ORAL HISTORY TRANSCRIPT

CHARLES H. FELTZ
INTERVIEWED BY SUMMER CHICK BERGEN
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BERGEN: Today is March 9, 1999. This oral history interview with Charles Feltz is being conducted in Temecula, California, for the Johnson Space Center Oral History Project. The interviewer is Summer Chick Bergen, assisted by Carol Butler and Rebecca Wright.

We thank you for letting us come here and share in your history. Why don't we start with how you got into aeronautics.

FELTZ: Okay. First of all, I graduated from Texas [Tech] University, was Texas [Technological College] at the time, in mechanical engineering, and because jobs were scarce in Texas in 1940, I came to California and got a job with North American Aviation [Inc.], October 3, 1940. I was in the design group and worked on airplanes such as the A-2J, the X-15, and the [F-]82 and [F-]86 airplanes.

In 1956, I was made assistant program manager on the 86 airplanes, and in 1956 also I was made chief engineer and management of the X-15 program. I stayed on that program until '62, at which time the president of Space Division at Downey [California] requested I come over to Downey…

We won the [Apollo Command and Service Module] contract then in 1962 for the—well, I guess it was in the latter part of 1962… The company had already won the program for the S-II at the time, and there was a question of why. We were not really the front runner, but for reasons beyond my knowledge, we won the contract.

I was made chief engineer of the Apollo Program for the command and service module at Downey, and I served in that capacity until 1964, at which time they made me assistant program manager, turning the engineering over to other people. My job then was

kind of, you might say, assistant program manager in charge of operations, which I had under me. They didn't report to me, but they were the chief engineer's job and the quality-control people and the purchasing people and the manufacturing people, and one other one, the test people. So the flow of the system went from engineering to manufacturing and purchasing, to test after it was built, and the test people then did all the testing and shipped it to Florida, where it was put together and tested more and mated with the boosters.

In 1972, we won the [Space Shuttle] Orbiter program, and the integration of the system was also given to North American at that time, which I was again chief engineer. Directly after we won, they decided that I should be program manager on the Orbiter. I held that job for about, oh, I guess a year and a half, two years, and the program manager on the Apollo became free at that time. They moved me up to technical assistant to the president, and I held that job at Downey until 1976.

In 1976, the president of the Downey division was made president of the Aerospace companies, which was airplanes, rocket engines, energy, Space Division, … and then he made me technical assistant to him … at the corporate office, [and] stayed there until 1980. In 1980, the Orbiter was in a pretty bad situation as far as schedules were concerned, and they had some technical problems… So they decided I should go back to Downey as president of the Shuttle Division… I think it was January of 1980, and I held that job until I retired in '81, directly after the Orbiter flights was made by John [W.] Young … who was a good friend of mine.

I guess that kind of wraps up until I retired in 1981, in June, after the flight, and we moved up here, and we've been traveling the world since we've been here.

BERGEN: Oh, wonderful. You were involved in so many things, it must have been a wonderful career.

FELTZ: It was.

BERGEN: When you were a child, did you have aspirations—

FELTZ: No way. [Laughter] I was brought up on a farm in Dumas, Texas, if you know that country, and I didn't go to Tech until 1935, when I was graduated from high school, … I laid out a year and then went to Tech, and I spent five years trying to get out of Tech. [Laughter]

BERGEN: You went into mechanical engineering?

FELTZ: Yes, and I don't know why, but that was the only thing I could think of, so that's the way I went. And I'm glad. During the summers I used to work on the Highway Department in Texas, and then in September the Highway Department had finished their particular job that I was on, and so I left and came to California. Then I went to Douglas [Aircraft Company] and tried to get a job, and they weren't hiring. Then I went across the street at that time to North American, and they hired me. I spent, oh, two or three months in what they called the Education Group, in which you learned the paperwork that you had to go through to get engineering done and how it got printed and how it went to the shop and how the shop then handled it, at which time, after that, I moved into what was known then as the Wing Group of the B-25.

In that group I spent until they started designing the A-2J. I'm sorry, the F-[8]2… It was a fighter, a Twin Mustang, what they called the 82 fighter. It wasn't very successful because of the engines and a few other things, and so they never did … produced a bunch of them… North American was a big outfit during the war. They produced some 50,000 airplanes, and the B-25, you've probably heard of it…

One of the first jobs I had out of the training group, if you please, … they would farm you out to the different groups. Like the first job I had was out to the powerplant group, and so the powerplant group give me a job, and they said, "Go down and look at the plumbing in the bomb bay and make a drawing of that plumbing in that area, because we'll make it just like the shop had put it together." So I'd go down and get a mental picture of it and come back and make a drawing, and then by that time that airplane had gone out the door and the next one would come by, and it was all different. [Laughter] So I had a heck of a time getting that information put down on paper. Then I was moved to the Wing Group.

In those days, they had all the information on drawings, of course, and when the drawing paper wore out, you had to re-draw it. You couldn't go get data and reprint it. So one of the first jobs I had in the Wing Group was—they gave it to me and another guy—to re-draw the center section of the wing. It was 150 foot long, and we re-drew that, and I don't know if you know, but in engineering, they write what they call engineering orders, and they go out as a sheet of paper about the size of this to tell the shop what else to do or whatever, and those things were running against this 150-foot drawing so fast, we could barely keep up. That's just a little bit of experience I had there.

Then I got on the 82s, and then I went from the 82 to the 86 airplane, and I was in charge of design of the first swept wing in America. It was an 86 airplane. It started out to be a straight wing, then they decided to build a swept wing. They swept it thirty-five degrees, I believe. So we designed that, and directly after that I got on the assistant program manager to the A-2J, which was a Navy bomber that had counterrotating props and had an Allison engine … [with] these counterrotating props, if something went wrong, they were supposed to feather. When that engine died, they were supposed to feather real quick, because they was like a blank wall [if they didn't feather]… Well, it flew nineteen times, and we had a pilot and a co-pilot on it, and the co-pilot sat and watched the engines and he

kept his finger on the button to feather the engine that went out, if it did, and we had timed it so that his reaction time from the time he saw something happen was a half a second.

The most unusual thing, I guess, when the pilot was flying it from the south base at Edwards [Air Force Base, California] up to the north base where the NASA operation is, … he says, "I'm going to land," and he says, "And don't wave me off."

The tower says, "Are you in emergency?"

He says, "Anytime I'm in this damn airplane, it's an emergency." [Laughter]

My eyes water all the time.

… I was assistant program manager on the 86 airplane until the X-15 came along. We won that contract. I think they forced us to win it, because we won it at the same time they won two other airplane contracts, and it kind of was a burden on the Engineering Department with three airplanes going at the same time. So they said, "We don't want it," our company did. They said, "You're going to take it anyway."

So they decided they would form a project group. Now, the project group, it consists of the people that was going to design it and the manager and the chief engineer. The technical people such as the structural analysis people and the thermoanalysis people and the aerodynamic people wasn't a part of that, but they supported us.

I had two assistants. One was a propulsion man and one was a structures type, and I had a pilot that they hired, named [A. Scott] Crossfield, and he was kind of an advisor to research airplanes. Then we worked very closely with NASA at Palmdale [California], and it was a very experiencing job. We never knew how to build anything with steel, and we were not familiar with building it hot, because the temperature of the airplane was supposed to get up to 1,200 degrees in spots, and it was supposed to go 6,600 feet a second—that's six times the speed of sound—and it's supposed to go at least 270,000 feet in the air. … [I]t finally went over that amount, and it was the first airplane in space, space being defined at fifty miles, and it still is, I think.

… [W]e couldn't get much advice from the people that made the material. … [W]e had to experiment on our own. We started in like [19]'56, the first of '56, and we rolled the airplane out in October '58, just about two years or so after we started, and [then] into tests. It had some problems that … [had to be] fixed… I left there in [1962]…

Am I boring you?

BERGEN: No. No. [Laughter] During the time you were working on the X-15, did you keep up with what was happening in Project Mercury?

FELTZ: Yes, a little bit. As a matter of fact, the Project Mercury people from St. Louis came out to see us, and I went there once. They came out to see us because they didn't know our attitude-control engines were hydrogen peroxide engines, … [it] used a catalyst to start the [engine], and … had piping all over the place. We made that piping steel, and I think St. Louis tried to make it aluminum. They came out to see [us], and we told them what we did. They went back, and I suppose they changed to steel or whatever they was doing. That's about the interface we had with Project Mercury.

We had originally bid on Mercury, but they rebid it after NASA took over, I think. The Air Force started that, didn't they? I believe they did. Then NASA took over, and they rebid it, so we didn't get that, thank goodness.

BERGEN: Why do you say that?

FELTZ: Well, we got better jobs. Moving to Downey, now—

BERGEN: Did you see the first test, the first successful completion of the X-15 flight before you left for Downey?

FELTZ: Oh, yes, several.

BERGEN: Tell us about it.

FELTZ: Scott Crossfield flew the airplane as long as … it was in the company's hands, and we turned it over after a few flights. We originally flew the X-15. We didn't get the engine that we were supposed to… We had to use some little engines, … we put eight [of] the little engines, … they'd … used on the X-1… [W]e put them in the X-15, … we flew with that several times. About the second or third flight, I'm not sure when, the engine caught on fire. Immediately they dumped the fuel, … landed it at Mudlake in place of the—dry lake, …when [it] landed, [it] had too much fuel [as] it didn't all come out… Everything didn't work quite right, and it busted the airplane right in two behind the pilot, and it bent the liquid oxygen tank up a little bit.

So about a day later, we picked that airplane up and brought it back to the factory, and the first thing we said we was going to do is see if we could straighten the oxygen tank out. We … [decided to] pressurize it up to the limit pressure. Then there an old German sheet metal worker there, [would see if he could straighten] when we got up to pressure—well, first of all, let me tell you, the safety people wouldn't let it go up to pressure, and I got mad and went home, and my assistant told me as soon as I got home that they finally agreed, … they checked with stress, and stress says, "If Feltz wants to do that, you let him." [Laughter]

So we pressurized it, and it popped out a little bit. Then the factory manager there was helping us out Saturday, it was a Saturday, and he says, "Well, let's let that guy hit it and see if he can straighten it out better," but he says, "I'd like to reduce the pressure about 5 psi."

I said, "Okay."

So we reduced the pressure about 5 psi, and this sheet metal guy went in and hit it with a mallet, I don't know whether it was rubber or not, and he straightened it out pretty well, said we could put it back together and put the rivets back in it, and we delivered it back to the test in six weeks.

BERGEN: Great. And then after those tests, you went to Downey?

FELTZ: Yes. I went to Downey in '62. Those tests happened probably in, oh, '59, something like that.

BERGEN: What was your job when you went to Downey?

FELTZ: I went to Downey as chief engineer on Apollo. I went to Downey during the proposal stages, and they, fortunately, won the contract, and then I went over there as chief engineer in the first place.

BERGEN: Tell us about the proposal and bidding stage.

FELTZ: On the Apollo?

BERGEN: Yes.

FELTZ: Well, I went over to Downey in '62, and they were well into studying this proposal. The RFP [Request for Proposal] had already come out. I concentrated, myself, on seeing the systems and how well they were designed, whether or not they were over-designed. I'd had a lot of experience with NASA, so I kind of knew the way they thought. Frankly, I don't know

if they knew Walt [Walter C.] Williams or not. He was, at the time, head of the test people at Florida, and I think he went on up to chief engineer, and he thought a lot of North American. Whether he was incidental in us getting the contract, I don't know, but we won the contract over Martin [Company] and, I think—I don't remember who all was in it. Well, Martin was favored for the contract because they'd done the most study.

Well, after we won the contract, we went to Williamsburg [Virginia] with the Engineering Department from Langley at that time. We went over and come up with the specifications that we were supposed to start with. The original Apollo service module was solid rocket. I think it had about eighteen of those solid rockets to help go to the Moon and to give it thrust coming back. We hadn't been on the program over—I don't know, three or four months, five months, six months, and NASA decided they'd rather have a fuel rocket engine. So we changed all the solids to a fuel system, which burned hypergolic fuel, if you know what that is. It's a fuel that kind of burns on its own as it goes through.

Later, in the early days of Apollo, they had ejection seats and blow-out panels for the ejection seats to go out. We originally tried to have a landing system that would go land on the Earth. It had a bunch of springs, but it dropped a big heat shield down and landed on the heat shield, but they got completely disenchanted with that because they didn't know how accurate they could land on terrain that would be stable. So they decided to land in water. So we changed the design so it would land in water.

… [D]uring the early phase of it, we said, "Well, we don't know what a water landing is, so let's test it," test the vehicle, not necessarily the—test the boilerplate, if you please. So we dug a ditch about fifty feet long and about fifteen or twenty feet wide and filled it full of water, and then we swung the boilerplate into it, and immediately it sunk.. [Laughter] So we had to modify the design, or thinking, at least, so that we could land in the water and not sink.

During the phase of the thing, I think—who was the guy that, when he landed, the door blew off?

BERGEN: Gus [Virgil I.] Grissom.

FELTZ: Gus Grissom, yes. Well, when Gus's door blew off—I don't think they ever found out why or when—they decided they didn't want ejection seats and they didn't want doors that opened with the fire [device], and they didn't want doors that you could get in and out, and somebody could hit the handle and the door would open, because you had pressure inside that would try to force the door open. So they'd asked us to put in a door that would open in and be sealed against the pressure so they couldn't have an accident. So we did, and, unfortunately, we lost three astronauts because they couldn't get them out. I don't want to go into that, frankly, but that was an unfortunate situation on the Apollo.

But we were kind of neophytes in the design of Apollo at the beginning, too, like we were on the X-15, because, at the same time, the outer cover of the command module was honeycomb steel, and we got the information at the same time that the people at Los Angeles in the airplane business were designing some honeycomb steel, so we cabbaged on to one of their designers and brought him over, and so he was then the primary designer, then, on honeycomb steel.

On the honeycomb steel, we had to have an ablator. In those days we didn't have insulation that we could put on the vehicle, so we put ablator. Now, the ablator was done by a little company back East, and I don't remember the name now, and what they did, we shipped these outer pieces of hardware to them, and they glued fiberglass honeycomb to the outer shell. They glued that fiberglass honeycomb to the outer shell, which had little honeycombs of about a quarter inch, like a—you know what a bee honeycomb looks like. It was about like that size of a honeycomb, and they filled that, then, with ablative.

Now, how they filled it with ablative was, they had a whole bunch of little people, like girls and boys and all, with kind of like eyedroppers, and they put it down there and filled it with this ablative material. After they got it full, they machined it to the proper contour, and they X-rayed it to see if there was any voids in that ablative down in the thing, and if there was, they dug it out and filled it again. So that was a big operation, to getting that heat shield [complete].

Let's see. Rather than jump around so much—

BERGEN: I was wondering if you could tell us about how North American hired engineers and people to do such a big job.

FELTZ: Well, okay. [Laughter] It was like open season, hiring people. They all wanted to work on it, and they all came from different parts of the friendly Western world, from different companies. We hired people that we had to get rid of, finally, but they just weren't hacking the course. I was chief engineer, and I didn't interview the guys. The guys were interviewed by my group leaders, and they knew they weren't any good after a while, so they had to get rid of them.

The same thing was happening, in my opinion, with Houston [Johnson Space Center]. They were hiring people all the way from the friendly Western world from different people. One of the major problems we had with Houston was they wanted to talk to our engineers straight. They didn't want to have to go through anybody; they wanted to talk to them. So we said, "Okay. You can talk to them." Well, the first thing you know, my engineers was working for their engineers, and whether they were doing the right job for me was two different things, see. So we had to set up a system. The system was that when my staff approved a design, they were not allowed to change it, regardless of who told them to. If they thought the conversation they had with people was proper and they should change, then

they brought it back to us and we communicated with them with what we called an MCR, master change record. We would describe on that piece of paper what the change was going to be, and I would sign it. If it involved the program manager or the manufacturing guys, we'd have a little meeting and agree that that's okay and it wouldn't affect the schedule and all that good stuff. Then we'd issue it to the Engineering Department, and they would go change it, and everybody knew that that particular part was being changed and they had to coordinate that design change.

After a while, it wasn't instantaneously, but after a while, the Engineering Department become accustomed to that method of operation and NASA become accustomed to that method of operation, and so then we started all walking down the same path, and I thought it was very good. I had brought that system over to Downey from L.A. [Los Angeles] because we had the MCR system in L.A. ever since I was there, but Downey didn't have it, and Downey was lacking in a lot of systems operations like MCRs and all kinds of different paperwork, and we finally worked … into…

One of the things that was a problem was our subcontracting effort. Now, in those days we didn't really—and our engineers didn't really know all the details of what they were subcontracting for, and so they'd write a specification and it would go out, and they'd get bids on it, and we'd pick the bidder on whether or not it was the low cost or not. It was evaluated as a bid. Well, the purchasing department wasn't set up to manage that, really, because the engineering would have to give them more data as the thing was developed.

So I designed a system that said that we would assign a program manager to each project that was a major item, like 10 million dollars or [more] or something like that, we'd assign a program manager, and he would be an engineer that was in charge of it. The contracting officer would be a purchasing guy, and he could communicate any way he wanted to with the subcontractor, providing it didn't change the contract. If it changed the contract, then he might have to come back through the Engineering Department and say,

"This is a major change to the whole program," and it had to have Purchasing Department as the contracting in case you have a contract change. The Purchasing Department wasn't used to that, so they resented it, but the president says, "That's the way you're going to do it." In addition to the Purchasing Department being the contracting officer, we assigned a manufacturing guy and a quality-control guy to this same individual that reported to him to manage the contract. That was a system that I thought—and that's still in use today. I thought that was the best system. We didn't have that at LAX, Los Angeles.

We went out for bids. I'll just throw this in. We went out for bids one time on some high-pressure bottles, and the Purchasing Department brought back the bids, and we evaluate them, and then I said, "What's the cost?"

"Oh, you don't need to know the cost," purchasing said.

"Well," I said, "you can stick this in your ear, then, because I'm not going to give you the winner until I know the cost." And that was the way that they kind of operated at LAX, because most of the things in the airplane business was already developed except what was having to be developed in-house and except when the X-15 come along. Well, they all had a little bit outside, but it was more they could write the speculative letter than we could at Downey.

BERGEN: Did your experience on the X-15 help you when you moved into Apollo?

FELTZ: Sure did.

BERGEN: In what ways?

FELTZ: Well, I think I was a systems type of guy, if you please, and I was well organized. I always had a schedule and a plan in which we go do something, and that's what we had to

develop at Downey, because they were not organized when we got there. I got there, and one of my assistants come over with me, and I had brought my propulsion guy and my propellant guy, so I had a team that knew how to operate. The biggest problem I had was our—in those days, we didn't use human factors of people much at LAX, and over at Downey we had to go human factors. That was the thing that everybody wanted to sure that the pilots and the astronauts and all those good things could reach every instrument and knew how to read it and where it should go and all that good stuff.

So Downey starting putting on—that particular group at that time didn't belong to me as what I'd call a pink slip. I couldn't raise—they belonged to a doctor over there who was a friend of the president, and the first thing I'd—I'd give them a budget, you know, and they'd pay no attention to the damned budget. They hired as many people as they wanted to. I went over there one time and they had about 120 people, and I said, "You guys have got too damned many people." Everything had to go through them, "And your comments are not always the proper comment, and we've got to straighten this out." So we worked for system and straightened it out.

We had another group in Apollo that we hadn't been used to, and it was the group that figured out what the percent of chances you would have in going to the Moon without failures. So we had a group that did that. They looked at all the designs, and one day I found out there was a letter went to one group, and a letter went from that group back, and here they … designing by mail, and I said, "No more letters until you guys get the design agreed to, then you can sign a letter, both of you, saying what you agreed to." So that stopped that, really.

I'm just telling you the problems you go through in engineering. And I was mean. I was really mean. No, I wasn't mean; I was firm. But I had never had one person dislike me, I don't think.

BERGEN: Well, that's good.

FELTZ: I had one guy in manufacturing that I don't think he liked me very much. One of the designs the guys made, on the top of the command module we had a structure with a rocket engine in it, and if we got in trouble downstairs in the boosters anywhere, that rocket engine was to lift the command module off, and then the rocket would go away, and then the parachutes could come out and land the Apollo.

Well, one day the guy come to me that was designing this and had already released the engineering, and he says, "Hey, we screwed up. We got some of the structure right in the middle of the blast of the rocket engine." [Laughter]

I said, "You've got to change it."

So the manufacturing guy, he said, "Well, that's going to cost six weeks."

I said, "You've got to be kidding. What have you got that it's going to cost six weeks?"

"Well, that's what it's going to cost."

I says, "It ain't either…"

So he went back to his boss, who I had known for years, and said, "That's what they're going to do, and that's what it's going to cost."

Well, I immediately went to his boss and said, "Jim, now that can be fixed. Now, don't give me that crap." And they did.

BERGEN: It seems like communications was really important to get the job done.

FELTZ: Yes, it was. Yes, it was. It was.

BERGEN: Were there any other systems you instituted to improve communications?

FELTZ: I approved—well, I'm getting out of my thing, but after I went from the program as the chief engineer into the assistant program manager's office, I approved every system that was issued at Downey, including the ones that were in manufacturing, the ones in quality control, because all of them interfaced with each other some way, and I wanted to be sure that interface was proper. So I approved all the systems at Downey that were implemented after I was program manager, and they're all in business, same today. They haven't changed. It's a real important thing to have a system that everybody's following, because if one ain't following it, it goes to hell.

I'll tell you a little incident. I told you about the one boilerplate landing. One morning I came in, and they had the service module in test. We had a big hole that they would test the service module in, and when I came into the gate, they said, "The service module blew up."

"Oh, you gotta be kidding."

Well, it had blown up, all right, and it was in the pit, and part of the thing had blown out. Well, we went into, along with NASA, of course, a big problem of finding out why, because we had titanium vessels, and we had this fuel that's supposed to be compatible with titanium and had been tested and all, but here it had been in there and it blew up. So they did an analysis, and they didn't do it overnight. It took about a month or two. We finally found out that the company that had made the fuel for NASA made it more pure. They took a little of the water out, and when you put that new fuel in titanium, it didn't work. So that's how critical you have to coordinate your decisions.

BERGEN: One special focus, I guess, that you had was Airframe 9. Were you giving special attention to this airframe that was going to be the first [flight article]?

FELTZ: Well, yes. I was program manager at that time, or assistant program manager, and I think at that time Bob [Robert O.] Piland was program manager at Houston, and we had this first vehicle coming through. We were having all kinds of trouble making schedule, and we knew where the problem was in making the schedule, but we didn't know what the problem was… The wiring system for the command module, they had trouble getting it out of the factory, and the reason they had trouble getting it out of the factory is they couldn't test it. Every time they tested it, they'd have so many failures they didn't know what to do. We found out later that what they had done, what the Engineering Department had done, had been releasing EOs [Engineering Orders] to change the wiring, and the manufacturing people kind of lost control of whether they had operated that engineering [order] into the wiring [or not], and they were trying to test it, and it was just chaotic.

They did that for about six weeks or so, and the guy that was in charge of the factory, he kept coming up with a different schedule every time I'd turn around. Piland was getting very unhappy and so was I, so I says, "Okay. You deliver that harness to the command module, and we'll put it in. We'll try to get the configuration fixed by that time, then, and make the corrections to the wiring." We had a hell of a time getting it fixed. We had guys—had two guys almost hand-measuring the wires pin-to-pin all over that command module, and it took them quite a while, and they finally were able to then put it on what they call a Ditmco machine, … a Ditmco machine puts high voltage so that if there's any wiring harness default, it breaks it down, and that's what we did finally, and we got it done.

Then, of course, went into test. In the test, we'd got into test, and we couldn't pass the test in some areas, as normal. Finally, as program manager, I found out, "What's the problem?"

"Well, we can't get the control system to work. It don't meet the specs."

I said, "Well, what's wrong with it?"

"Well, to make it honest, we didn't take into account wiring links and all that [loss], and so we made it perfect as we bought it, so we have to degrade it a little."

Well, the astronauts didn't like that worth a dang. They said, "You're changing the hardware to meet what it is rather than what's the requirement is."

Well, we went through about two or three days of that argument with the customer, and we finally convinced them that what we were going to do was okay. So we changed the testing requirements so that it took into account the deterioration due to length of wires and system… One of the things we got into was the controls, the attitude control system. We found out that we had corrosion in there. So my factory guy said, "Let's take all the plumbing out and redo it, and we'll change from aluminum to steel," or something. When I'd found out about it, I'd put the lab engineers in charge of finding out how we can flush that system out, get that corrosion out. So they worked very hard on it, and they come up with the answer in a few days, and I still had to fight the factory to make them go do that, but they went and … did it, and we were successful in that.

At the same time, I think we were concerned that the joints we had in the vehicle might leak, so we developed a secondary seal that we put around the joint and sealed the joint so it couldn't leak. If it leaked, it leaked into the secondary shield, and then at that time we put those on the vehicle, too.

I'm doing all the talking.

BERGEN: That's the way it's supposed to be. [Laughter]

You mentioned Bob Piland at NASA. Were there any other people that you worked with a great deal?

FELTZ: Well, I worked with Bob. I worked with Max [Maxime A.] Faget. I worked with the structures guy. I can't remember his name right offhand. I think he's passed on. Bob was the

program manager at the time. He was an interim program manager. When [Charles W.] Frick left—Frick was the original program manager, and we had an original program manager named [John W.] Paup. He was an Air Force guy, and I don't want to say much against him, because he really never managed the program, and I don't think Frick either did, so don't put that in your book.

So both the customer and ourselves decided we'd better change program managers, and then a guy by the name of Dale [D.] Myers was put in as program manager, and Bob Piland was interim program manager, and I think after him was Joe [Joseph F.] Shea. I worked with Joe Shea very well. Joe Shea passed away, I understand, just recently. I'm not sure of that, but I heard he did. After that came—he was Gilruth's assistant.

BERGEN: George [M.] Low.

FELTZ: George Low. After that came George Low. I worked very close with George Low, and I thought George Low was the best program manager I ever worked with and the best guy to work with, because he worked the problems not necessary to the people, and he didn't get upset because of a problem, and he worked the problem. He was instrumental, as far as I'm concerned, in the first shot around the Moon and back on Apollo 8.

BERGEN: Why don't you tell us what you remember about Apollo 8.

FELTZ: Okay. We shipped Apollo 8 to the Cape, and at the same time, I had staffed with me a program manager for each spacecraft by that time. A guy by the name of [Joseph W.] Cuzzupoli, Cuzzupoli, was program manager on Apollo 8, and he went to the Cape with the vehicle. After we got it to the Cape, the word came, "Can we go around the Moon with

that?" [Laughter] So we searched ourselves, and finally I don't remember how many changes, if any, we made in the Apollo, but we said, yes, we thought we could make it.

So the crew went—they only was going to go around the Moon and back home. They weren't going to circle the Moon; they were just going to shoot around the Moon … and come home if they didn't [need] a service module to change them and bring them home, but they'd come home very good. The guy that was the head mother on that was—he eventually was Eastern Airlines' CEO, Frank Borman.

BERGEN: Right.

FELTZ: God, my computer just can't bring it up instantaneously. Frank Borman was a very good friend of mine, too. I loved Frank Borman. I think they did an outstanding job, and it was at Christmastime when they did it and come back home, and without incident. I don't know any problems that they had on that flight.

BERGEN: I don't think they had any.

FELTZ: I don't either.

BERGEN: That must have been a great triumph for North American.

FELTZ: It was. It was. It was a confidence-builder that we could do, and I think it was a confidence-builder for NASA also.

The one that was the most scary flight we ever had was Apollo 13, in which we had an oxygen tank that supplied oxygen to the fuel cells who generated it into electricity, as well as breathing for the people, and that blew up on the way. Of course, we had the LM [Lunar

Module], what we was going to land on the Moon, and the LEM, fortunately, we had not launched it, so we had enough fuel to push us home.

But the crew, they really suffered on that flight. It was cold. I don't know as they had any permanent problems with that temperature, but it was cold as heck, and they didn't try to turn the heat on because they was afraid something else would go wrong. They didn't try to run the engines in the back of the service module because they was afraid something else would go wrong, so they just took it coming back home. Then they finally jettisoned the LM on the way back and also they jettisoned the fuel, the service module, and landed successfully except for that incident.

We later found out—and that was the most hairy. We sat here in Downey, just trying our best to figure out what the heck went wrong. We didn't know that—we knew that they wasn't getting oxygen. We knew that they didn't want to turn on the thing because oxygen was a problem, but we didn't know to the extent of what the problem was. When they got home, we finally figured out that we had a quality-control problem in the tank. The supplier had installed a wiring that wasn't 100 percent engineering quality. I said, "Change the design," and we had no more problem after that. But that was hairy, that flight… I consulted for the pilot—he went to Grumman on the Space Station, integration, and I consulted on the Space Station for a couple of years. What the hell was his name? You ought to know it. He's back in Houston now. I'll look it up.

BERGEN: Was it one of the astronauts?

FELTZ: Yes.

BERGEN: Well, you can fill that in later if you want.

FELTZ: Yes. I'll fill it in for you. [Fred W. Haise, Jr.]

BERGEN: You mentioned Frank Borman, and he had a special team that [came] to Downey after—

FELTZ: After the fire. NASA says, "To speed things up, we'll send Borman to Downey so that you guys can work and get a decision quickly so we don't go forever back and forth with paper to get things done." So they sent Frank Borman out there, and he worked closely with the chief engineer and with the rest of us, frankly, to come up with designs that would make it almost impossible, we hoped, to screw up. Now, don't get me wrong. I don't know what screwed up on the fire, and I don't think anybody else does, but at least when we got through, we were sure that almost something couldn't screw up.

And Frank was a very good—I went to the twenty-fifth celebration of going around the Moon, and Frank and all his three guys were there, and Frank says, "You got mad at me, didn't you?"

I said, "Frank, I didn't get mad. You guys just wouldn't settle down. I was trying to get the stuff done, see." But it turned out to be a very good operation when we finally got it all done.

At that same time, the president of the company was transferred out and your counterpart came in as president, which was Bergen, Bill [William B.] Bergen.

BERGEN: Yes, Bill Bergen.

FELTZ: And Bill was a kind of hard guy. He later told my wife—we were at Houston one time to a particular event, I don't remember, kind of a party, and he told my wife, he says,

"The worst thing I ever almost did was to fire Feltz." And that's what he—he would come in, you know, clear people out so that they'd get the job done.

And then he told me, he says, "You were the only guy I had faith in after I'd fairly got to know you." He'd brought in a program manager on the first vehicle after that, and we had all these changes, so after we kind of got our feet on the floor and got most of the changes well under way, NASA brought [Robert R.] Gilruth and, I think, Bob—what's the guy's name that I just mentioned, went to Washington? He was the program manager I thought was so good?

BERGEN: George Low.

FELTZ: George Low. I'm sorry. A number of them come out. There must have been close to a dozen of them come out. Dale Myers was out of town on vacation, and so they wanted to know what the schedule was, when we was going to get that thing delivered. Well, I says, "God, how do I make it look at least real?" I'm beating my head against a wall for a day or two, thinking how in the heck do you communicate with that many people on what the schedule really is?

So I finally decided I would make a perspective of the command module. You know what a perspective is, a drawing that's kind of three-dimensional. And then I would make copies of that, and I would make each group in engineering lay out what they had to do on that particular command module so that we could see what the job was to be done in each group. I made them brief it and say when they was going to get it done. So when we got through briefing them all on when the engineering—I made the chief engineer, who was George [W.] Jeffs at the time, get up and say he was going to support that. Then I got the manufacturing guy to get up and say how he was going to support it, including the Purchasing Department. And when they got through, I presented the schedule, and they all

went away happy. They knew what the hell we were doing. We didn't know everything, but we knew most of it, and that's how we got the first airplane after the fire, the first vehicle after the fire out.

BERGEN: Apollo 7.

FELTZ: I don't remember what it was.

BERGEN: It was Apollo 7, and it was a very successful mission.

FELTZ: Yes, it was.

BERGEN: That must have made you feel good—

FELTZ: Sure.

BERGEN: —that everything worked just like it should. And speaking of successful missions, Apollo 11 finally accomplished Kennedy's goal of landing on the Moon. Do you remember where you were when it happened?

FELTZ: Yes, I was in the office listening to it. We had direct line from Houston. We had put that in, and we had direct line from Houston, and we knew what they was doing. We didn't have television, but we had communication. Armstrong was a very good friend of mine. He flew the X-15, and I thought he was probably one of the better pilots on the X-15. He was relatively small, and so he had a lot of room in there, and he was a very good communicator on what was going on during the flight. Crossfield was a good communicator, too, but some

of them, they didn't open their mouth, hardly. So if you got people in the air on something that you aren't 100 percent positive of, you like for them to keep talking to you on what's going on. I thought Apollo 11 was outstanding, frankly.

BERGEN: It was a great mission.

FELTZ: Yes.

BERGEN: You had worked on airplanes for so many years, and then all of a sudden you were working on a spacecraft. What were some of the differences that you encountered to make that transition?

FELTZ: I'll tell you what I think was a major difference, to me, at least. In the old days we worked on the airplanes and we had contracts from the Air Force, and we would brief the Air Force periodically on the airplane. I recall going back to Wright Field several times during the year and communicating with the different facets back there, and that's about the interface. Now, our chief engineer told us one time—I said, "I'm going to ask the Air Force."

He almost threw me out of the office. He said, "You don't ask them nothing. You tell them." [Laughter]

So, as a result, the Air Force wasn't in the middle of your pants. And X-15 was about the same way. I had outstanding communications with Edwards [AFB]. We briefed the Air Force and we briefed industry about twice a year, but they weren't looking at my drawings. They were five minutes like NASA turned out to be. So I think the biggest problem was communication with NASA and the different people that was involved, and it was very difficult to manage a program when you've got people talking to each other and you wonder,

"Is that his idea or somebody else's? Is that the proper thing?" So I think that was the biggest changeover, was the customer in your back pocket.

BERGEN: We talked about Apollo 11 and landing on the Moon, but I didn't ask you earlier, what did you think in 1961 when President Kennedy announced that—

FELTZ: I didn't think. I was in Texas at my folks' place in 1962, in August, when the president of Downey called and says, "I want you here as chief engineer on Apollo." Well, I had just had two shots, one in each knee, because I had bursitis, and I couldn't even walk, much less drive, and so after a day or two, I said, "Okay." About the same time, one of the neighbors—I had a brand-new car, and one of the neighbors come and sideswiped it, trying to miss a dog. So I told Juanita, I says, "You gotta drive. I can't drive, but we're going." So she started out. I got cured by the time I got to Albuquerque [New Mexico], so I could drive, and we come on home. And I went to Downey right off of that.

BERGEN: We were talking about systems and the Apollo command and service module. One of the more technical systems was the docking module. Did you have any special problems with that system?

FELTZ: Yes. We had a good engineer designing that, and when he got the first one built, it didn't work like he wanted it to work, or like it should work, not necessarily like he wanted it. So Dusty [Rhodes] was … engineer, and a guy by the name of Ralph Ruud was at the time vice president and assistant to Bergen, and so Ralph was a manufacturing type, and the manufacturing type, when he walked down the aisle, they all bowed because he was an outstanding individual. So Dusty come to me, and he said, "I don't think we'll ever get this done the way things are going."

I was program manager at the time. I says, "Don't you know what you're going to do?"

He says, "Well, I don't know if it will work or not," he says, "but I'd like to try a bunch of things and see if it works."

So I called Ralph Ruud over, and I says, "Ralph, if we give you a drawing tonight, will you have a part in the morning?"

"Yeah."

So between the designer and Ralph Ruud and myself, we, in about a week or so, had that thing working, and it was one you put in and take out and add shocks in it and all that good stuff.

BERGEN: And it was successful every time.

FELTZ: Yes.

BERGEN: Although there were some problems on Apollo 14 in docking, but it managed to work.

FELTZ: Yeah. I don't remember those, though. When we landed on the Moon, when, in '69? I went from [there] to the Shuttle as program manager on the Orbiter, and so we were, at that time, doing studies for what should be the Shuttle… At that time I was on the Shuttle, so I don't remember that problem.

BERGEN: Before we go into Shuttle, were there any other issues that came up during your time working on Apollo that stand out in your mind?

FELTZ: One of the problems we had developing was the parachute system, and we were working with the parachute people up in the valley who were managed by a guy that used to work for me. As a result, he would do whatever both of us thought we ought to do, but we had a lot of problems, and we had boilerplates to throw the parachutes out and land them on the Earth and then make a correction and do it again. That was kind of a tough problem. We wanted to be sure—we had three parachutes, as I remember, and we wanted to be sure at least two of them worked. That was a major problem. I'll have to think more. I just don't remember. There was so many damned many of them that I can hardly separate them. [Laughter]

BERGEN: What is your most fond memory of your work on Apollo?

FELTZ: I think my most fond memory of working on Apollo was the people and, in particular, George Low. [George W. S.] Abbey was good to work with, too, … he was kind of assistant to George Low and Gilruth. Well, he was with the astronauts first. He was head of the astronaut group, but then he had moved, I think, from assistant to George Low and Gilruth, over to head the astronauts, and I don't know if he ever went back. I don't remember whether he was assistant after Gilruth when George Low was there and then after him was Chris [Christopher C.] Kraft [Jr.]. I loved Chris Kraft, too, because he was a reasonable individual and, I thought, smart individual.

BERGEN: Seemed like there were a lot of brilliant people who worked on the early space program.

FELTZ: Yes, there were. They were…

BERGEN: Well, we can move into Shuttle.

[Break]

BERGEN: Well, let's start again with Shuttle, when you went into the proposal stage on this.

FELTZ: Okay. We went into proposal stage and study stage, really. It was a study stage for about two years on what it should look like, and we worked with General Dynamics [Corp.]. The first Shuttle was supposed to have a booster that flew back home, and they launched the orbiter off of that booster, and it went into orbit with its propulsion system. That become a little too expensive for the government and NASA, because by the time you developed effectively two airplanes, they decided it—[John F.] Yardley came up with the solid boosters, if you ever heard that name, and at the latter part of our studies, he proposed the solid boosters with the replaceable boosters and the throw-away tanks—tank, rather. So we all focused on that after NASA kind of said, "Well, we think that we can meet that dollar sign." And it was primarily for money and maybe schedule that we went to the solid boosters and the throw-away tank.

Then we got into proposal stage after we submitted it and NASA says, "Here's the spec [specification] we want you guys all to bid to." So we did, and everybody else that was interested in it also bid. I can't remember. I know St. Louis bid. I think, honestly, we bid not only on Orbiter, but on integration of the booster and tanks with the Orbiter, and we won both contracts. I really believe that we won them because of the job we did on Apollo, not saying our proposal wasn't any good, but our proposal had to be good. NASA evaluates the proposal based on what it is, they base it on what the people is on the job and what they think you are capable of doing, I think. I'm not 100 percent sure of that, but anyway, we won that proposal in 1972, and at that time I was program manager on the Orbiter. After we won—as

we went in with the proposal, though, I changed from program manager to chief engineer, and I was chief engineer when the proposal went in. That was strategy, really.

Well, after we won, then I went back to the program manager, with NASA's concurrence, of course, and we had a guy by the name of Al [Alan B.] Kehlet, who I had hired from Langley on the Apollo days, and he then was chief engineer on the Orbiter. We had another guy that was chief integration individual manager named Bud [R. L.] Benner, who was my assistant during the X-15 and one of my assistant chief engineers and one of the spacecraft program managers. So he was spacecraft program manager on the Apollo that went into the vacuum chamber down at Houston.

Anyway, getting back to the Shuttle, it was, I think, a lot easier than the Apollo because we were always able to communicate. We had our systems all in operation. We had developed a schedule in terms of what we thought the government would let us spend and what NASA would get, and we worked close with the program management at Houston. I became very close to the program manager at Houston, a guy by the name of—it'll come to me—Bob—

BERGEN: [Robert F.] Thompson?

FELTZ: Thompson. Bob Thompson was program manager on the Orbiter and the Shuttle at that time.

Then we got the Shuttle, and we decided that—in the Apollo days, we had some 30,000 people at Downey, and 30,000 people, approximately 30, is very tough to manage …, and we decided on the Orbiter and the integration of the system that we would try to keep our force down to 10,000 people, which would be a lot easier managing, and then we would farm out pieces of it to other aircraft companies so they could manage some things, too, with us. So that's what we did.

The first thing we did was [to get] people to bid on the wing, for example, the mid-fuselage, for example, the vertical tail, for example. Of course, we always bought the landing gears and stuff like that from the landing-gear people, but Grumman built the wing, Fairchild built the vertical tail, General Dynamics at San Diego built the mid-body, and we built the remaining, the aft fuselage and the front fuselage, and we integrated them all together. That was a much easier job, because we had now learned how to manage our subs, and they were very capable people in the first place.

… They first come out to our plant, most of them, and we sat down and developed that particular interface, if you please, guessed at loads to start with, and then as we would get more aerodynamic information, we would upgrade the loads, and they would upgrade their piece of the action. I thought that worked outstanding, frankly. By that time we had learned to work with the customer also. So that made it easier, too, and our piece of paper was one almost that the customer used, the Apollo. They knew our piece of paper almost as good as we did, and they liked it, too.

Bob Thomas we program manager at that time, and he had a system. They wrote a lot of the specs that we all worked to. Bob was a very easy guy to work with, and he went to St. Louis after—I guess he retired at NASA, and I guess he's back at Houston now. I don't know.

Now, what have I missed?

BERGEN: What were some of the challenges of developing the Orbiter?

FELTZ: The biggest challenge, I think, of the Orbiter was the insulation. The Orbiter was designed of aluminum material, not exotic material, and all the outside of the vehicle was covered with insulation. That insulation was developed in the early days of the Shuttle, and it was done by Lockheed. They had won the contract for—I think two or three people

worked on that, and they finally won the contract on the integration. That was probably one of the most toughest things that we did. There were some 30,000 tiles on that airplane, plus some felt and a few other things, but there was 30,000 tile on that airplane, and they were all about that big square, and they were all glued to a piece of material that was then glued to the airplane, and that material was soft, kind of soft. It was hard, really, but it weighed, for example, it weighed nine pounds per cubic foot compared to the Apollo, which weighed about sixty-five pounds per cubic foot. So you see we went a long way in technology to get that.

Now, one of the problems we had was attaching that to the airplane. First of all, it had to be machined so that it would have the same contour as the airplane. It had to be close between the gaps, that you couldn't get the heat down. As a matter of fact, we had to put fillers in between them on some of them, and it had to be light, and it had to have enough strength to take the aerodynamic loads trying to lift it [off].

Now, in ordinary airplanes, the aerodynamics people give you a lift curve over the wing and a lift curve on the bottom, and you say, well, we can take all that. But on this one, we had to know what the load was on each individual tile to be sure that that tile was strong enough to stay on the vehicle. So they had to work each individual tile and give the loads to the structures guys, and they had to calculate whether that thing would stay on or not. So that took a lot of time.

As a matter of fact, that's the reason I went back to Downey, is because they got in all kinds of problems… When I went back, the first two or three months I tried to find out where the hell did we stand. Where is all the problems? Then I decided that I was going to take a room that was about twice as big as this, with not all these windows, and we were going to put the schedule on the wall. Everything that had to be done by the Purchasing Department, the Manufacturing Department, the Engineering Department, had to go on that wall, and if we needed something from the customer, it went on the wall. So we had the

entire program that remained, qual [qualification] testing of parts had to go on the wall, everything had to go on the wall. Everything we had to do had to go on that wall.

Soon as it got on the wall, then every Friday I would have a meeting in that room with all the managers, the head of engineering, the head of manufacturing, the head of purchasing, and if Houston wanted to be in there, they were welcome. We had no secrets, and we just followed that thing, then, until we got it all done. The airplane, in the meantime, is at the Cape, and we had a crew down there taking those dang tiles off, and we found out that we had to take some of them off and put—if you know what those tiles look like, they have a black coating outside. We had to put the same type of coating on the inside so that it was more uniform in terms of its sticking, because they were aerodynamic, would try to lift it up at the front and tear it off. I use the phrase to describe that as that material had a bunch of fine hairs, and those hairs then were glued, but they worked as an individual, see. So we coated those hairs, and then they worked as a total, then it became possible to glue them on there the way they say.

BERGEN: And you finally got them to stay.

FELTZ: And we finally got them on, and the guys worked, and it must have took close to 50 percent of them off and surfaced them and put them back on and glued them. It took from the time I went until it went into test down at the Cape, finally I thought it was well enough along that I'd give it to our test people down there, go into test, and then finally mounted it on the airplane, and we flew then in March, April. April, I think. And I watched the launch. We flew back and it landed at Edwards, and I was back when it landed at Edwards.

Now, what was interesting to me, John Young was the pilot, and John Young would be worried about things. I at the time was at corporate office, so John would give me a call, and he says, "Charlie, I'm not sure about this." One of the instances was that the bomb bay,

or the cargo bay, had doors on each side, I think there was about four of them, that you had open during launch, you could close them on orbit, and you closed them on entry until you got down into the atmosphere and the temperature was such that you could open them and then let the crushing load from the atmosphere into the cargo bay so you didn't screw up the structure.

So John says, "What if I don't get one of the doors shut?" which is a good question.

I said, "God, I don't know, John. Let me check that."

So I got the question to people, and I says, "Suppose that door's open. What will burn up?"

They come back and say, "Well, that's okay. It'll get a little hotter, and we may have to change the material a little bit when we get back, but that's no big deal."

So John says, "Okay."

One of the other problems we had with the Orbiter was that at the time I was at the corporate office, I was kind of a technical assistant to the group president, and we were over the Rocketdyne people, too. So they blew up one engine right after the other. They had instigated the engine with a seal between the turbine on the oxygen pump, … and the pump itself, between the power that run the pump and the pump itself, and that seal was failing like mad, it just wouldn't work. NASA had done a lot of technology work on it, but it was—the surface of that slope was measured in light—I'll think of it in a minute. It was so exact it had to be measured by light. So I don't know if we could never manufacture it or whether the damned thing didn't work, but they blew up an engine or two. So they screwed around, and a guy that was in charge of the engine at Huntsville asked me, he says, "Do you think it will ever work?"

I said, "No, it won't ever work. It's too dangerous." I don't care if it worked once or twice, you don't know it's going to work every time, and it's too dangerous, and you might as well change to a labrunt seal, which is something we all knew about.

He said, "Well, it'll take more gas to keep it—"

I says, "So we'll put another fifteen pounds of gas in the airplane, but it'll be safer." They haven't had a blow-up since that new seal went in… So that was a big accomplishment as far as the engines were concerned.

The engine has a computer that runs each engine. Just like your cars today, they've got a computer. You can't work on them, because you don't know what the hell the computer's doing. But they had a computer that run each one of those engines, and they were high pressure, high-pressure engines. They were 3,000 psi on the chamber pressure, … they each developed 540,000 pounds of thrust at vacuum, which was a little less than that at sea level, of course, and there was three of them, and they all gimbled, and they were controlled—the guidance control for the Shuttle along with the gimbling of the solid motor thrust chambers, which give it all the power it needed to operate.

I guess out of the hardware that keep the thing—the insulation, the next—probably the biggest thing that we had was the electronic system. To start with, it was a very tough thing to decide what. We had a guy that was an outstanding electronic guy. So he come up with all the electronic things that we needed to do in the airplane. I says, "Well, we'd better go down to Houston and discuss the whole thing further, because they're no dummies, either, you know, what they want."

So we went down there, and he had a whole stack of briefing charts that he'd developed, and he put up, I think, about the second one, which was a total schematic of all the electronic, and he never got off of that during the briefing. He stayed on that one thing because of the questions that were asked and his answers. Finally they said, "Well, that's what we want." So that was a tough one to get settled, if you please, but not as tough after you got it settled.

The other thing that was kind of a mean thing and a worrisome thing was the software that—see, that Orbiter just flies on software. If the pilot wasn't there, it would fly anyway.

You punch in the right program, and it has an automatic landing system. I don't know whether the thing ever has used the automatic landing system, because the pilots were nervous about an automatic landing system at that time. So I don't know whether they've ever used it or not.

BERGEN: You mentioned that the Shuttle could probably fly itself without a man in there. How did you feel about the first test of the Shuttle being a manned flight?

FELTZ: Oh, that didn't bother me. … [B]ut I'll tell you the thing that bothered me, was the tiles all staying on, because the heat coming [in] that, you didn't want to get to that aluminum surface. So that's what bothered me more than anything… I guess the launch would worry you, because it all has to be integrated, and if one of those solid motors don't start, it's a bad day in black rock, because you've got one doing tumbling. But all of them seemed to work okay.

I don't mind saying that I cried when it come back. It just went in orbit a couple of times, as I remember it, and come back because they didn't want to take a chance. See, if you go in orbit, you've got a cross-range problem when you come back if you don't do it in the first orbit, and every time you orbit, you move over about X number of miles from your home base, and so they didn't want to have all that cross-range problem as well as the regular problems, so that's the reason it didn't go but a couple of orbits. I don't know if they ever use the cross range to speak of at all now. They try to either land at Edwards or the Cape.

One of the interesting things on the Shuttle was, how do you get it from Edwards, where we had final assembly, to the Cape? It didn't have any engines in it that you could burn. So we tried everything. We had engine packages that we bolted to the mid-body, and they would go about 500 miles and you'd have to refill them all. So you had a dangerous situation.

So one day the guys from Boeing came down, and they come into my office, and they said, "We've got an idea. You guys are having all kinds of trouble getting this thing to the Cape. Why don't we put it on the back of a 747."

So they briefed me on that, and I says, "That sounds good. Why don't we brief NASA on that so that we're all in the same boat, if you please."

So they briefed NASA on it, and they said, "Yeah, that's okay. That sounds like the best thing you've had yet."

So we said, "Okay, Boeing, I want you to go design the 747 to take the loads and put the necessary connections on to the Orbiter."

In the meantime, we had to have a 747. So at the time we had American Airlines trying to help us on turnaround so we could turn around faster. We wanted to turn the vehicle around as fast as we could. So they said, "Well, we've got some over here in New Mexico sitting there because we're not using them." They says, "We'll sell one of them to you for fifteen million bucks," which was cheap, really, because they cost a hell of a lot more than that.

So I sent a guy down, and they looked all the paperwork over and finally decided that was okay, and so they bought it and brought it back and give it to Boeing to modify to do the [unclear]. Well, then people got a little worried about how do you get off of that damned thing and test the Orbiter before we go into space on how it lands? So, well, we did the aerodynamic analysis and the wind tunnel analysis and said, "Well, it'll go," because the Orbiter's got more drag than the—it's got no engine and the engines are in the 747, so you turn it loose and … then the Orbiter flies off. And it did. The astronauts did the check-out on it, and it worked very well. But those are the things you run into that are brand new and different.

BERGEN: And it was a very different vehicle than anything that had been designed before.

FELTZ: Yes. It was, yes. It had insulation all over it. See, the X-15 was designed for 1,200 degrees and it's steel, and they never got over that. But this thing had to be designed for 3,000 degrees in some parts of it, and on that particular part we had carbon leading edges with insulation behind the leading edge, rather than in front of the leading edge. And then behind the carbon we put the tile.

BERGEN: You mentioned that North American, or Rockwell at that time, was also in charge of integration. Did you have any other integration difficulties aside from the tiles?

FELTZ: The integration of the tiles was Orbiter's responsibility, okay? The integration of the boosters to the tank and the tank to the airplane, the Orbiter, was our responsibility to give them all the loads, all the interfaces, and the flight mission. So we developed the flight mission, we developed what we thought was necessary for the thrust, and we developed what we thought was necessary for the engines in the back of the airplane in terms of their thrust, how we wanted the nozzles to be. The integration of the total is what we were doing, too. We had about five or six hundred people doing that.

One of the major problems on that was getting the loads. You get the loads out of the wind tunnel—I mean, you get coefficients out of the wind tunnel and develop the loads from that, and you go through, as a preliminary load, and then you go through as a second iteration and a third and a fourth. I think we went through about five iterations on the loads. Not all of them were major, but at least to be sure we had the loads. The load sometimes also depends on how you fly the vehicle. We had a very critical first flight through the max Q that we had to make, and after we got all the loads, then we figured out how to fly through that max Q without overloading the vehicle, and that's what the integration job was to do.

BERGEN: After having worked on the Shuttle and it's flown for so many years, what's your overall view of the Space Shuttle?

FELTZ: I think it's a very good vehicle, frankly. It probably is a little bit obsolete in some of the areas, and I understand they're trying to upgrade it in time, and I really think it's a very good vehicle. I thought it was at the beginning, and it's proved itself to be a very good vehicle. Unfortunately, the boosters screwed up.

I was on the NASA team to review the solid motor redesign after they went ape, and that took about a year. I was disappointed in it taking so long, but that wasn't my job to redo the—I recommended a change that would have done it much quicker, but it would have been an interim fix, and so they didn't want to do an interim, they wanted to do the full stink, and that's okay.

BERGEN: What exactly did you do as part of that team?

FELTZ: We looked at every facet of it, primarily in the seals and how they were done and what Thiokol was doing to prove these seals. They went into O-rings, they went into all kinds of different designs, and we looked at those different designs about every couple of months. Finally we come to the conclusion we had to—the one thing that was unique, I'll tell you, was that every seal had to have a double seal, so if one failed, it was backed up by the second, and every seal—in order to know that that first seal was working and you weren't depending upon the second seal so you only had one seal, you had to have a test port between the seals. So you could test it by air pressure, that the seals were both working.

Finally you get to the last thing you're going to close out. You've got ports that you've tested these ports or seals. Now you've got to screw the thing in to stop any leakage that might come through. So then they screw it in, and they had two seals on that, and they

had to check that, too. I said, "Look, you're just going as far as you can go, so why don't you just put one seal on that one? It's a small hole." But they put two seals, and they never could check the last—let one of those seals out, so they were relying on the buddy system to install them.

BERGEN: So you were satisfied with the final result of their revisions?

FELTZ: Yes, I was. I was only a part of the team, so everybody was having their say on it. We were all giving Thiokol a rough time. Unfortunately, that problem they knew about a long time ago on the first flight. I think they knew about it. They had scorching of some of those seals, and they thought, well, that's okay, you know. It was a misjudgment of what might happen. I saw that flight on television, and I saw that flame come out of that booster. I said, "Oh, my God, that's it," because you'll blow that tank up in no time.

BERGEN: It was very sad.

FELTZ: Yes.

BERGEN: Well, later, you said, you also did some consulting for Space Station?

FELTZ: Yes.

BERGEN: Tell us about that.

FELTZ: Well, I was consulting for Space Station with Grumman, and I was very concerned, and I spoke about it, but they eventually changed it a little bit, that NASA had a group of

what they call "integration people" at Washington, which was a mistake in the first place, I think. But anyway, that's what they was. They had a communication problem, because they were trying to direct Grumman by each function in NASA directing each function in Grumman. So I'm not sure if anybody knew what the hell was going on. One of the guys that was on the team was a Grumman guy. The first meeting I went to, we were talking about what should be done, and he says, "Well, now, that's what should be done, but what's best for Grumman?"

I just had a sinking feeling. I says to myself, "This is—I'm through." So I got home, and I wrote the program manager on Grumman a letter saying, "Sorry about that, but I don't know what's best for Grumman, but I think what's best for Grumman is what's best for the country. If Grumman will do it, than that's best for Grumman."

So he called me and says, "Come on back. Come on back. We'll fix that problem."

So I went back, and we worked for—I guess I worked about two or three years back there. One of the problem they had back there is, they had a weight problem, first of all, and every time you turned around they was redesigning it because it was too heavy.

Another problem they had is they didn't sit down and write good specs. The integration team should have wrote good specs. They should have told each of the major contractors what the weight should be and what the hell they had to meet and what the requirements was, and they never did it. So they would go to St. Louis, and St. Louis, "Well, you haven't given us any weights, so we haven't imposed any weights on our subcontractors." So nobody knew what the weight was except by guess and by God.

That finally got fixed, and I think NASA finally got concerned that Grumman wasn't doing their job and finally got concerned that maybe NASA wasn't doing their job, and I think they moved the integration into Houston and then they give the job to Boeing. That become a little bit of a problem, too, because Boeing Aircraft Company didn't get the job of integrating because they've been integrating airplanes for years. They give it to the Space

Division at Boeing. So that took a little bit of problems of getting that straightened out, as I understand it.

I know one thing that was studied for at least well over a year was, how do you test this total mess? Put it all together, have mock-up of all the hardware that goes into it and have it all integrated together and test it. And a lot of people, including, I think, Houston says, "No, we'll do—we'll just set the—" Each system had to have its own tape, own program. "We'll just test them all together and not have the hardware." So I think that's the way they finally did it, and it probably turned out okay. Maybe it didn't turn—we haven't got it up there yet, but—I know [Thomas P.] Stafford had a committee that works for [Daniel S.] Goldin on investigation of what the heck should be [tested by mating hardware].

He had me on the committee once, and I think they didn't like what I said, because I ain't been back. But it was at Houston, and the people at Goddard [Space Flight Center] wanted the vehicle put in a vacuum chamber and shaken. It was an argument between the Houston people and Goddard, and why Goldin didn't satisfy that by saying yes or no, but he wanted somebody to look at that problem, so we did. Max Faget was on the meeting and the ex-president of Boeing and several guys was on the committee. We listened to briefing all day long from what they were doing and what the objection was from Goddard, and then they were about to close out the meeting, and Max said, "Can I say something?" Then he spoke his peace. When he got through, I said, "I'd like to say something, too." And I says, "I don't believe in necessary thermovacuum on a big vehicle. You have a problem of making it real because you have heat coming in that's different from the heat that you get up in space. You have it shining on one side, and you might, in space, have it shining on two sides, and you don't know that you've created a problem by having it in a vacuum chamber that you don't even have." I says, "I don't believe in that, and I would recommend you don't do that, and I recommend you shake all your small components and put them in a vacuum chamber, whatever the heck you do to make them good, but leave that big structure alone." And I

think they finally did. They went to the Cape after that, and I didn't go with them, because they didn't pay you for going to those meetings. When I retired, I told my wife I'd take her to the meetings if she wanted to go. I took her to Houston, to that meeting, and I was going to take her to the Cape if I went, but I said, "I ain't going. I got other plans." So they dropped me out of that.

BERGEN: You've had an amazing career. As you look back over your career, what do you feel is your most significant accomplishment?

FELTZ: I think staying alive. [Laughter] I don't know. I think I'm happy that I was able to contribute to the space program what small knowledge I have of space and all that good stuff, but I think that was an accomplishment I really feel proud of. I think, if anything, I am not a highly technical person, I'm a very practical person, and I can understand hardware probably as good as anybody, and I think the fact that I can work with people and people respect me is a great accomplishment on my part.

BERGEN: What do you feel was your biggest challenge?

FELTZ: I first thought the biggest challenge I had was the X-15, because we didn't know from Shinola kind of what we were doing. We were welding material that the material people didn't even know we could do, but we said, "We're going to do it, and if it works, we're ahead of you, and if it don't, we're behind you." So we did it, and it worked.

I'm a firm believer that if you're doing something, you've got to make a decision to go, and if you go, you'll find out if you're going in the wrong direction quickly, and you change your decision and go again. Otherwise, you just sit and stall. The biggest challenge, I think, really, was the Apollo.

BERGEN: And you met that challenge and accomplished one of the greatest feats that mankind has ever accomplished.

FELTZ: Yes, well, not by myself.

BERGEN: It took a lot of people.

FELTZ: Yes.

BERGEN: Where would you like to see space flight go in the future?

FELTZ: Oh, God. I don't know. I guess what's the way it's going is as good a way as any. I have my doubts we'll ever go to Mars or anything like that. Maybe it's because I'm so dumb, but I just don't think we'll ever go that far, frankly. It takes a long time to get there and a long time to get back, and you don't send people off without knowing pretty well that they're going to come home, because that's not the American way. I don't think this generation will live long enough to go there.

BERGEN: Before we close, I'd like to ask Rebecca and Carol if they have any questions for you. Carol?

BUTLER: While you were working on Apollo, it was such a big project and you had to focus so much of your time on it, yet there was so much else going on in the country and in the world, all the civil unrest and the Vietnam War. Did that affect your work at all?

FELTZ: No. The only thing that affected me is that I worked seven days a week. I didn't work all day Sunday and didn't work all day Saturday necessarily, but every Saturday I went in, and I would go through the people and go through what they were doing in the shop as well as in the Engineering Department that we were working on time, and then I would go home to the family. Lots of times I went in on Sunday, but I worked mostly about—I'd say at least ten hours, twelve hours a day during the week. When I got through, I would call my wife and say, "I'm coming home," and we'd have dinner. Most of the kids would have already eaten. But the outside world didn't affect me. I didn't even look at the damned thing. I doubt if I read many papers.

BUTLER: Looking at your work on Shuttle, on the first mission, you talked a lot about the tiles and the problems and how you were concerned on that mission that those tiles stay on. When they did get up into orbit and opened the panel of bay doors and looked out, they did notice a couple of tiles missing. When you heard that, did you have concerns about the tiles that couldn't be seen?

FELTZ: Well, you have concern, but there ain't a damned thing you could do about it. Okay? You just have to take your chance.

BUTLER: And it did come home safely.

FELTZ: There was several tiles that was kind of overheated a little bit, but it was in pretty good shape. It had no more than landed till we was looking at the tiles. And Chris [Kraft] came out to look with us, too. I guess he was Center director then.

BUTLER: That's all I had.

WRIGHT: Mr. Feltz, you mentioned when you were working with Grumman that you felt that that decision was to be made for what was the best for the country, best for the program. Was that your focus that you used all through your career in making those decisions?

FELTZ: Yes.

WRIGHT: You had so many partners. Was that sometimes hard to keep them focused there as well?

FELTZ: No. I thought if I did a good job, that was best for me and the company and the customer. I got in an argument with a general down at Houston. From that meeting, he wanted to review the award fees contract with Boeing, and I said, "I disagree. I don't believe award fee should take any facet in the decision made by [Boeing]. That's a big outfit, and they ain't going to make a decision based on award fee." I never made a decision based on award fee. I made decisions based on what I thought was right.

And he says, "Well, you must have had a lot of stock in the company."

I said, "I didn't have a dime of stock in the company when I was doing some of that," and they never did look at the contract, so— [Laughter]

WRIGHT: Did that focus also help you help the program recover after the tragedies that you experienced?

FELTZ: Yes.

WRIGHT: Did you feel the team move toward that focus to keep everything going?

FELTZ: Our whole company was that way. They thought the product should speak for itself, and I was taught that way by the CEO [J. Leland Atwood] that just passed away, and he was a very good friend of mine, and the CEO that just resigned from Rockwell was a very good friend of mine. I had received a Christmas card from him every year until he resigned at Christmas.

WRIGHT: You also mentioned you're a very practical man. When you saw that Shuttle sitting on top that Boeing 747, was that a practical thought or did that seem odd to you?

FELTZ: Well, no, I was convinced that was okay. That was the only way we was going to get there, because all the ways we tried, we just was going to jump from one little airport to another, and the danger of every time you have to land a vehicle is greater, and then you've got to—and I thought if we could fly maybe half the way at least with it on a 747, they had instructions that if they got in trouble, they'd let it go, see? You'd lose the vehicle, of course. But we'd debated, even, putting an astronaut in there on the way to the Cape in case we got in trouble. But then you say, "Where the hell am I going to land it when I get in trouble? I don't know where I'm going to land it. It might be on a mountain." The first Orbiter, we had ejection seats in it.

WRIGHT: Was it better for the Orbiter to start landing at Kennedy than coming out here to Edwards?

FELTZ: It was less dangerous, I think, because then you had to go transport it by the 747, and that's a risk that you have every time you do that, and if you land at the Cape you don't have that risk. So it eliminates one risk.

WRIGHT: I have one other question. Of all the partners that you mentioned, I guess the last one that you briefly talked about was your wife. I'm sure it's a good feeling for you to know that you could work those many hours, that she was here, and she supported your work and all that you were able to accomplish.

FELTZ: Yes, and take care of the kids and educate them. Although it was a trying experience for her, for the most part, but she stuck with us.

WRIGHT: Thank you.

BERGEN: We want to thank you again for sharing with us and taking time out of your schedule to do this.

FELTZ: I didn't have a schedule today. Don't put something that's critical to other people in your catalogue.

BERGEN: Well, we will get you a copy of both the audio and the video and the transcript, probably within a month, and you'll have a chance to look over it…

[End of interview]