there were times when you couldn't do much about that sort of thing. We were pretty lucky. We didn't have a lot of—we had very few real instrument failures on the Moon. Most of them worked very well. In fact, most of them—and they were built the way a lot of other Apollo equipment was built. They built maybe a couple of versions and tested them to death and found out exactly what worked and what didn't. So the equipment was pretty good equipment, high quality, very rugged, very reliable. We didn't have very many failures. So, most of it went pretty well.

But the flight director's job then was to sort out what you do next and what's high priority and what's not high priority. And I think those guys did a good job of that.

ROSS-NAZZAL: You had also mentioned that you went on a field trip, with the prime crew and the backup crew.

PETERSON: Yes.

ROSS-NAZZAL: How many simulations did you participate in for the mission?

PETERSON: Oh, I don't know. Probably a few dozen, but many as an observer. I mean, the crews were training, and if, like, in the lunar module, there was room for maybe one observer, and so sometimes I'd just go stand in the lunar module with those guys and watch them work and listen to what they were doing and go sit through the debriefing and that sort of thing. You learn a lot that way. You learn a great deal about how the vehicle works. Of course, if there were things you didn't understand, you didn't bother the crew and the simulation guys; you went and got one of the technical experts from downstairs and said, "Tell me about this." So, yes, it worked. The sims [simulations] and the rest of that stuff worked very well, I thought.

NASA does an excellent engineering and operations job. If they have a weakness, it's their budgetary side, and in some ways they're almost lured into that by the way Congress works. Congress wants you to come in with low bids because that's easy to sell to the American public. It makes your congressman look good, and he brought in some money. Then if you overrun later, the congressman can always—he has what you call plausible deniability. He didn't know that was going to happen, but lord knows if he'd known that, he'd never have agreed to this program that brought $500 million to his district. But that kind of gets to be a game, I think.

But the NASA guys down in the trenches that are doing the engineering work, they don't participate in that. They do their job, and they keep doing their job unless somebody comes to them and says, "We've got to stop. We're out of money. We can't do this test," or that test. Then they do the best they can with whatever they're given to work with.

ROSS-NAZZAL: Well, are there any memories or stories that you'd like to tell us about Apollo 16? Anything memorable?

PETERSON: Apollo 16. I think just that it was a fun time to work with the program because everybody was dedicated. At the Cape or at Houston when you needed anything done, all you had to do was ask, and there was always somebody that was willing to do whatever needed to be done, and everybody worked together on—it was a good team and really highly qualified people and very dedicated people.

A lot of those people worked with very little reward. About the only people in any of the programs that ever get any recognition are the flight crews and maybe some of the flight controllers, and that's pretty rare. I remember, this was after I left the program, and I can't remember what flight it was, but I do remember it was one of the flights that [F.] Story Musgrave was on, because he and I were friends and I was kind of watching. During launch, they got an indication from instrumentation that one of the engines on the Orbiter was overheating, I believe it was. It was overpressure or overheat, something, and they shut it down. They were far enough along in launch that they could still get to orbit.

Well, then they got the same indication on the second engine. Now, if you shut down a second engine, you're into an abort, and that's a pretty messy operation. There was a young woman, whose name I cannot remember now, and I should because I teased her about it later, but she looked at that. She was the booster control in the [Mission Control Center] and this is happening in real time. You've to realize, this sucker's up there burning away and you've got people, human beings, onboard and all that.

She looked at that and said, "I don't believe we've got two engine failures on the same flight. That's highly improbable. I believe we've got an instrumentation failure. Don't shut the engine down."

Now, in hindsight, that was a wonderful decision, but had she been wrong, the back end of the vehicle would have blown out, and killed everybody onboard [and lost a Shuttle]. And, you know, she got one interview with *Newsweek* magazine, I think, or *Time.* Of course, the flight crew and all us people thanked her profusely, and she was recognized, but I don't think she ever really got any public recognition for that at all. But, I mean, that's a life-or-death decision under tremendous pressure with four or five human beings and a two-and-a-half billion-dollar vehicle. Okay? And you can't get under much more pressure than that, and she called it right.

What I did to her was terrible. I called her up later. I waited about a month and called her up and said, "I'm Robert Smith, and I'm a reporter with *Life* magazine. I understand that you're the woman that saved Story Musgrave's life."

And there was this long, long silence. And finally she said, "Who the hell is this?"

I presume you know a little bit about Story. Story has a reputation as a lady's man. So she kind of got a kick out of that, I think.

ROSS-NAZZAL: Well, once Apollo 16 ended, what did you end up doing for the next couple of years?

PETERSON: Worked on Shuttle. Went back to working on the Shuttle. In fact, most of my career was spent working Shuttle. The way the Astronaut Office was set up in those days was we had, for each of the major systems, we had an astronaut who served as the office point of contact, and that meant his job was to go look at the systems, make sure that the crew would know how to use them, that they were safe, that operational procedures were being developed, and so on.

I worked the avionics systems, which was the computers, the guidance, the navigation control, the air data system, some of the other things. We found some fairly interesting things. For example, Hank Hartsfield and I worked together. We found a fairly serious flaw in one of the flight control programs and got it fixed. It was easy to find the little things, because we not only got to see the engineering analysis, we got to go work in the simulator, and we got to see how things really were working when you tried to run them all together, which some of the engineers never got to see. In other words, they built a program to do one particular job. They never really knew how that played with everything else. I mean, they might, but they didn't have to. And that was the job of the team that was integrating it, and we were part of that team. So we got to see a lot of that.

But those systems are very complicated, as you can imagine. I say that, and you look back now, that my little desktop computer at home is about 100 times faster and it has about 100 times more capacity than the computers that are now flying on the Orbiter. They're afraid to change the computers very much because part of the flight control scheme is based on timing. If you change the computer, you change the timing, and you'd have to redo all the testing. There are thousands of hours of testing that have gone into there, and they know this thing works, and they're very loathe to make those kinds of changes.

They can't change the outside of the vehicle for the same reason; that affects the aerodynamics. So they can change some things in that vehicle, and they are improving some of it. But they're not going to make big drastic changes to the control systems. It's just too complicated and too costly.

But, yes, that's the kind of stuff I did, and it was fun. By the way, my other claim to fame was that nobody has ever flown a manual controlled launch on ascent. It's always been done automatically, and the question was, could a crew do that? You needed some kind of cues to fly from. We weren't trying to find a way to get to a perfect orbit; we were trying to find a way to get to a safe orbit.

The Shuttle uses something called Lambert steering in ascent. Basically what it does is it tilts at an angle so that the downward component of the thrust fights gravity, and the rest of the thrust is used to accelerate. As it gets lighter and lighter and goes faster and faster, the gravity force diminishes because of centrifugal force. So it tips more and more as it flies out toward orbit.

I just sat in the simulator and said, "You know, I believe that we could do a linear approximation." You can read the acceleration onboard and you can read the pitch angle onboard, and if you multiple those two together throughout most of the launch, that's a constant. And I just said, "Guys, you look at the acceleration and your pitch to get this constant value, and you can fly a safe launch that way."

I was working for Ken [Thomas K.] Mattingly [II] at the time, and his comment was, "How on Earth did you ever—why would you ever think of this?"

And I said, "Well, it's math." It's Lambert steering, and it's a linear approximation to the mathematics. It's not a very scientific—you certainly wouldn't program that algorithm in a computer. But for a guy working with his head in real time, it was a very simple way to do it. It wasn't a perfect orbit, but it got you there.

So we did a lot of that kind of stuff, and that kind of stuff is kind of fun. I mean, you get to understand a lot about the vehicle. I don't know who was the first guy to do this, but I did one of the studies that showed what TACANS [Tactical Air Control and Navigation Systems] on the vehicle would cover in terms of what they could see on the ground. For a long time they had not used TACANS until they were almost to the landing site. But after that, they would turn them on on orbit and use them to update the navigation base. That was a fairly simple little math exercise. I mean, some geometry was about all that was involved. But just nobody had bothered to look at that.

I was interested in that because we used TACANS in airplanes all the time and they worked extremely well. There are some constraints on them, velocity constraints, and that's why you had to bring in some geometry. Can't look straight ahead. You're going too fast. You have to look out through the side.

But I did a lot of stuff like that. I enjoyed that because, like I say, I like math and I like physics, and I enjoyed that kind of stuff. Some of the other guys, you couldn't have paid them to do that kind of [work] you know. That wasn't what they wanted to do.

ROSS-NAZZAL: Was your work primarily self-directed, or were you given instructions from Mattingly?

PETERSON: A lot of times I was given—like I say, I worked for Ken Mattingly a lot of the time. But Ken was one of these guys that, Ken had about a thousand different things he was interested in. He'd come to you and say, "Here's my list. Do you see anything on there you'd like to work on?"

On his flight, on Apollo 17, I actually devised a couple or three experiments for them to do in their spare time, which they didn't have much. I don't think they did any of the experiments, but it was something he wanted done. But basically he was in charge of this little team of us guys that worked together. But if you went to him and said, "Ken, I think we ought to look at so-and-so," normally he'd go along with that. I mean, sometimes he had some priority thing he wanted to look at, but that's kind of how we did it.

There were always things to be done, like I say, we found a couple of flaws in things over the years, but there's probably 500 little things like that that nobody's ever found out. We just didn't have time to look at all of them.

The flight control system on the Orbiter is really—in a sense it's almost an experimental design. In other words, they built the system and then they tested it and tested it and tested it. They just kept changing little bits and pieces, primarily in the software, until it all worked. But if you went back and looked at it from a theoretical point of view, that's not very pretty. You know what I mean? It's like, gee, there doesn't seem to be any consistent deep underlying theory here. It's all patchwork and it's all pieced together. And in a sense, that's true. But that's why now they would be very loathe to try to make big changes to that, because putting all that stuff together took a long, long time.

ROSS-NAZZAL: If we can, I'd like to go back to Apollo 17. You just mentioned that you designed three experiments which they didn't actually end up using. I'm wondering if you could tell us a little bit about the experiments.

PETERSON: Ken wanted to use the sunlight, for example, coming through the window of the vehicle to see if he could build a reflector that they could use to heat something on the inside. So I went through a little quick design thing and designed a little reflector.

You have to understand it couldn't be something that was built in advance, because it couldn't be stowed. Didn't have room to store it. You had to use material that was onboard, so we used some of the Mylar material that was onboard the spacecraft and some of the cardboard. I said, you build it this size and like that, and then you fold it like this. [Peterson gestures.] Then we marked it and you fasten the edges together here, and, by golly, it makes a forty-five-degree cone. If you put something right on the centerline of the cone and you shine sunlight in here, what's on the centerline'll get really hot.

So that was one of the things he was going to do. Again, that's a fairly simple math problem. The challenging part of that was to find the materials onboard that were already there and figure out how to put them together to do that sort of thing. We did a couple of other little things like that, that was stuff primarily—he wanted—I think there were some springs on some piece of equipment. They were just coil springs, and we figured a way to rig them up so we could do some kind of experiments with some different masses in zero gravity that would have been interesting.

Of course, we were going to photograph all of it. One of them, we were going to use the spring to accelerate an object. There was a piece of material onboard that happened to have vertical lines on it. So we said, that'll make a nice grid. We'll put that right here, and we'll put the camera over here, and we'll put the object here. Then we'll do this experiment, and we'll film it as it moves across. Then later on we'll be able to go back and measure accelerations and all that.

I don't think that would have proved any new theory in physics or science, but it would have been interesting, for example, to show to school kids and stuff, because here was an experiment done in zero gravity, and he was going to use different-mass objects to show how the spring pull worked on those in the zero-gravity environment. They still do that kind of stuff on the Orbiter. You don't see much of that because a lot of it isn't a very profound discovery. It's just interesting things to do.

Have you seen a video called *Astronaut Smiles*?

ROSS-NAZZAL: No.

PETERSON: They show it at the Cape. They show it to visitors. It's a cute movie. It's just fun. I mean, it just shows guys onboard the—this is on the Shuttle, onboard the Shuttle, doing things kind of to amuse themselves. Some of it's funny, and some of it's kind of cute and all that. But there are a couple of things in there where they show people handling blobs of liquid floating in the cabin. One of the guys, I think it was Jeff [Jeffrey A.] Hoffman, had marbles that had been magnetized, and he floated them across the cabin and showed how a magnetic field causes them to move and all that. You can do things like that in zero gravity that you really can't do on the surface. The experiments were kind of interesting.

There was a scene in there with [S.] Dave [David] Griggs, I believe it was, using a yo-yo, which is pretty fascinating. A yo-yo can do amazing things in zero gravity. But there's a lot of that kind of stuff that goes on, and some of it's just for fun. I mean, some of it has nothing to do with science. It's just the guys need a break, and they need something to do.

This Russians became masters at that. A fellow named [Musa] Manarov took a guitar on his flight, and he and the other crew member actually wrote music in their spare time. Of course, I don't know how good the music is, but it became very popular in Russia for a while.

I think on Space Station, for example, you'll see more of that kind of stuff, because the people are there for longer periods of time and they need—see, our mission was terribly, terribly compressed. Our first day was about twenty-one hours long, and we were doing something every minute. Then we slept, I don't know, six and a half or seven hours and put in another eighteen-hour day. So it wasn't until, like, the third day of the mission that the pace slowed down a little, and even then, the last couple or three days in the mission, we worked twelve-, fourteen-hour days. And on a short mission where you're trying to cram in as much work as you can, you can do that. But you can't do that on the Space Station for six months. Human beings finally just get so tired they just can't function anymore, and so you have to give people in that environment more time off.

The Russians, of course, there are some very famous incidents in the Russian program where the cosmonauts just said, "We're not doing that. We're taking an hour off. We're tired." People think the Russian program was pretty heartless and that those people were little robots. They really aren't. Some of them were very independent-minded and did whatever they felt they could do best. But they have most of the long-term flight experience, too.

I worked with a guy a couple of times named [Valery] Poliakov, who spent fourteen months on the Mir. That gives you a whole different perspective of what space flight's all about, because you're away from your family and your friends and anything that's familiar. You're pinned in that vehicle all the time, and that's got to be a different kind of environment altogether. I mean, you know, I flew for five days. That's like a camping trip.

ROSS-NAZZAL: A fun camping trip. Let's go back and talk some more about Shuttle and the Shuttle development process that you took part in.

PETERSON: Could we get a break and let me fill my coffee cup?

ROSS-NAZZAL: Yes, let's take a break, yes.

PETERSON: Let's do that.

[Tape recorder turned off.]

ROSS-NAZZAL: I'd like to continue talking about Shuttle development and your role in the Shuttle development. You had mentioned that you and Hank Hartsfield had noticed that there was a flight control program problem. Can you tell us a little bit more about that problem?

PETERSON: Yes, it's pretty mathematical. When you fly the Shuttle, the nose is pitched up. In other words, most airplanes, when you fly an airplane, the wind is coming in essentially straight over the nose. I mean, the nose is not perfectly straight. That's how you cause an airplane to get lift, is you tilt the wings a little. But in the Shuttle sometimes you're tilted a lot. So the wind's coming this way. [Peterson gestures.] When you roll the vehicle, it doesn't roll about this axis; it rolls about what's called the wind axis, [the reference axis along the velocity direction]. So when it rolls, it not only has to roll, but it has to yaw. So it's like it's rolling around the outside of a cone.

Well, when you do that, the flight control system has to know what this angle is, and it does that by looking at the inertial platform. Then it commands a certain amount of roll and a certain amount of yaw to keep that angle constant as you move around. Well, what they had done is, they had fed in a term that affected the [pitch] rate, and they had [calculated] the term [based on] the yaw rate you'd have when you were [rolling]. But that's not the yaw rate you need while you're [turning], and that's what they had built in there.

What it caused the vehicle to do was, when you tried to roll, the vehicle would dip a wing and [raise] the nose. Then the crew had to counteract all of that when they were flying. So we got them to change the control law, to correct it. It wasn't that hard to correct. It just—they hadn't done it. And we ran into a couple of guys who really, I think, didn't quite understand what they were doing. But it's a very complicated system.

Up at high altitude they used what's called wind axis, which is the direction the wind, [air flowing over the vehicle], is coming. At a low altitude most airplanes use body axis. In both cases, you build in little terms that cause them to change in small ways as you maneuver. Then in the Shuttle they had to patch those two together, so that as you come down through the atmosphere, you literally transition from one set of control laws to another whole set of control laws, and all that has to be done very smoothly. That game is done by changing gains and putting in little magical terms here and there in the control laws. The Shuttle, it's maybe the only vehicle that I know of that flies in the atmosphere that has to know essentially where it is over the Earth in order to maintain control.

Most airplanes, you turn them loose. As long as they're flying in the air, it doesn't matter where you are. The controls work the same way everywhere [because the vehicle is measuring the airflow]. In the Shuttle, [at high attitude], the Shuttle doesn't fly literally by measuring the atmosphere. It knows which way is up and which way it's going [based on its inertial measurement system and navigation]. So all of its controls are based on that knowledge. So in the Shuttle, if you lost navigation, you'd have a terrible problem with flight control, and that makes the navigation a lot more critical.

See, in a typical fighter airplane or a commercial airplane, the whole navigation system can fail, and the flight control system works fine. They're essentially independent of one another. Now, as one of my military friends points out, you might not [find your way] home if your navigation system goes out, because you might not know where you are, but you'd still be able to fly the airplane. That allows them to separate those different functions out. In the Shuttle they're all integrated together. So it makes it more complicated and, again, you don't want to go in and change things once you've got all that working together.

ROSS-NAZZAL: That's interesting. I had not known that. Why don't you tell us a little bit about your work with the Program Assessment Office and your work with Arnold [D.] Aldrich.

PETERSON: Well, Arnie and I, I thought very highly of Arnie.… He's a good guy. I enjoyed working with him. In fact, I enjoyed working with the people in that office.

The idea of that office was—I don't know. I really don't know why the office was created. I don't know the history of that. But someone somewhere, maybe at [NASA] Headquarters [Washington, D.C.], maybe someone at the Johnson Space Center, decided that there needed to be an office that sort of looked at the vehicle and said, "Is this vehicle really safe? Is it really reliable? Is it really able to perform the way it's supposed to perform? Let's make sure we've done this job right." They wanted a little independent office that wasn't tied up in the day-to-day engineering of everything.

I had had a problem that kept me grounded for several months, so I couldn't fly. So they said, "While you can't fly, why don't you go over and do this job." I had done some other analysis along those lines. So I went over there, and basically the job was to assess reliability and performance of the vehicle.

About the only big study I did was the study of the reliability of the avionics system, and that at the time created, I don't whether you'd called it concern, but anyway, I pointed out that failure rates on some of the avionics were going to be fairly high.

See, on the Apollo and the earlier vehicles, they did something, and I forget what it was really called, but they built what they called ultra-reliability components. That is, they built components that were overdesigned and tested to the nth degree to make sure they would never fail, and failures on Apollo, for that reason, were pretty rare. But that's very expensive. That's a very difficult thing to do.

You're trying to build—I was told that after the lunar program ended, MIT [Massachusetts Institute of Technology, Cambridge, Massachusetts] had two of the lunar module computers left over, spares. So they just turned them on and programmed them to run cyclically through all the programs. I think they ran one of those computers for, like, fifteen years, and it never failed. It just kept running, and finally they turned it off. I mean, they just said, "It's not ever going to fail." But that's the way that equipment was built. But that makes it very expensive.

So when they built the Shuttle, they said, "We can't do that. So what we're going to do is, instead of ultra-reliability components, we're going to rely on something called redundancy." Do you understand what that—

ROSS-NAZZAL: Yes.

PETERSON: Yes. Okay, so they were going to have four computers, and they were going to have three TACANS, and they were going to have four of this and two of that and so on. That way you could tolerate failures. But as a result of that, the failure rates on some of that equipment was fairly high, compared to Apollo.

The other thing they did [was make the multiple units inter-dependent]. On a typical automobile you have five tires, but that's not five levels of redundancy because you need four of them. So you can really only tolerate one failure. You can have one tire go bad and you can take care of that.

But we got into that same situation on the Shuttle because of the way they did the software. The Shuttle, when it's flying, the computers all compare answers with one another, and then they vote among themselves to see if anybody's gone nuts. If a computer has gone bad, the other computers can [override] its output so that it isn't commanding anything. But to make that scheme work, you have to have at least three computers working. Otherwise, you can't vote. Okay? You could have [two systems voting], but if they vote against each other, you don't know which one's the bad one.

Well, we got into that thing, and when I did this study, we looked at that and said, "You know, guys, the problem is you've got these computers, and you put—." Actually, we put five of them onboard, put four of them in the primary system, and we said, 'Now, that way we can tolerate three failures.' But it turns out, because of the way you configured it, you can't. You can only really tolerate one failure, because [then], you're only running three, and when the next one fails, you're down to [two systems and the voting logic won't work].

So then they first said, "Well, we'll run four at a time." Then they found out they still had fairly high failure rates. But the complexity of the way the thing was put together kind of defeated the simplistic redundancy scheme that they had. It'd be like driving a car that had two engines, okay, or three engines, and any one of them would work. Well, that way you could fail two engines and you'd still drive right along. But if it takes two engines to power the vehicle, then you don't have that, and if it takes three engines to power the vehicle, you don't have any redundancy at all. It gets to be a game then as [to] how you trade all this off.

When I looked at all that and we put the study together, we said, "You know, you're going to have some failures that are going to really bother you because you're going to lose components." For example, you're on orbit and you've got four computers and one of them fails. Well, now you've got three computers left in the primary set. But do you stay on orbit? Because if you suffer one more failure, your voting algorithm no longer works. Now you're down then into coming home on a single computer and trusting it. And nobody wanted to do that.

So that said, "Gee, I've got four computers. I can only tolerate one failure, and then I've got to come home." We had four of some of the other components, and it was kind of the same sort of thing. If one of them fails, [we are no longer failure tolerant]. We've lost the capability to compare results and vote, and so we don't want to stay on orbit that way. So now, all of a sudden, the fact that you've got four of them causes more aborts because the more things you have, the more likely you are to have one fail. You'd get more failures and more aborts with four computers than if you'd gone with some other plan.

That was pretty controversial for a while. I talked to Gene [Eugene F.] Kranz, and I talked to some other people about that. Basically what Gene did was, he then went and had his ground control people build programs to say, "Okay, if this and this and this fails, where am I? What do I have left? How can I configure the vehicle to make it the safest and stay on orbit and complete the mission?" But it led to a lot of changes in the way they operated things. But we predicted—and there were some people that were really upset about that—we predicted a couple of ground aborts due to computer failures. Essentially we'd get chewed out for saying that, but in the first thirteen flights, we hit it right on the money. We had two ground aborts in thirteen flights.

Now, all they did was pull that computer out and put another one in, but ground aborts costs a tremendous amount of money. An extra day on the pad costs, I think, what, like, $50 million or something like that in support costs? Well, you've got everybody in the world up and waiting to go. You've got the control rooms up. You've got all the backup rooms up. You've got all the tracking sites, in those days, up and running.

Now they said, "Whoops! Hold on. We're not going till day after tomorrow." Well, you can take all that stuff down, but bringing it up back up costs about as much as keeping it up. So the guys said, "Well, we'll just stay on Station." But that's very costly. I mean, you're talking about a lot of money when you do that sort of thing.

So when we said, "Your system, the way you have it configured, is going to cause you to have some ground aborts and some delays," there were some people that were pretty unhappy about that. But it actually proved out to be correct.

Now, I don't know what they've done now. They don't have as many ground aborts, and I suspect what happens is, as you go along—for example, let's say you have a problem with the computers, and that was one of the weakest points in terms of the number of failures. By the way, the IBM people were furious when we said that. We quickly pointed that, "Hey, it's not really your guys' fault. You were given a set of specifications, and you built to those specs and your computers actually meet those requirements. It's just that we didn't ask for very high reliability, and so if your computers fail, they're operating the way the specs say they should."

But what happens over a period of time is, if computers continue to fail, there's usually one or two weak components that are causing that. So you have four or five computers fail, and you find out, gosh, half of these were caused by this one little chip. Well, you make a better chip and you put it in there. So you've increased the reliability. Over a period of years, that stuff gets extremely reliable.

There's a special technique for doing that. The Japanese perfected it, and I can't right now think of the name of it. But what they do is they statistically study failures, and they say, "Let's identify the parts that failed the most, and let's fix those." Pretty soon you've made the whole thing much more reliable. I think you don't hear very often anymore of ground aborts from avionics. Now, this abort they just had was a whole different [situation], that was an oxygen line somewhere.

Of course, the other problem they've got now is, the Shuttles are getting older. The Shuttles, unfortunately, they're pretty difficult to work on. When the military builds an airplane, it tries to make everything in the airplane designed so that you can remove and replace parts quickly and easily. The Shuttle is much more difficult to get to some of the stuff. There're not big [easily-opened] panels on it. You can't [release a few latches and] open a big panel on the side of the Orbiter. You literally have to take it apart to get into it. You can go in through the inside, through the bay, and get to some of that stuff, but even then you're removing parts that aren't designed—it's not like opening doors and looking inside. The military builds a lot of their stuff to be easy to work on, and they really didn't build the Shuttle that way.

So the Shuttle is more expensive to operate. For example, the little jet engines, there's, like, thirty-eight of them, I think, on the Orbiter that control attitude when it's on orbit. If one of those engines fails, you can't just unscrew some things and take it out. You have to cut it out with a torch, and you have to weld the new one back in, because they didn't build it to be removed. The heat shield is a—there are [24,300] little individual tiles, and they're all different shapes and different thicknesses, and so every tile is like a little individual item.

When the Shuttle comes back, they have to inspect visually, and with a pull device, every single tile. If any of them don't pass, you've got to cut that one out and clean off the glue and go get the new one and put it all back. Those are very high-maintenance items.

So the Shuttle really wasn't built to be easy to maintain, and that's because NASA has always had, as Jerry Griffith used to say, a standing army at the Cape that did all that, and nobody really worried about it. If you needed something done, you just called and they sent over four or five guys and they fixed it. But that's expensive. I don't know, the last time I looked, the typical Shuttle flight now, if you count all the ground support and everything, for a week costs about $300 million, $350 million, to fly for a week. So it makes it a very expensive vehicle.

Part of that cost, by the way, is because the traffic model never developed. The Shuttle was designed to fly—they were going to fly, I think it was fifty flights a year, and they were going to have five Shuttles to do that. So each Shuttle would fly ten times in a year. Well, right now we're flying—the whole fleet's only flying about eight times a year. Well, you're trying to amortize the cost of the whole program over eight flights. It's like we've got all this capability to repair and replace and analyze and monitor things, and we're not using a whole lot of it. If you were flying fifty times a year, the cost per flight would go way down because you wouldn't add that much to the facilities and the maintenance costs.

The facilities costs don't change much if you never flew. You've still got to have all the facilities, and you've got to pay for all that. You have to keep this whole group of specialists on, technicians and people, to do the work. With eight flights a year, some of those guys may only get used twice a year, but you've got to pay them and you've still got to have them there. If you were flying a lot more, the cost per flight would go way down.

Nobody had payloads that would justify the cost of putting the thing on the Shuttle, and so we don't get that many payloads. Of course, the Russians and the French have cheaper launch systems. If you don't need human beings to work your payload, a lot of people are going that way. Most communications satellites are launched on expendable vehicles now, just because it's cheaper.

I think, by the way, that communication satellites are the only satellites on orbit that are making money, that are actually earning more than they cost. So it's very hard. At one time it was thought, boy, these entrepreneurs are going to come in and they're going to fly hundreds of payloads. But nobody's found a way to make money. Obviously if you're an investment banker, you don't want a bunch of guys to invest in something that's going to cost them more than they're going to make. People won't do that, and they want payoffs relatively quickly. There are some things that could probably be done on orbit that would pay a profit in ten years or twelve years, but people making investments, they won't do that. They want a payoff. Most of them want a payoff within five or six years, or they're just not interested.

So it's hard in terms of cost to make the Shuttle a paying [investment]. And they keep saying we're going to privatize it. Well, I can't imagine any company stepping up and saying, "Okay, we'll run the Shuttle as a private enterprise," because nobody's found a way to make money with it. I mean, you just can't do that. Somebody'll say, "Well, you could do away with a lot of the maintenance." Well, I'm not sure you can. I'm not sure the way the big vehicle is designed, that you can do away with the maintenance. I think you have to have most of those guys and most of those facilities. So, privatizing the Shuttle is going to be a real challenge, I think.

Of course, they're getting more money now, I guess, out of the NASA budget to run the Shuttle. So I think they'll be able to keep running, and I think they'll make the Space Station go. But that's costing a lot of other NASA programs. NASA's total budget didn't change; they're just moving money from one program to another. Tom DeLay and those folks are going to be very happy because it's coming into the Johnson Space Center. But some guy in California, where they're cutting [NASA] Ames' [Research Center, Moffett Field, California] budget to give the money to the Johnson Space Center, is not going to be happy, and the guy over in [Marshall Space Flight Center, Huntsville] Alabama is not going to be happy, and the guy up in Ohio with the [NASA Glenn Research Center at] Lewis [Field, Cleveland, Ohio], those people are going to be very unhappy, because they thought they had an agreed-upon budget when they all voted on it. So I don't know how that's all going to play out.

But the days of unlimited funding for things are way behind us now, especially with the war situation. I mean, this war is going to cost a ton of money, and I think Saddam [Hussein] has done the cleverest thing he could have done. He said, "Oh, yeah, come on in." But I notice he did not say he accepted the conditions. His wording was, "We are willing to deal with the conditions," and that just leaves the door open. I mean, this guy's going to foot-drag and argue about every little detail, and we'll be over there a year from now. We'll still be arguing about whether or not we can look at this and what did we really see over there.

I sometimes think we'd have been better off if first we had dropped some bombs and said, "Now we'd like to talk to you," because I really don't think he's going to cooperate very well. He'll do what he has to do, but you can hide an awful lot of stuff in a country if you want to.

I'm sorry. I didn't mean to go off on that. Go ahead.

ROSS-NAZZAL: I'd like to go back to the avionics study.

PETERSON: Okay.

ROSS-NAZZAL: You pointed out that there were some problems with the design. Did you come up with any suggestions in your report, any alternate solutions?

PETERSON: Basically, yes, we did. I think, if I remember correctly, we gave them, like, five choices. One of the things was, if you want to play the redundancy game, you've got to put on more systems. They actually did. They now fly six computers instead of five, and they're able to put all six of them into the primary system if they need to. So now you can tolerate more failures.

The other thing was something they've also already done, and that was, as you go along and these things fail, you find out what causes the failure and you fix that, not just in the one that failed, but you change the design so that you eliminate that one failure mode. I think they added a fourth-rate gyro. They did not add TACANS, but they decided that a TACAN was really most critical close in when you're landing, and they backed that up with radars on the ground.

So we suggested different ways to compensate for this, and most of those things they've done in one form or another. Yes, we tried to point out ways. It wasn't very popular, because the guys that designed this thing were very proud of their redundancy scheme, and they did that not realizing that the software programmers were going to link them all together, because the original plan was, any one computer, any one avionics string, that was a set of components, could operate the Shuttle. But the way it was lashed together, that didn't work out.

It's interesting, too, when NASA built the Shuttle, the Air Force was also using redundancy, and the Air Force built what they called confederated systems, which meant that each little component was kind of independent. They cooperated with each other, but they shipped data to each other, but they weren't really closely tied together.

The Shuttle was tightly integrated. It runs on a very rigid timing scheme. The computers on the Shuttle actually compare results about a little more than 300 times a second. So it's all tightly tied together. Well, when they decided to build the Space Station, NASA said, "We're not doing this integrated stuff anymore. Boy, that was a real pain. We're going to use a confederated system."

The Air Force, on their latest fighter, said, "This confederated stuff doesn't work worth a damn. We're going to build a tightly integrated [system]." So they both went along for ten years or twelve years, and then they flip-flopped. The military's going the way NASA originally went, and NASA's now going the way the military [went] originally.

I think the answer is, there is no magic answer to all that. Probably one concept is maybe not that much better than the other. It's how you implement it and how much money you spend and how much to test. What do they say? The devil's in the details. I think that's right with all this stuff.

ROSS-NAZZAL: When you worked on the avionics study, did you do any work in SAIL [Shuttle Avionics Integration Laboratory] or did you work with anyone working on the HAL [High-Order Assembly Language] software?

PETERSON: Worked in SAIL quite a bit, and I, again, don't remember a lot of the details. But basically what I was looking at was things like the crew interface. How does the crew interface with this stuff? How does the crew understand what's going on? Some of it was very poorly designed from a crew interface point of view.

The orbital maneuvering system controls, basically you plug some numbers into the computer, and you look at the answer, and the answer was in terms of stuff that you just flat couldn't interpret physically. We said, "You know, no crew's going to ever understand that," and the guys said, "Don't worry. The ground people will verify all that." Well, the question was—and in those days it was feasible that you might actually lose communication with the ground because we were not using the tracking and data relay satellites. We were using ground stations, and if you lost a couple of ground stations, you might not have communications if you needed to deorbit at a certain point in time.

They said, "Well, in that case, you'd just plug the numbers in the computer and you'd trust that it's okay." But you really couldn't look at the output of the guidance routines and tell what they were going to do. That could have been different, but it would have been more complicated. It wouldn't have been as compact a software program. So they didn't want to change it, because they had already tested it, they figured it worked well, and we could never convince them to make that change.

The attitude indicator, what's called the eight-ball, on the Shuttle is different than in an airplane. I don't know how much time you want to listen to this, so stop me if you get tired of it. But on an airplane, the eight-ball moves, it's a three-axis system, and the first angle that moves is yaw. That is, if you turn the airplane this way [gestures], point it toward north and you turn it, the eight-ball rotates to show that you're turning toward the east or toward the south. The next thing it measures is pitch. So you know my heading is now east, and I'm pitched up thirty degrees, and then it measures roll. So the roll angle is relative to the horizon out there.

Well, on Apollo that wasn't the way the system worked. So they took the Apollo system and put it on the Shuttle. What it measures is pitch, yaw, and roll. So the first thing it measures is pitch, okay? Well, that's okay. But the next thing it measures is yaw, and that means motion this way. [Peterson gestures.] So you could pitch up forty-five degrees, yaw ninety degrees, and you'd be pointed east, [and] the yaw angle would read ninety. The pitch angle would still read fifty degrees, but you're back down on the horizon, and the roll angle would read zero, even though you're rolled fifty degrees relative to the horizon. So no pilot on earth could interpret that.

Now, we got them to change it for entry. For entry the ball now, when you're down low, works like an airplane. They never did change it for ascent, and that's really not important unless you get into an abort. But if they ever have to fly an abort, reading the eight-ball [angles] is not going to be at all intuitive.

I've talked to a couple of the new astronauts. They don't even understand that. That's not even taught. We understood it because I spent about a year working on some of those problems and trying to get them to change stuff. They [didn't] want to change it because they said it would cost, I don't know, $10 million, which, in my mind, it shouldn't have cost that much because you could have gone to any guy who manufactured aircraft attitude indicators and bought them for a lot less than that and put them in the Shuttle. All you had to do was hook them up to the platforms. But they didn't want to do that, so they said, "No, we can't afford to do that."

But there are those kind of things that some of that stuff is still not like I would have wanted it. But they have never had to do an abort. By the way, abort modes in the Orbiter are very demanding. A lot of people think, well, if something goes wrong in the Orbiter, you abort and then everything's okay. The vehicle performance in some of the abort modes is more demanding than it is on a normal mission. The engines have to burn at a higher thrust level than normal, and some of the maneuvers are pretty dynamic.

The return-to-launch-site abort, for example, is just unbelievable. You're flying outbound and you're inverted. If you have to come back to the launch site, the first thing you do is pitch the vehicle over, and then you're flying backward, and you're flying backward for a long period with the engines burning to slow you down and start you back in. Then there comes a point where you fly up to what's called a target line, which says, "If I can make it to that target line, then from that point I can make it back to the runway."

When you get to that target line, essentially what you do is you pitch the vehicle down pretty violently and you shut off all the engines and you dump the tank, and you do all kinds of very dynamic maneuvers that you don't do in a normal flight. None of that has ever been tested. We didn't fly any unmanned vehicles.

The Russians did fly a shuttle, and they flew it unmanned one time. Then they decided they didn't want to fool with it, or maybe they couldn't afford to fool with it. But that shuttle now sits up near Red Square [Moscow, Russia] on a pedestal, and they have never flown it again.

I've talked to the guy, Igor Volk, who was going to be one of the pilots on that.… [He flew in 1984 as part of the Soyuz T-12 mission.]

But there are a lot of things about the Shuttle system that we looked at. Some of them we got fixed, and some of them we didn't. Sometimes it's hard to tell. For example, if you have a fuel flow problem in your Orbital Maneuvering [System], it's hard to tell what has actually failed. You have to read several different instruments inside the cockpit to figure that out, and you're doing that while you're in ascent. So you're under heavy G-load. You're in a pressure suit, there's vibration and noise and all the rest of that. We said, you know, there's a lot simpler way to fix the display so the crew would better know what's going on.

They've got new displays, if they ever get them all built and put in the Shuttle. They've moved away from all the little [round dials that] they called clocks, the little hard-mounted instruments. They're going now to, like, computer screens. And once you do that, you can change what's displayed on those things by changing software. So maybe that will allow them the flexibility to change some of the displays to make them a little easier for people to understand.

For example, the problem with the attitude indicator that I talked about a minute ago, you could fix that very simply. You could change that whole display concept with just a few lines of code, and you could use the code that's on every airplane in the world now. I mean, you don't have to come up, really, with anything new in order to do that.

In studying that problem, I got to do some really interesting flying. We needed to know what to do with an eight-ball if you got in a ninety-degree pitch attitude, and we needed to know what does an airplane do when that happens. So I took a T-38 and went out over the Gulf, and I'd get, like, 500 feet above the water and run up to about, like, Mach [1] and then pull straight

[up], full power, and I did rolls, and watched, took pictures of the eight-ball. When I got all the way up to where I was almost out of air speed, I'd pitch over and put the power in idle, put the speed brakes out, and come straight back down, and do the same thing on the way back down till I was about 6,000 feet. Then I'd pull out, push the throttle up, and do another one.

That was fun flying. I mean, that's test flying, but that's fun. We got some interesting results out of it. It turns out aircraft eight-balls switch modes when they get within five degrees of vertical. They go to a different way of depicting what's going on. So they have two different sets of drives. But, yes, that's the kind of stuff I spent a lot of my time doing, and a lot of that was fun and kind of challenging work.

Of course, we did an EVA [Extravehicular Activity] and that was fun—for Story and me, anyway.

ROSS-NAZZAL: Let's talk a little bit about your work with the Orbiter flight test program. You worked on that for about a year.

PETERSON: Very little. Very little. I saw that in your questions, and I did so little work that I, frankly, don't remember very much of that. It was an interesting program. I mean, as Joe [H.] Engle used to say, it doesn't get to be fun until we drop the 747.

The parts of that that I worked on were things that had to do with some of the avionics systems, in particular the air data system. There was a big fight about the [air data system.] The Shuttle air data system has the little probes that fold out of a side on the nose, one on each side. The question was, do you have those things properly calibrated? Because if you look at most military airplanes, the early ones at least, they had these big long booms that stuck out the front of the nose, and that was to get the air data sensors out in front of the airplane so the airflow over the airplane itself didn't change the air data reading. Air data means things like air speed and attitude and that sort of thing. You wanted to be sure you were actually reading what's called the free air stream, not the air stream that's perturbed by the body of the airplane itself.

Well, the Shuttle's sensors [aren't on a boom], and they had tested them in a wind tunnel with a tiny little model. So the model was about maybe this big [gestures], and the little air data probes on the side of it were tiny, and there were several people that told them those tests might not be any good because when you try to scale things down that much, you start to get into skin effects and molecular effects and things that change the data. You can't just take that data and scale it up to a full-size vehicle.

So we fought with them a long time and said, "You guys really need to put some kind of a boom on this vehicle," because in the Shuttle if you read the air data wrong, it changes all the gains in the flight control system, and then you can't fly the vehicle. An air data failure on the test program could have conceivably caused the loss of a vehicle. We finally convinced them. They finally put a flight test boom on the vehicle the first few times they flew it.

The engineers said, "Well, but the other system would have worked. It worked out fine." But we found out later they did change some of the gains and some of the numbers. So they learned something from doing that, to make the thing more precise.

There was even a proposal from some of the engineers that they would fly it without air data; they would use the inertial system to tell them how fast they were going. The problem with that is, the inertial system doesn't measure wind. They're going to fly at Edwards, and the winds at Edwards are sometimes fairly high. So if you've got a wind going thirty miles an hour, and your inertial system says, "I'm going forward 180 miles an hour," if you're flying into the wind, you're actually going 210 miles an hour [airspeed], which changes the gains in the flight control. It also changes the handling of the vehicle for landing. We talked about that.

But there was all of that kind of stuff that went on. I didn't really do any of the flying, which was kind of the fun part of that program.

ROSS-NAZZAL: Well, let's talk about your flight, your Space Shuttle flight. When did you learn that you were selected for this crew?

PETERSON: This is going to surprise you, but, you know, I don't know. I don't remember. Our flight got delayed. We trained for about, as I remember, thirteen months, and we were all ready to go, and then they had a hydrogen leak, and they couldn't find it. We then got, like, a two- or two-and-a-half-month delay, and so we just kept on training. So we were in training for a long, long time.

So I had to have been told sixteen, seventeen, eighteen months before the time we actually flew, because we trained sixteen or seventeen months, all told. Of course, you had to know you were on the crew before you'd start training. But I don't remember exactly how I found out. I don't know whether [George W. S.] Abbey called or Paul [J.] Weitz called. Somebody called on the phone and said, "I offer you a flight on STS-6 if you want to do that," and it was always that kind of thing.

But as I remember, it wasn't a huge big deal. I mean, I just figured sooner or later I'd get a chance to fly, and when it came along, obviously [I accepted]. Now, we didn't know at the time, we didn't know until very late in the training cycle that we were going to do a space walk.

That was not planned. That happened because the spacesuits on the flight before ours, both of the suits failed, and those guys could not do the space walk that they were supposed to do.

It's kind of funny, George Abbey, I think, had some people already picked out that he wanted to have the honor of doing the first space walk, and when that cancelled, he said, "Well, we'll have to slip now. It'll take months to get another crew ready." Jim Abrahamson, who's an old friend of mine, was the [Associate] Administrator. He called me on the phone and said, "Can you and Story do the space walk?"

And I said, "Yeah."

So he said, "Okay. We're going to do it on the next flight."

Well, it didn't give us much time to train. I didn't have very much experience in the suit, but the advantage we had was, Story was the Astronaut Office point of contact for the suit development, so Story knew everything about the suit there was to know. Story had spent, like, 400 hours in the suit in the water tank, so he didn't really have to be trained. He probably knew as much as anybody on the training team about that.

Now, my training was pretty rushed, pretty hurried. I think I was in the water, I don't know, fifteen, twenty times, but that's really not enough to really know everything you need to know. But, see, all we were doing was testing the suit, testing the airlock, so we weren't really doing anything that was critical to the survival of the vehicle. We were just testing equipment, and the deal was, if something went wrong, you'd just stop and come back inside. So the fact that I wasn't highly skilled in the suit really didn't matter that much.

It's interesting, I think, that my suit leaked pretty badly for a while [about twenty seconds] and then stopped, and the ground didn't know that at the time, or they'd have told us to stop.

I was working with a ratchet wrench. We were just testing tools and stuff. We had launched a satellite out of a big collar that's mounted in the back of the Orbiter, and the collar was tilted forty-five degrees. It had to be tilted back down before we could close the payload bay doors and come home. So instead of driving it with the electric motors, they said, "Let's go back and see if we can crank it down with a wrench, to simulate a failure. Suppose it failed, and we'll see if we can do that."

So that was one of my jobs. We had foot restraints, but it took so long to set them up and move them around, that we didn't want to do that. So I just held on with one hand, actually, to a piece of sheet metal, which is not the best way to hold on, and cranked the wrench with my other hand, and my legs floated out behind me. So as I cranked, my legs were flailing back and forth, like a swimmer, to react the load on the wrench. The waist ring was rotating back and forth, and the seal in the waist ring popped out, and the suit leaked bad enough to set off the alarms.

[We did not know] what it was. I stopped and said, "I've got an alarm." Story stopped what he was doing and came over. We were trying to check what was going on, and the seal popped back in place and the leak stopped. So we went ahead and finished the EVA.

Now, in those days we didn't have constant contact with the ground. They didn't see that. They weren't watching at the time that that happened. They didn't have any way to watch. By the time we dumped the data from the computer to the ground that showed that leak, we were already back inside the Orbiter. Then they called up, and they were all upset about what happened here and what was that.

We said, "Well, we really don't know. We got an alarm. The alarm stayed on for about twenty seconds or so, and then it went off, and everything seemed okay. So we just finished what we were doing. I mean, everything seemed all right."

Well, the next story I was told was that "You were working so hard that you were breathing so much oxygen, that you depleted the oxygen in the suit and forced a higher feed level and that set off the alarm." Well, I talked to some of the doctors, and they said, "We don't think that's right."

Well, my heart rate was very high. Working in the suit's very hard. My heart rate was 192, okay, when I was cranking that wrench, so I was working very hard at the time. But a guy my size can't work hard enough to breathe enough oxygen to set off the alarm that way. We didn't find out what that was, really find out what that was for, like, two years, because they just sort of said, "No, we think you just breathed up too much oxygen. Don't worry about it," and nobody really did.

Before you fly, you put your suit on. The suit's so heavy, you can't hardly stand up in it. So they put you in a sling that holds up the weight, and they put you in a vacuum chamber on a treadmill, and they let you walk the treadmill. That's just to exercise the suit, because each suit's a little different. They make funny noises, and the valves open and close a little different, and they want you to get used to that.

[Before] Shannon [W.] Lucid [flew, she was testing her suit.] So she's walking on the treadmill, and all of a sudden her suit—the alarm went off. What it says is, the oxygen flow rate's too high, and that means that you're pumping oxygen from the tank into the suit, but that also means the oxygen is going somewhere. It's going out of the suit somewhere. So they knew they had a leak, in her case, and they could also see the oxygen coming into the vacuum chamber, because they were getting pressure inside the chamber.

She stopped walking, and when she stopped walking and stood around a little, the leak stopped. There was a technician sitting there. These guys amaze me, but he looked at that, and he said, "You know, I've seen this same thing before. I don't remember the details, but I've seen this same phenomenon before." They went back and got the video of my flight and looked at it. He said—and this is kind of interesting—he said when Shannon Lucid was walking, since she's a woman, her hips swivel, and her suit was actually rotating, and we'd never seen that with a guy because guys don't walk that way. But he said, "That's the same thing that happened to Peterson's suit two years ago."

So then they went in and changed the seals and all and fixed the problem. But it always amazed me that those guys were dedicated enough to have that kind of memory fixed in their heads, and as soon he saw that, he said, "I don't know where I saw this. I've seen this before. I don't remember where, but I'll go find out," and sure enough, he did, went back and went through a lot of film and said, "Looks just like this, doesn't it?"

Of course, I got a lot of insulting calls from that guy. "You know, your hips move just like Shannon's."

I said, "Not for you." [Laughter]

ROSS-NAZZAL: Well, you mentioned that you did the first Space Shuttle EVA.

PETERSON: Yes, that was fun.

ROSS-NAZZAL: I'd like for you to tell us how you prepare for the EVA in the Orbiter, from putting on the suit until the time that you actually exit the Orbiter, if you can go through the process for us.

PETERSON: Okay. Then I'd like to show you a little gadget after we get through with that, that I brought with me, because the gloves are hard to work in. The suit's extremely stiff, and I had to get my hands strengthened, and I used a little hand exerciser. But I'll show it to you in a minute.

Now, basically what you do is, first of all, obviously you get all the equipment out and you just check it over. You make sure everything's laid out properly, and everything that you can check is working properly. The whole thing is set up so that you test as you go along. In other words, you don't just put the suit on and open the hatch. You make sure that everything's working before you go that final step.

We were instrumented. We wore these little stick-on things to measure heart rate and that sort of thing. That all has to be hooked to a little black box kind of like this, and that's, of course, inside the suit. Then you put on the—there's what looks like long underwear, but it's a cooling garment. Are you familiar with that?

ROSS-NAZZAL: Yes, I believe we've seen those.

PETERSON: The cooling garment has water tubes that run through it, and they also hook through a connector to the suit, and you pump water through there. You can change the temperature with a valve on the outside of the suit. So if you get too hot, you can run a little more cold water, and too cold, you can turn it off or turn it down. But you get all that stuff on.

I wore glasses, and so they have something they rub on the glasses so they won't fog up, [that's one of] the worst thing that could happen to you. You're inside a helmet and you can't get your hands inside the suit. So they want to make sure that didn't happen. I had glasses that had, like, a strap that went around the back of my head so you couldn't have them fall off inside the suit.

On our flight, see, the Shuttle operates at typically sea-level pressure, like the pressure in this room, which is not quite fifteen pounds per square inch (psi). The suit operates at about 4.3 pounds per square inch. But what happens is, if you took a human being and suddenly went from 14.7 down to 4.3, your body has a lot of nitrogen in it, absorbed. It's absorbed in tissues and fluids, particularly in fatty tissue. If you take the pressure off, that nitrogen starts to form bubbles, and that's what's called bends.

Some divers, deep-sea divers, have died from that because they came up too fast and the pressure decreased, and they'd been breathing high-pressure air at depth, and when they came up, the hydrogen will actually—those bubbles'll get big enough that they'll mess up your heart. They will cause problems in your brain, and they can kill you, and they cause extreme pain, like, in joints and things like that.

To prevent that, there are two different ways of doing it. We did it by breathing pure oxygen, and we had to breath pure oxygen for, like, three and a half hours. So you put the suit on, and all this time the suit's fastened to the walls of the airlock. So you've got the suit on, and you're essentially just hanging on the wall there. All you can do is just wait while you breathe oxygen. Now, what happens is, as you breathe oxygen, the nitrogen, the gasses that are inside your body try to equalize with the gasses that are on the outside. So you're breathing oxygen. So the nitrogen gets displaced by oxygen, and little by little, the nitrogen all comes out of your body—not all of it, but most of it comes out of your body. It literally goes out into the suit, but it gets flushed through the suit while you're in the airlock, because you're hooked to the Shuttle system. It gets flushed out into the Orbiter. So they get most of the nitrogen out.

[During the time that you are prebreathing, the suit pressure regulator is set to maintain suit pressure slightly above airlock pressure (a delta pressure of 0.9 plus or minus 0.5 psi). That's done because the suit is not absolutely air tight, and you want to be certain that any small leakage flow goes from the higher pressure inside the suit to the lower pressure outside and thus none of the outside atmosphere which contains nitrogen will get back into the suit.]

[After you get most of the nitrogen out of your body, you can start pressure checking the suit. That's done by lowering the pressure in the airlock while the suit pressure regulator is set to maintain 4.3 plus or minus 0.1 psi above outside pressure. If I remember correctly, the airlock is bled down in a couple of steps while the crew observes the rate at which the suit pressure drops to its assigned value and then there is a waiting period to be certain the suit is not leaking.]

[When the pressure checks are complete, you can let all the air out of the airlock, open the outer hatch and go outside.]

Now, you have tethers. You have a safety tether that's a little short tether. Then you have the safety reel that you use when you're outside, because you need to be able to move around. So what you do is you hook the safety tether inside the airlock, and you go out through the hatch. There's a line that you hook your reel to. Now you're hooked on the [slidewire], and you can run up and down the handrail and drag this tether up and down with you.

Then you unhook the safety tether that's hooked inside the airlock. So you're always tethered to something. Now, that's not going to be true, I think, on the Space Station all the time, but it will be most of the time. But we had a great advantage. Even if you came loose from the Orbiter, if you drifted away, the Orbiter can maneuver. So the Orbiter could literally come pick you up. I mean, it's not like you're going to float away and be lost forever.

The Space Station cannot maneuver that way, so the guys there wear the little jet pack, and they can actually maneuver themselves back to get back to the Space Station. But, I mean, that's kind of the sequence we went through. People don't believe this, but, like I say, we'd had a very busy and a long hard mission, and while we were breathing oxygen for three and a half hours, you can't really do anything. Story and I slept. I mean, I slept about two and a half hours, probably the best sleep I had on orbit, because you've got fresh oxygen coming in over your head, and it kind of makes a nice whishing sound, and there's no other noise. We turned the radio receivers way down so we weren't bothered by people talking. Got some really good sleep before we went outside.

People asked, "How in the world can you sleep just before you're getting ready to go?

I said, "Well, you know, you get tired enough, you can sleep almost anywhere."

The EVA went pretty well, except for the suit leak and a couple of very minor things. Story had a winch thing that was supposed to be used, if you had to, to pull the payload doors closed, and he was testing it. He wasn't really using it on the doors, but he got the rope hung over something and then couldn't release the winch. It was under a lot of tension. There was some talk about how can we get this thing loose so we can get it re-stowed, and we couldn't leave it where it was because it was on the rollers that are used to latch the doors down. We said, well, we could cut it. They said, "No, we don't want to cut the rope." So finally he just got up there and managed to pry the thing off with his hands.

But other than little minor stuff and very brief stuff, it all went pretty well.

The other thing we did was, as Story and I have said before, the Shuttle flies with the bay toward the Earth all the time. Story and I said, you know, wouldn't it be neat when we get on the dark side of the Earth, if we could look out at the sky, at the night sky, see all the stars?

So we went to the flight control team and said, "Guys, when we get on the dark side, we'd like you to roll the vehicle over so we can look out."

[M.] Pete Frank said, "Oh, just for you guys' amusement, you want us to roll the damned vehicle upside down."

And we said, "Yes, you know, wouldn't that be great?" So what they did was even better than that. When they were on the daylight side at noon, they went into what [I] called the Ferris wheel mode. You know how a Ferris wheel seat goes around and it never changes attitude? Well, that's what we did. We went around the Earth holding one attitude. So we went around the Earth like this [gestures], so that when we got on the dark side, we were faced exactly away. But because they did that, with the cameras running and all, we got some beautiful pictures of the Earth from a lot of different attitudes that we wouldn't have gotten otherwise.

So we got on the dark side, and Paul Weitz, the commander—he was a fun guy to work with—he said, "Okay, guys, you asked for this. Now stop whatever the hell you're doing and look." So we did, and there's lot of light in the payload bay, and the helmet's got these big things. You couldn't see anything. I mean, it was just too much glare. So we got over in a one corner and kind of shielded our eyes, and you could see a little patch of sky about this big, but that was about the best we could do. [Peterson demonstrates.]

So then Story said, "P.J., why don't you turn off the lights."

And P.J. said, "Not going to happen. We're not turning off any lights, because they might not come back on and then you'd be out there in the dark." So, no, they wouldn't do that. So we didn't get much of a view that way. But what we could see was pretty interesting.

I was surprised that when I was working, if you got sunlight into the helmet, you could feel the sunlight on your face. I mean, the visor protects you from the ultraviolet and all that, but you could feel the heat as soon as the sun came in through the visor. You could tell.

Of course, we were out about four hours, so that's a little more than two orbits. So part of the time we were in nighttime and part of the time we were in daylight. But you have lights on the helmet and lights in the bay and all that. So it wasn't really like—we were never out working in the dark. We tested a few of the tools, wrenches and some of the foot restraints and that, but mainly it was to make sure the suits were okay.

Of course, I said the suits on the earlier flight failed, but the failures were really—somebody had set the pressure regulators wrong, had calibrated them incorrectly, and so instead of holding 4.3 pounds per square inch, they dropped down to, like, 3.8 or something like that. But since they didn't really know what was causing that, they were scared to let the guys go outside. But it wasn't really the kind of thing that would have been dangerous. I mean, 3.8, you'd have been fine at 3.8; 4.3 gives you a little more margin if you get a leak. It also gives you a little better protection against the bends, because you're not going to quite as low a pressure.

EVA would be fun if the suits weren't so hard to work in. The suits are fairly uncomfortable. They're pressurized. They're not pressurized like an automobile tire, but they're pressurized so they're fairly rigid. The suit has a—I forget what they call it, but it's a suit-neutral position. If you just blow the suit up and nobody in it, it goes to a certain position. If you move it away from that position, it tries to come back because the arms and all over are very rigid and they're under pressure.

So anytime you're doing anything in the suit, you're typically fighting against the suit itself. The gloves are the same way. If you look at a lot of photography from space walks, you see people doing things like they don't grab something like this, because to do that, you've got to fight the glove. [Peterson gestures.] They wedge things between their fingers, and that way you don't have to exert pressure.

That's what I was going to show you. I've got a little gizmo here. [Peterson brings out a pair of hand grips.] I'm not a big, strong-muscle guy, so my hands weren't very strong, and I took one of these. If you're going to work in that suit, you have to be able to do sixty of those with either hand in one minute. [Peterson uses the hand grips.] I'll let you guys give that a whirl.

ROSS-NAZZAL: I'm sure I can't do sixty of them. Oh, wow. Pass that along.

PETERSON: So after I quit, I kept doing that just so I could show off.

ROSS-NAZZAL: You'll be ready in case they call?

PETERSON: Well, somebody asked me, "Would you ever fly again?"

I said, "Well, in twelve years I'll be as old as John [H.] Glenn [Jr.]. Maybe."

ROSS-NAZZAL: Talk to us about testing the EMU [Extravehicular Mobility Unit] and the tools. How did you evaluate the suit and the tools and the techniques and the gloves and the tethers?

PETERSON: Basically we used different tools, and we filmed everything. We did certain motions with your arms and legs and head and all that to make sure that the suit was okay. But the basic test was just to get the suit out in the environment and see if the suit was going to work properly. Then we changed the settings on the temperature control to see if all that was working okay.

If I remember correctly, before we flew, when we were training in the water tank and training in the vacuum chambers, things like that, I think Story was always too hot. He could never get his suit cool enough, and I was always too cool. And when we got into space, it was the exact opposite; he was freezing to death, and I was warm.

So the suits worked differently, a little differently, in the real environment than we had seen them work on the ground, but basically they did exactly what they were supposed to, and they worked the way we expected them to. They're just big, cumbersome. The suits weigh about 275 pounds, and so you can't just put them on and walk around. You're either in the water tank or you're supported in some kind of a sling to take the weight off of you.

And they have to fit. The fit of the suit is very important. You grow a little bit in zero-G. I presume that you're aware. You know that. So they have to fit the suit to allow for a certain amount of growth, and they really can't measure that growth on the ground. In other words, they can't cause that to happen on the ground. But the suit has to fit tightly.

My suit, when I stood up in it, I could plant my heels against the heels of the boot, and the shoulder harness up here was right against my shoulders, and the top of my head was right against the top of the helmet. [Peterson gestures.] The gloves have to be really close to your fingertips. Like, if they're more than about an eighth of an inch off, you'll lose your ability to feel things and to do precise movements.

The problems we had had was, at least in some of the early programs, the gloves were too tight on the fingertips. What they'd do is, they'd pinch your fingernail. Several guys lost their fingernails, not while they were in orbit. But it pinched them so bad that it pulled the roots loose in the back. It's very uncomfortable. I mean, it used to be a form medieval torture once to hurt people's fingernails. But anyway, the gloves, if they're wrong, they can be really bad.

I think Dave [David R.] Scott actually lost some fingernails or lost a fingernail or two on the Moon and wound up taking a bunch of aspirin so he could keep working. That crew, of course, pushed themselves way beyond the normal. What they had to do was extremely demanding physically, and they pushed themselves really hard. [James B.] Irwin, of course, pushed himself way too hard. But they all did.

But, yes, the suits can be pretty tough. Actually they're better, they're more comfortable in zero gravity than they are trying to test them on the ground. See, when you're in a water tank, they weight the suit to make it what's called neutrally buoyant. The divers are really good. They take you down, half-way down in the pool, and they put weights all over the suit, and they change them all around. When they get through, they can turn you loose and the suit just hangs in the water. It doesn't sink to the bottom and it doesn't float to the surface; it just hangs there.

So the suit is neutrally buoyant. But inside the suit, your body's not floating. Your body is supported by the suit. So if you turn upside-down in the water tank, the weight is on your head and on your shoulders. I mean, your body is hanging in the suit, and the suit's hanging in the water.

So it's totally different on orbit. In orbit, your body floats inside the suit, so you don't have the pressure points. In other words, you're not being pressed on by the suit in various places. Of course, the other thing that's interesting, in zero-G is, your internal organs float inside your body, and that's a little different feeling. That's why you can't tell which way is up. Your middle ear is floating; it doesn't detect anything. But your stomach floats and things like that, and that's a little different feeling.

You get used to that very quickly. I was never sick on orbit. I mean, a lot of people have some illness from that, I think about half the guys. Some people made a big thing of that. I don't think that was ever considered a serious problem. For one thing, it's certainly not life-threatening. I know nobody's going to die from that, and it usually goes away in a few hours.

Now they have a drug they give the guys, Promethazine, that they can inject, and it stops space sickness almost immediately, and once you stop it, it doesn't seem to come back. In other words, by the time the drug wears off, you've adapted essentially to zero gravity, so you just don't get sick after that.

ROSS-NAZZAL: Well, onboard there were a couple of other payloads, primarily the TDRS-A [Tracking and Data Relay Satellite-A]. Did you have any responsibility for that?

PETERSON: Yes, Story and I were responsible for launching that, and Story's the kind of guy that he wants to throw the switches. So what I did was took the checklist and made sure—Story was not real good about following the checklist, and so you had to kind of say, "Wait, Story. Let's go step by step here and make sure we get this right."

The scary part of that, and I don't—this is back a long time ago and my memory may not be correct. But we were in quarantine. We were in the crew quarters at the Cape, and, I don't know, a couple or three nights before we were supposed to launch, these two guys showed up and they were from Boeing [Company], or said they were from Boeing. They had badges. They said, "We need to talk to you." They said, "It turns out the load, the software that you trained on in the simulator is not exactly the same as the software that's flying, and a lot of the codes are different. We need to give you the new codes."

Story and I literally copied a bunch of stuff down with pen and ink and used that on orbit. And that's really scary, because, you know, you're taking these guys' words. You've never seen some of this stuff in the simulator. It's, like, suppose what they're telling us is not right, and we do something and we mess up the payload. Then they ain't never going to find those two guys again. They'll be gone, and it'll be, like, "Why the hell didn't you guys do it the way you were trained to do it?" And we really didn't have time to coordinate it.

I think Story called somebody at Houston, and they said, "Yeah, we think there were some—." You know. But it was pretty vague. That kind of stuff, that bothers you a lot, because those payloads are extremely expensive, and that was a very important thing to get on orbit and have it worked properly. And even then, the engines didn't work right. They almost lost it. Didn't affect us because it was already deployed out of the Orbiter before all that happened.

But, yes, you worry about stuff like that. When there are last-minute changes, you really get concerned. You wonder, has all this really been tested and has all this really been thrashed out? Are we really sure that this is what we need to do?

The way you did commands on that thing was, you could send commands and you had a set of three dials and you dialed in a set of numbers and then you hit a switch that said "Execute that command."

Well, the command was determined by what three numbers were set in there, and they gave us some numbers that we'd never used before. You had no way of knowing, really, whether that's right or not right. But it seemed to work okay. At least the deployment went fine, and the failure afterward had nothing to do with the commands we sent. So I guess the guys were right.

ROSS-NAZZAL: What a relief.

PETERSON: Yes. Story was a fun guy to work with. On the job he is extremely dedicated, would just do anything. He'll work twenty hours a day. He'll do anything. If you say, "Story, we need some sandwiches."

"Yes, I'll go get some."

"We need to put the garbage out."

"Yes, I'll get that."

He doesn't argue about anything. He just does whatever needs to be done. It's really delightful to work with a guy like that. I mean, I never understood some of that, but I'm not going to talk about Story on the tape. But he was really good to work with. Did a super job.

ROSS-NAZZAL: Why don't you tell us a little bit about the crew relationship. I know that you were called "the Geritol bunch."

PETERSON: You know, we never heard that term much. In fact, we have a picture, an F-Troop picture, I don't know if you've ever seen it, but we had on the little flight teeshirts and the flight pants. But we went out and bought cowboys hats. I had a sword that had once belonged to some lieutenant in Napoleon's army. We got a Winchester rifle, the lever-action rifle, and a bugle and a cavalry flag, and we posed for this picture.

Weitz, of course, is the commander, and he's sitting there very stern-looking, with the sword sticking in the floor. I had the rifle, and I think Story had the bugle. Anyway, we had that picture made, and we were passing them out, and NASA asked us not to do that. They thought that was not dignified. But I thought it was hilarious. I still have a bunch of them.

But, anyway, we knew about, and we sort of laughed about and took advantage of the F-Troop thing, because there were a lot of little jokes about that that went around. But I didn't hear "the Geritol bunch" until, I guess, after the flight was over. Maybe that was something that everybody said about us when we weren't around, you know, probably.

We were on orbit, and somebody was talking about "how old you guys are." We had taken a bunch of pictures, and I couldn't resist, I said, "You know, we're not going to show the pictures to anybody under thirty-five when we come back. So some of you guys, some of you wise asses, won't see them."

But the crew was great. I don't think in the whole time we were together we ever had a cross word, literally. And that's unusual, because the training is really intense and very demanding, and you're working long hours, and things go wrong, and there are delays, and there's this and there's that. The guys, everybody, just went along, and we got along great.

Of course, we picked on Story all the time, but I think he kind of liked it. I told him he was bald from licking his forehead and all that kind of stuff. But he was fun to work with, and none of that bothered him. I really enjoyed the guys. I really did. You couldn't ask for anything to go better than the way our crew worked together, I don't think.

And some crews hadn't. There were some crews that really didn't get along. I mean, the guys were disciplined enough to do the job and cooperate and do what was necessary, but that's got to be very unpleasant. And that went all the way back to some of the Apollo flights. Some of those guys didn't really care for each other either. But you do what you need to do.

But our group, we just had a ball with each other, and that makes it a lot more fun to work that way.

ROSS-NAZZAL: Well, you retired from NASA in '84, and you went into consulting.

PETERSON: Yes.

ROSS-NAZZAL: Why don't we talk a little bit about your work as a consultant.

PETERSON: Basically I did the same kind of things as a consultant that I had done as an astronaut. I worked for several different companies, and I worked on things like crew interfaces and crew procedures and habitability, that is, all the things you put on a spacecraft so people can live there and be reasonably comfortable. But I did that same kind of work with a lot of different companies. I did that up through, like, full-time pretty much through '93 and then part-time since then, and I still do it a little, but about the only thing I do now is stuff like Astronaut Encounter and those kinds of things.

But, yes, I enjoyed that, and particularly I worked for Grumman [Aerospace Corporation] when they were on Long Island [New York], from about early '85 through '92. So I worked with them a long, long time, and I got to know a lot of those people. I thought that was a great company, a really good bunch of guys, very dedicated. Of course, they built the LM [Lunar Module], and I worked with the guy who was the chief engineer on the LM for a while. Super little guy. But all of those guys were good guys.

I didn't work with any company that I thought was—that the people were bad or that the people were not doing their job or that people were goofing off or taking money for nothing. There was a firm out there that did that, I understand. I knew some of the guys that worked for them. I don't think those guys knew what was going on, but I talked to them about working for them, and they didn't seem interested. So I never pursued that.

I worked for one small company that, frankly, they just didn't have the skill and the ability within their team to know—I mean, they had taken on a project they didn't know how to do. About all I was able to do was say, "Hey, guys, the problem you're solving is only a small part of the problem."

What they were trying to do was build a system that would work as an instructor. So you could put a guy in a simulator, and the system would teach them, okay? The system that they had built would detect errors and point out to the guy, "Oop, made a mistake here." [Their] first approach [was] to teach a guy how to fly a final approach in an airplane. The system would say, "You're too high," "You're too low," "You're too far to the right."

I said, "That's fine to tell a guy that, but that doesn't help him. The system, if you want to teach a guy, you've got to tell him how he made the mistake and what he needs to do to correct it, so it doesn't happen again and again and again. It's not just enough to tell the guy, 'You're going too fast again.' You need to tell him why, and you need to tell him what to do about that."

Of course, building a system that will interact in that way with a human being is really difficult, and these guys just—they just flat didn't know how to do that. So I think they finally just gave up on that project. Now, the firm's still around, and they're still doing useful work; it's just that that particular project didn't work out for them. And I didn't know how to tell them how to program a system to do that, because I don't think there are very many people in the world that certainly back then knew how to do that, but maybe not today.

These systems, if you've ever used a tutorial thing on a computer, you realize they only go so far. Most of the things that they're teaching is pretty much canned stuff. It's like a spellcheck. A spellcheck tells you how to spell certain words, but if you've got a new word, it may not recognize the word or know what to do, and it doesn't know how to say to you, "I'm lost. I don't know what you're doing here." And that's part of the problem with these systems.

But, anyway, this little firm was about the only firm I ever worked with that I thought really didn't know what they were doing. Most of the firms out there were good folks. Of course, the contractors, NASA's different. The Air Force contractors often work pretty much independently.

There was a period of time when I considered going back to the Air Force, and they literally, at that time they were talking about flying their own astronauts, and they wanted me to come out and be the chief of the office. Well, I looked at that, and it meant moving to Los Angeles [California] and it meant doing a lot of things, and I thought, "This program really is not very well thought out. I'm not sure it's ever going to go," and it really didn't go very well.

But while I was out talking to them, they briefed me on a lot of their space programs, all of which are classified and I'm scared to talk about them, except to say they had programs—they had guys, like, a major—there's a lot of real senior officers in the military—running a $2 billion space program, okay? And basically that guy was monitoring contracts, and the contractors were essentially responsible for doing the work and producing a product that met certain requirements. If it didn't meet them, the contractor didn't get paid.

But the major wasn't constantly in there saying, "No, don't do that. Do this." He just sort of said, "Here are the requirements, and I'll come check with you every couple of weeks and find out how you're doing."

NASA doesn't work that way. NASA gives a guy a contract, and then forty NASA people come and look over everybody's shoulder all the time. So no matter what the guy does, NASA says, "I don't think that's—why don't you try this?" That's one reason NASA programs cost so much money, is because they don't let the contractor go do his thing and then measure the product. They keep injecting changes.

Well, every time you change a contract, you re-negotiate the cost, because contractors won't make changes for free. So NASA, they get a good product that way because they're right there every step of the way, and they kind of watch it through the development process. But it costs a lot of money to do things that way, and the Air Force doesn't have the money to do that.

But the Air Force, at the time I was briefed by those guys, were flying twenty-seven different space programs for less money than the Shuttle. Okay? Twenty-seven different kinds of satellites on orbit, for less money than NASA was spending on the Shuttle alone. So there is a difference in the way you work that could save you some money. Whether you'd get the same quality or not, I don't know.

Of course, none of these programs had human crews on them. They were all unmanned things, and they weren't high-publicity. I mean, if something went wrong, it was just an accident, and the Air Force treated it and improved and tried again, whereas, as you know, in the Shuttle Program, when we lost the Shuttle, that was a national—it was in the all the news media and everything else. Of course, they blamed Mr. Malloy [phonetic], which was unfair.

Of course, you know—probably shouldn't say this, and I won't call names—but one of the contractors used to delight to playing that game. If there was any mistake made, it didn't matter who made it or what went wrong, they would happily step up and say, "That was our fault. We did that."

NASA like that, because then NASA didn't have to step up and say, "It was our—." And they'd say, "Not only that, we're going to find the guilty guy, and we're going to kick him out of the program." But they always had a group of guys who were looking for transfers. So they'd pick some guy who wanted to transfer out of the program anyway, and they said, "Yep, it's his fault, and we're moving him." Of course, he's getting a promotion and a little higher pay, and we're paying his travel expenses and buying him a house, but other than that, he's being punished. And everybody was delighted. They even had guys saying, "Can I be the next scapegoat?" But it's a different world. That was a long time ago.

ROSS-NAZZAL: Well, I think this would be a good time to change the tape.

[Tape change.]

PETERSON: —tools and things that were tiny, little tiny tools and all that stuff, and that's really tough in the gloves. But most of the work you do in the suit is kind of crude. It's more like digging ditches and moving things around. You're not normally doing precision work, and almost none of it requires any real mental—I mean, you're not calculating anything. You're just using normal human hand-eye coordination to do physical tasks.

Of course, it's been extremely—you know, at one time we weren't going to do EVA from the Shuttle. It wasn't even going to have an airlock. They decided EVA was too difficult, and they could do it all robotically or automatically. They didn't need that, and so they weren't going to spend the money, and they weren't going to put crews at risk and so on. Somewhere in the course of the program as things went along, people kept saying, "What do we do if this happens? What do we do if that happens? How do we handle such-and-such?"

Finally they said, "Yeah, I guess we ought to have the capability at least to put people outside." What they were worried about was things like, suppose you think you've got one of those heat tiles absolutely torn off or a big gap torn in them. You need to be able to put somebody out there to look and see and maybe even to do repairs. What if you can't close the payload bay doors? You're going to have to send somebody out there to close them. And there were a lot of other little things like that.

Finally they just decided, "Yeah, we'd better have EVA capability at least, whether we ever really use it." Of course, now EVA is the way they're building the Space Station. I mean, a lot of that construction is done by people. A lot of it could have been done robotically, but it would have been much more expensive. I mean, running robots that way and doing all that stuff automatically is really demanding. Changes all the designs. And just simple tasks are very difficult with a robot.

But some day they will. Some day they'll get there, and robots will do what human beings do. But we aren't there yet. Robots don't work very well with soft goods like cloth, rope, cabling, that kind of stuff. They can work pretty well with something that's rigid and fixed in shape. This guy said he could probably teach a robot to tie your shoes, but God help you if the string breaks, because he sure won't know what to do with that. That'll completely stop it.

ROSS-NAZZAL: During the break, you mentioned that you use your hand tool quite a bit when you work with kids. Can you tell us about your work with Astronaut Encounter and the space agency?

PETERSON: Yes, that's a good program, I think, and it's a fun program. First of all, basically it's done at the Cape. You go down there, and the way it's run right now, you do four appearances a day, and your appearances run about thirty-five, forty minutes. They're done on an outdoor stage, and anybody that has a ticket to go to the Visitor Center can come and sit in the audience. Basically what they do is they have someone who acts like a master of ceremonies. But all they do is they go out and say, "This is Don Peterson," or Joe Blow or whoever, "and he flew on this flight, and here's what he did in space. He's going to give you a few words, and then he's going to do questions and answers."

Most of it is questions and answers. That way the audience asks whatever they're interested in, and if you know the answer to that, fine. If you don't, you just say, "I'm sorry, I don't know that."

You get several different kinds of questions. Kids normally want to know, "What's it like? How do you eat in space? How do you go to the bathroom? How do you take a bath? How do you move around? What's it like to sleep?"

The questions you get from adults are more like, "Why do we go there?" or, "What are we doing there?" and sometimes, "What are the requirements to become an astronaut? What do you have to do to get into the program?"

Then there are always a few oddball questions. The oddest one I've ever had, I think the last time I was at the Cape, a young guy in the audience—and he asked the wrong guy. I think this question was asked just to create a little flap. I don't think the guy was really interested, but he said, "There's a mathematical theorem that if you're going from point A to point B, you first have to go halfway. Then you have to go halfway again, and then you go—and so you would never get there."

Well, that is called—and he didn't know this—that's called Zeno's paradox. It's been around since the ancient Greeks, and it's been solved. Since I love mathematics, I knew that, and I also knew the answer. So I gave him the answer, and then he sat there, like—and I don't think he understood the problem or the answer, and I don't think that was the point. I think he was just trying to create a little stir.

But most people ask, I mean, they ask about what they're really interested in. What can you see from up there? What does it feel like? How do you eat? Is eating a problem? Can you talk when you're outside the vehicle?

Kids, they ask all kinds, and they ask because they're interested, and so do most of the adults. So it's a fun program, and it's not demanding. And if you don't know the answer to something, you just say, "I don't know. I'm sorry." You aren't required to have the answer to every single thing.

A guy named [Gevorg] Mutafyan came up to me after [my presentation], and he wants to become a Russian cosmonaut. He's in this country as a medical doctor, and he wants to go back to Russia, and he wants to know who to get in touch with. I've been trying now for a month and a half to put him in touch with somebody, and I can't find anybody in Russia that wants to talk to the guy. But I think maybe by the end of this month we'll get a name for him and all that.

We used to do [a Make a Wish Program]. They did for the first year and a half I was down there—and I only go down, like, a week at a time, and I do it maybe three or four times a year. I think if you did it a whole lot, it'd get to be kind of a grind. You're constantly out and dealing with people and doing all that sort of thing. But we used to do the program called the—you know what the Make A Wish Program is? They used to bring in young people down there, and then we'd take them in the office and talk to them one-on-one, I mean, with their parents or guardians or whoever. They stopped doing that. I don't know why. I mean, I don't know why they do what they do.

The other thing they do, which is pretty neat, they also have what they call Lunch With An Astronaut. The people have to buy—that's an additional expense. It's, I think, more expensive than it should be, but, anyway, the people pay like twenty-five bucks, and they get a meal, and they sit in a—that's indoors, like in a dining room. They show the movie I was telling you about, called *The Astronaut Smiles*. They show that kind of while the people are eating. Then the guest astronaut comes in, and you do the same thing indoors that you'd do on the outdoor stage, but it's a little nicer setting.

The thing I did that was fun was after you get through all that, they offer you a meal, and I really didn't want the meal, but I would always take it and take it back to the emcee, who was a kid that didn't make much money, and so they always got a free meal out of it.

But that was a good program, I thought, and I think the public really liked that. They liked the idea that "Here's a guy that's actually been in space and I can talk to him and I can ask him anything." Then afterwards they'd let them come up and take pictures and stuff with the family and this, that, and the other. So it's a nice little thing.

ROSS-NAZZAL: Let's wrap things up and [I'll] ask you just a couple of questions.

PETERSON: Okay.

ROSS-NAZZAL: What do you think is your most significant milestone in your career working with NASA?

PETERSON: I looked at that question last night and puzzled. I don't know. I don't know how to answer that. What happens is, as you—and not just with NASA. It goes all the way back to when I started at school. The most traumatic thing I ever did was go to West Point. I went right out of a small-town Mississippi high school to West Point, and I had never been away from home. That's a drastic change in your whole lifestyle, and that was probably the toughest thing that I ever did in my life.

But as you go along, you know, I learned to fly, okay? That takes quite a bit of work and a lot of effort. It's fun, but you still have to learn a lot of stuff. I got a master's degree in nuclear engineering. That takes work. Every job that I did, there were certain challenges and certain things. I don't know who said this, some probably famous philosopher, but you make your decisions typically day by day, and oftentimes it's a yes-no decision or "I'll pick this choice," or that choice, and while you're doing all that, you may not even realize where that's leading to.

So I really can't go back and say, "That was it. That was the decision that set my course or changed my life." I think it was a combination of a lot of things, and it started when I was very young. Like I said, my first interest in space came from science fiction. So I don't know.

But, what, 500 little individual decisions, none of which I thought at the time were of critical importance, and here I am. It's hard to say how I got here, but it's been fun.

And I've had the privilege of working with a tremendous number of really good people. I mean, the people that I worked with in the military were just topnotch. Very, very few weak people there. NASA was the same way. The workforce at NASA, the engineering and technical workforce at NASA is just superb. The companies that I've worked with as a consultant, most of those people are very dedicated, very talented, very hard-working.

So I've had a kind of wonderful life all the way along and enjoyed most of it and got some pretty nice rewards along the way—three grown kids and four [grandkids]—I've got a granddaughter going to college this year. So it's something new all the time. But it was fun.

But I really can't answer that. I don't know. I mean, I don't have a single event or a single thing that changed either my career with NASA or my life. It was a whole bunch of things.

ROSS-NAZZAL: All right. Let me ask Rebecca and Sandra if they have any questions.

PETERSON: All right.

WRIGHT: No, I think all mine were covered very well. Thank you.

PETERSON: Okay.

ROSS-NAZZAL: Do you have anything?

JOHNSON: I was just curious, when you were talking about the ultra-reliability in the computer systems and the redundancy, was there ever any thought to go back to the ultra-reliability once the redundancy was causing a problem?

PETERSON: They really couldn't. It just wasn't feasible to do that. We were too far down the road designing and testing. Like I say, the ultra-reliable systems cost a tremendous amount of money, and they would have to had to start designing replacement pieces of equipment for the things that were already in place, and the cost would have just been staggering.

Redundancy can be made to work if you've got enough—one of two ways. Either you design a system that only needs one system to operate it, and a lot of redundant systems work that way. I mean, there are a lot of, for example, electrical circuits that have two fuses in series. If either fuse blows, the circuit is safe. Now, the circuit doesn't keep working, but in that case you don't care, because what you'll do is you'll go back and put in a new fuse. If that one blows, then you go look for a short somewhere, okay? So if you don't need a bunch of systems, three systems is probably adequate.

A lot of things that happen slowly can work that way. A lot of things on ships, for example, in the Navy they carry redundant equipment, but they don't need all of it operating at any one time. That's more like carrying spare parts. In other words, if something breaks, go get the spare part and I'll replace the broken thing and now I'm back in service. It doesn't matter if the ship, for example, isn't operating for, say, a couple of hours while I make the repair.

On the Space Shuttle, there are places in flight where you can't afford to do that. A Shuttle is an unstable vehicle. It won't fly for a second in the atmosphere without control, without active control. So you can't have things shut down and spend half an hour fixing something. It's got to work all the time.

But if you can build a system where you don't need everything working all the time, you don't need a whole of redundant units. On the other hand, like the Shuttle, if you've got to have three units running all the time to vote, well, then you've got to have at least one more unit on what's called hot standby, in other words, ready to go at an instant's notice. One of these fails, and the other two vote and they say, "This guy's dead." Well, you just bring the third guy in. But that means the third guy has been there all along and has been watching and knows where and how to step in.

If you have multiple failures, you've got to have more of those hot standbys. So you can beat the problem by having seven or eight identical units onboard, and then you can tolerate three or four failures. Part of that depends on which one of those do you think is cheaper, and which one of those do you think is safer, and which way you want to go with that, and how much time you've got to work the problem.

See, some of the things on the Shuttle are not redundant at all. Structure's not redundant. If some major piece of structure fails on the Shuttle, you've just had a really bad day. That's kind of what happened with the *Challenger*. The seal allowed that hot gas to come in there, and it just happened to burn the strut. It separated the strut that holds the solid rocket up against the tank, and the solid rocket turned sideways and punched a hole in the tank. See, a lot of people think the vehicle was torn apart by the explosion, which is not true. The vehicle was torn apart by the force of the air. The force of the air where they were is about the same as standing outside here and the wind blowing 500 miles an hour. So when that vehicle turned sideways, the wind force just ripped it apart.

A couple of things I tell people when I'm talking to them. When we launch the Shuttle and we light all five engines, we're burning ten and a half tons of fuel per second. That's the weight of three full-sized automobiles every second being burned up. So the amount of energy and the force and the power that's in that vehicle is gigantic, and it's not as powerful as Apollo. Apollo is more powerful than that.

So the forces involved are very high, and when you're boring through the atmosphere at high speed, the wind force is tremendous. The Shuttle is not designed to stand big side loads. You've got to keep it pointed exactly properly. Once that rocket came loose and pushed the stack sideways, it just came apart. It just literally disintegrated.

A lot of people have asked me how long did the crew survive, and I don't know the answer to that, because we don't know how much damage was done by the wind and how much was done when it hit the water, which was quite a while later. We do know the crew lived a short while because some of the emergency gear was activated. But we don't know how long. All the voice recorders and everything else run off power supplies that were in the back of the payload bay, and when the cabin separated, they lost all that. They lost the power. So they didn't have radios. They didn't have recorders. They didn't have anything. So there's not much recorded data as to what really did happen on that day.

ROSS-NAZZAL: Do you have any other questions?

PETERSON: Anything else?

ROSS-NAZZAL: No? Well, is there anything else that you would like to talk about that we haven't touched on?

PETERSON: No, I don't think so.

ROSS-NAZZAL: All right. Well, thank you for coming in.

PETERSON: Yes, ma'am. I enjoyed talking with you.

[End of interview]