NASA JOHNSON SPACE CENTER ORAL HISTORY PROJECT
ORAL HISTORY TRANSCRIPT

FLOYD V. BENNETT
INTERVIEWED BY JENNIFER ROSS-NAZZAL
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ROSS-NAZZAL: Today is October 22nd, 2003. This oral history with Floyd Bennett 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.

Thank you for joining us this morning. We really appreciate it.

BENNETT: You're welcome.

ROSS-NAZZAL: I'd like to begin by asking you what your interest was in engineering as you were growing up.

BENNETT: Well, when I was growing up, I didn't know what an engineer was. I had uncle that drove a train, but I had no idea of going to college when I was in high school. But when I got out, I said, "What am I going to do with the rest of my life?" And I loved math, but in those days you didn't have computers and mathematician [jobs were primarily in the teaching profession. I didn't think I would be a very good teacher.]

But anyway, I grew up in World War II as a kid, and rockets came along, and I was convinced that man was going to go to the Moon in my lifetime, and I figured it would take pilots. So I went down to join the—I don't know if it was the Army Air Corps at that time or the regular Air Force, but they said, "Young man, you need two years of college to be a pilot."

And I said, "Why's that? I have a high school degree. I'm sure I know all there is to know at this point in my life."

So anyway, some friend of mine said, "Come take engineering with us."

And that's when I said, "What does an engineer do?" And I said, "Does it have any math in it?"

"Yeah, we think so."

So anyway, I flunked Introduction to Engineering. But after that, I made very good grades. And I wasn't prepared for it in the end of my high school. I didn't have the right—although I loved math, I didn't have solid geometry and that sort of thing. But I took it over and passed it very well. I never told any of the astronauts that I flunked Introduction to Engineering, I don't believe.

So anyway, I wound up getting married in college, and I never did join the Air Force and become a pilot, but I did enjoy my engineering and went to work at the NACA [National Advisory Committee for Aeronautics] in Langley [Aeronautical Laboratory, Hampton, Virginia], taking aeronautical engineering.

ROSS-NAZZAL: When did you officially join NACA?

BENNETT: It was 1954, and I stayed there in research in the Dynamic Loads Division of Langley. And we did a lot of the first analysis to study an airplane of a flexible body going through gusts and turbulence, and our research helped redesign some of the fixes on the Lockheed Electra, for example, because it was designed as a rigid body and it really wasn't. And we started work on the flexible-wing airplane, the swept-wing airplanes like the B-47, and that

thing really did flex a lot, quite a few feet, and it was very interesting.

And then I worked on the—they started the Echo. When satellites came along, they started the Echo Project. It was a balloon where we bounced [communication] signals off of it, and I worked on that and studied how many satellites [would be needed to have continuous communications between two points on Earth]. We couldn't put them up in geo sync [geosynchronous orbit] in those days, and so you put them at low altitude and in randomly spaced [orbits]. So I did a probability analysis on how many it would take to maintain communication between Europe and the United States. So it was very interesting work.

And then they announced the lunar program, and I said, "That's what I always wanted to work on, so I'm going with that." And didn't know where we were going, Florida, Massachusetts, or Texas, or what, but we came here.

ROSS-NAZZAL: And when did you become affiliated with the Space Task Group?

BENNETT: That was in '61, and we worked about six months there before we came down here in February of 1962. I wasn't one of the original members of the task group. They were already under way, and when I joined them, we had just started working on the lunar rendezvous concept for Apollo, where you orbit the Moon and come back and rendezvous. And I worked on that from the beginning with the task group and then for the next ten years.

ROSS-NAZZAL: Did you take a look-and-see trip out to Houston?

BENNETT: No, I did not. Some other people did, and they brought movies back and showed us

the ravages of Hurricane Carla and we said, "What are we doing?" [Laughs]

ROSS-NAZZAL: But you decided to move out here anyway.

BENNETT: Yes, yes. My wife [Carolyn] didn't want to come at first, but she learned to love it after a while. We came as a group, and so it was—everybody was family, so to speak. They said they had the Husband of the Week because we traveled so much. Whosever husband was home was in charge of repairs.

ROSS-NAZZAL: What did you initially think of Houston when you arrived?

BENNETT: Hot and humid. But when I was thinking about coming down here, some Virginians told me that, "You don't want to go there. It's too hot and too humid."

I said, "It may be hotter than here, but it can't be more humid." I was wrong. But thank goodness for air-conditioning.

ROSS-NAZZAL: We've heard that from a number of people, actually.

How did your job change when you moved from Virginia down here to Houston?

BENNETT: Well, in Virginia, it was more of a research atmosphere and time wasn't critical until I started working for the task group. And then, like I say, we started traveling a lot, and we had to go get ourselves educated more on orbital mechanics and other aspects of space operations. And with all the various contractors around the country, we had to go to Rockwell [formerly

North American Aviation Corporation], to Grumman [Aircraft Engineering Corporation] in New York, and that sort of thing. And you had to do your homework, and we worked awful long hours. You didn't get paid the extra hours, but we lived and breathed it. It was a dream to work on something like that, and I think everybody was totally dedicated to it.

ROSS-NAZZAL: You mentioned just a few minutes ago that you worked on the lunar rendezvous concept. Can you talk to us about a paper that you wrote on a study of Earth orbit simulation of lunar orbit rendezvous?

BENNETT: That was a long time ago. I'd almost forgotten that one. But what we did, we looked at—rendezvous was checked out during the Gemini Program around Earth. And to make the lunar landing a successful mission, we had to rendezvous the LM [Lunar Module] back to the command module after the landing. And so we were very nervous about that, and although we checked it out here, what happens if he can't come back, if something happened to propulsion?

So we looked at a concept of what we call an equal period [or equi-period] transfer. If you're in one orbit and you fire at a certain angle, you can change the orbit to come down to a lower altitude or come up to higher altitude, and the period around will be the same so it will come back and intercept with that orbit [in one revolution at the same point that you left]. But it turned out to be too expensive from a propulsion standpoint to do that, so we opted for what they call the Hohmann Transfer. That was named after a fellow by the name of [Walter] Hohmann, and he—you fire parallel to the velocity vector or against the velocity vector and just reduce your altitude. And it changes the period of the orbit, so you wind up going faster, but it was the cheapest way to do it. So that's why we wound up doing that.

ROSS-NAZZAL: How were you able to create this simulation when the lunar module and the command and service module weren't actually finished at this point?

BENNETT: We didn't have many simulations. As far as the rendezvous, it was mostly mathematical, and then they did the simulators. They had visuals of everything, and you had the cockpit layouts and you had the same plans of the lunar module and the command module, so you worked it from that standpoint with computers.

ROSS-NAZZAL: You were also heavily involved in the trajectory analysis planning for the lunar landings themselves.

BENNETT: Yes. Right.

ROSS-NAZZAL: Can we talk about that a little bit?

BENNETT: Yes. Right.

ROSS-NAZZAL: Can you talk about your role in planning the mission trajectories for the Apollo Program?

BENNETT: Yes. And I don't know if you've got this report or not. [Bennett hands Ross-Nazzal a report.] This is one that we wrote right after Apollo 11, and it goes into details on the planning

of it. But basically, like I said, we did a Hohmann Transfer to come out of an orbit, but I think we finally wound up at 50 miles or 60 miles and would come down to 50,000 feet, I think it was. And then you started a power descent maneuver.

It probably doesn't seem as complicated today in what we do, but in those days it was very complicated to us that you had to plan the trajectory with the limitations of the rocket that's on the descent engine. You had a landing radar there to measure how far you were above the surface and how fast you were going, to update the guidance system. You had to have the guidance equations to command what thrust level you wanted out of the engine and what attitude you wanted to be at to fire it.

We started out with what we called a fuel optimum descent. Based on the mathematics of that, you had an optimization equation and basically would fire against the velocity vector just to slow down the velocity. So it didn't have much respect for the lunar surface in those equations, and the most optimum way was to get gravity to aid you. And we'd come down and fly through the surface and come back to the site. Well, that was not quite acceptable. So at about fifteen, ten or fifteen thousand feet, we stopped the fuel optimum guidance and went to a constant attitude and pitched the vehicle up so the crew could look out the window and see where they were going, because otherwise, [in the fuel optimum phase], they were just looking back along the [velocity] vector there. [Actually perpendicular to velocity rector.]

And then as you got down to about 600 feet, you wanted to pitch up further and allow the conditions to be such that the crew could take over the automatic system, because none of the crew wanted to land with an automatic system. And then you had a vertical descent option there. So you had all the constraints of—you didn't have a whole lot of excess fuel, so you had to be very efficient with it. And on Apollo 11, I think we all heard the call out of thirty seconds, we

were just about out of fuel.

So then in what we call the approach phase, where you had a fixed attitude and would look out the window, you had a grid on the window itself called the landing point designator. It was the inner and outer markings on the window, and Apollo [commander] could line up. It was like a range finder. He could line his eye up with that, and the computer would tell him what angle to look at to see where he was going, to see the landing site. And if he didn't like where he was going, he could take his stick and change it left, right, or forward. It couldn't go backwards very easily, but you could go forward. You could come back a little bit, but it was very inefficient to do that.

And on Apollo 11, we wound up five miles off target because of the navigation errors coming around the Moon, and we didn't mathematically model the Moon all that well. And there was some—we've assumed it to be homogenous gravity, and it wasn't. It had what they call mass concentration, or mass cons. So that caused us to be off when we started in the descent, and subsequently we were; we were off at the landing.

And I think there's a little picture in there. I don't know if it will show up all that well, [flips through report] but—it's not going to show up that well. But we had a 3-[sigma dispersion ellipse for landing accuracy]. We called it [3-sigma] landing dispersions. With all of our uncertainties, we figured we'd be like this. [Points to a picture of an ellipse.] Well, he was all the way down at the end of that [forward end of dispersion ellipse], and he wound up over a boulder field. We'd picked the landing site to be as smooth an area as possible, no unusual features and all. But he was over a boulder field, and that's why he almost ran out of fuel, because he kept going down, down range and trying to get a place to land.

And this is a picture here of his angle of pitch, and he was going, and he was [continually

changing attitude and altitude rates—speeding up and slowing down]. At the experimental test pilots' meeting in Los Angeles after they came back, I asked him about that, and he said, "Well, I was just absolutely adamant about my God-given right to be wishy-washy about where I was going to land." Now, I was allowed to put that in this AIAA [American Institute of Aeronautics and Astronautics] paper, but when I did a NASA paper on it, they wouldn't let me. They said that wasn't technical enough.

I said, "Well, that's what he felt." [Laughs]

So then after that, we went to Apollo 12, and I mentioned we had a navigational error. And we had a technique that the navigation folks said, "We can give you a better vector of the position after we get into the power descent based on the burn and everything if you can update your guidance system to do that." So we had to do various simulations to see how much, if it was five miles, could we do that much without disrupting the guidance too much and everything like that. So we were able to do that.

And we picked a landing site that a Surveyor spacecraft had landed at before. In here, the Apollo 12 site had a crater pattern like this [shows image], and it looked like a snowman. So we called it the snowman. This was the belly of the snowman and the head. And in the belly of the snowman, the Surveyor landing craft was right there. So he had been practicing to try to land in here and actually moved in here. And you can see where he changed his landing site with the landing point designator. And this picture here shows how close he landed. [Bennett shows a different image.] This is after they landed, and he's over at the Surveyor, and the lunar module was up here.

Now, we did get a lot of dust kicked up because he was on the edge of that crater, but even before Apollo 11, a lot of scientists had told us that we were going to land in 100 feet of

dust. How they came up with that number, I don't know. But anyway, we said the Surveyor didn't do that, [get buried]. So anyway, they had their theories, and then we had some concerns. The thing about Apollo 11, there was just so many unknowns—you couldn't really simulate these type of maneuvers [with total realism. However, the "flying bedstead" was close—an experimental hovercraft with simulation 1/6 gravity field.]

When they did Apollo 10 and they sent the lunar module down to a lower altitude and came back, I asked Chris [Christopher C.] Kraft, I said, "Why don't we do an unmanned landing, because we can check out all these interactions of everything like that."

And his answer was, "No, we don't want to do that, Floyd, because some of the politicians will then say we've got to do an unmanned landing before we can do a manned landing," and he was probably right. But it would have been a good test flight. So we did[n't do it]. We were able to land on target with that one, [Apollo 12].

The scientists then wanted us to go to more interesting places, and Apollo 13 was supposed to go into a science area where the terrain wasn't too bad. Apollo 14 did land near what they called, I think it was the Cone Crater they wanted to go investigate. [Alan B.] Shepard and them never did find the Cone Crater, though. The vision was limited on the surface there. You couldn't see over the hill, [lip of crater], but we had a camera in the lunar module during the descent, and it showed Cone Crater. And so I said, "Well, see, you went right by it." But they came close to it. They just couldn't get up to the top [edge] to see it.

Then on Apollo 15, the scientists found this particular site here [shows image], and these are some of the highest mountains on the Moon, 12,000 feet, the Hadley-Appenines. And they'd previously wanted to land further down here, and I said, "No, we've got to come over these mountains, and we can't get down that close." This is a wider area [further distance from

mountains to landing site] here where the radar would get adjusted and everything, so we actually flew—we moved the landing site up here, and you flew over these 12,000-foot mountains [in front of landing sites]. And this was a gorge about 1,200 foot deep [in front of the landing site]. That's pretty deep. And there was a crater here. There's pictures of them on the side here and walking over here, and had the Lunar Rover on that flight and go back a ways.

We had a real rudimentary computer program in those days to draw—I told you about the picture out the window, and that you could see out the window. And we simulated drawings of that and modeled this terrain in there so that would give him an idea of what he was going to be able to see coming down.

This mountain here, which is about 4,000 feet high, it's about ten miles from the landing site. And when they came in like this, when you pitched up, it was right dead center of where you were going, so it gave them a good clue of if they were off track left or right. Dave [David R.] Scott got them to model that on the simulator down at the Cape [Canaveral, Florida] and named it Bennett Hill, so I was very pleased with that. It's not official astronomically; it's just a NASA landmark.

But it was a very challenging mission, and we had to change our trajectories again to go over these mountains, and we steepened up the approach quite a bit. But it turned out they liked that approach better. We had been at a lower approach before. It was probably a little more fuel-efficient, but the pilots, in the landing approach phase, we modeled [the lower approach] pretty much after the way they came in with airplane [landing approaches]. And, in fact, early on, they said they wanted to fly 360 degrees around the landing site.

I said, "Why?"

And they said, "Well, we always do that when coming into an unknown field to see

what's what."

And I said, "Well, that's nice, but you don't have the fuel to do it." So they had to learn it was a one-shot thing.

And again, you had to model the trajectories. Again, another constraint I didn't mention was you had the ascent stage there that if the descent engine quit, the ascent stage would fire and separate the descent stage and lift you off. And so you had to keep the altitude rates above the capability for the engine to take you up, otherwise you would hit the surface before you take off. So that was another constraint that they had.

ROSS-NAZZAL: Let me go back and ask you a few questions. You've brought in these wonderful pictures that have been signed. What sort of contact did you have with the astronauts or the flight crews themselves?

BENNETT: Basically, the commanders and the lunar landing pilots, I didn't have much work with the command module pilots, but with Neil [A. Armstrong] and [Edwin E.] Buzz [Aldrin] and Pete [Charles] Conrad and—Shepard didn't pay much attention to [us], and he found a glitch in the guidance logic, too. It wasn't a major thing, but he did in his simulation and everything. But he was quite a guy. And John [W.] Young, I worked with him, and with Apollo 17, [Eugene A.] Cernan, yes. [And I worked quite a lot with Dave Scott on landing site selection for Apollo 15 and the steep approach and trajectory.]

We would give them briefings before the mission, then go down and monitor their training down there [at Kennedy Space Center, Florida], so we were the background teachers, I guess, for them to understand why we did what we did. And, "We'd like to do so-and-so," and

we'd have to say, "Okay, that's good to do," or, "No, we can't do that." So we had a very good working relationship.

ROSS-NAZZAL: And how long did these briefings last?

BENNETT: Oh, they were usually a couple hours when we'd go down for training sessions and all, and we were always in various meetings together proposing changes and everything. So we worked on and off with them throughout their training.

ROSS-NAZZAL: Did you participate in any of the lunar landing simulations?

BENNETT: I got in the simulator and rode it down on automatic. They said, "That's not flying."

I said, "I've got to see if my system works," and it did. I said, "No, I don't have the confidence to go take this thing over manually. That would waste everybody's time." But it was very interesting.

They did a good job with those simulations, too. The video was very good the way they had the view out the window.

ROSS-NAZZAL: What about Grumman? Did you have any contact with them?

BENNETT: Yes, we were planning the concept before the lunar module was ever built. In fact, we worked on the team to evaluate the lunar module contractors, and which Grumman won. They had a very good concept. So we had to have tradeoffs between their system design

capabilities and what we were doing in the trajectory.

One of the first things was that the descent engine was supposed to be able to throttle from maximum thrust for the initial braking phase where you needed all that thrust, to down to 10 percent of that when the guy was just hovering around over the surface. [This throttle range] was beyond the state of the art. They can give us the maximum thrust, but they couldn't throttle it from maximum thrust down to about 60 percent, [but] then they could throttle it continuously from 60 percent down to 10 percent. So that meant we had to change our trajectory a little bit.

And the guidance, it was commanding a throttle position to go to, so what we had to wind up doing was command the throttle above what it could give us and just control with attitude. So you didn't have complete—what's the word—you weren't getting what you really wanted. The guidance equation wasn't getting what it wanted, but it would eventually command less and less thrust and get down to that 60 percent level, and then we'd switch targets and go to the approach phase where he could throttle the rest of the way down.

The landing radar, we had influences on that, too. They had to locate its beams on two separate orientations, one when he's back on his back coming in, and then later on when he [is] pitched up. So there was give and take on the system design as well, which we'd call systems integration today, [that's] what you would call it.

ROSS-NAZZAL: Did you spend much time out in New York?

BENNETT: Yes, we went there a few times on critical design reviews and that sort of thing. Ken [Kenneth J.] Cox and I were driving from the airport there, going out to Bethpage on Long Island. It was about dusk. And we were trying to decide whether we wanted to go into the city

before we went out to the island that night or go out and check in and come back. We thought we'd take in the Playboy Club. So, anyway, we decided to go to the hotel first, and as it gets a little bit dark, the lights don't come on. And I said, "Boy, they roll the sidewalks up early around here." The traffic lights [were]n't working, and I heard on the radio it was a blackout. That was the first blackout in the sixties, somewhere in the sixties, '65 or '6[6], somewhere like that.

So I'm glad we went to Bethpage first. We got there, it was candle lights and that was it, because a lot of people were in the dark there [in the city], trapped in buildings and everything.

ROSS-NAZZAL: What was your relationship like with Grumman?

BENNETT: Fine. We got along very well. They respected us and we respect[ed] them, and no problems. Like I say, everybody was dedicated to doing that. It was really great. They had some very, very smart people.

ROSS-NAZZAL: You mentioned that some changes had to be made to the trajectories as a result of changes to the LM. Can you talk to us about how the maneuvers changed over time as a result of mission requirements or different changes that NASA would require?

BENNETT: Yes. The major change was when we went to—well, there were more subtle changes, I guess, like the thing that the engine wouldn't throttle from 100 percent down. That changed things. But it was mostly in the fuel-efficient phase, so you really never saw much difference there. It just meant you had to maybe thrust a little bit longer in that phase.

The biggest one was when we went to the landing sites over in the mountainous terrains

and everything where you got the steep-[approach] trajectories, and it gave them [a better view of the landing site]. Before, we were on a more shallow approach, and at 10,000 feet when you pitched up, you were much further away from the landing site so you couldn't see it as well. This one, you were closer in, and, like I say, they liked that better because they could see the landing site better.

And then that let us on Apollo 17—that was a very mountainous [area around the] landing site, too. It had mountains to the left, to the right, and up range; it was the only thing [open] was out in front of you. So without the change in accuracy of navigation and without the change in the trajectory, we wouldn't have been able to land in those sites. They even had us looking at landing in the crater Tycho one time, and I said, "Hey, get real." [Laughs]

ROSS-NAZZAL: Speaking of landing sites, I understand that you also chose some of the landing locations on the Moon. Can we talk about that?

BENNETT: Yes, that's what we did on Apollo 15. That's when we worked with the scientists to find the site that they wanted to be along here somewhere. And, like I say, they had one further down. And we went to [NASA] Headquarters [Washington, D.C.] and Dr. [Rocco A.] Petrone was chairing the meeting there, and he said he would not lock the doors, but nobody was leaving the room till we got a landing site.

There were so many different disciplines, and I think scientists tend to work more on their own than engineers. Engineers need to work [as] a team more. And I'm not being negative to the scientists; I'm just saying that's the way they're trained. But bless their hearts, I'm in this discipline and he's in that discipline, and I want to land at this place because it's got the best for

me, and they want to land over there. And I told them one day, I said, "You guys remind me of a kid in a candy store and you've got a quarter. And there's ten pieces of candy and they all cost a quarter and you [still] want one of each." And [Dr.] Noel [W.] Hinners was there, the head fellow of the scientists' group, and he did a terrific job of pulling those egos together. He really did.

ROSS-NAZZAL: What were some of the primary characteristics that you looked for in terms of the landing site, from your perspective?

BENNETT: From our perspective, it was to be as free of any mountains or anything like that as possible. And, like I say, on Apollo 11 and even 12, although we landed near craters, there were flat areas, no high mountains around, or anything like that. We had to model the terrain into guidance logic when we went to like to this site [points to picture of Apollo 15], because when he flies over a 12,000-foot mountain and the radar says it thought that was the landing site height and said, "Hey, you're only at 4,000-feet elevation," so that would throw the guidance all crazy. So you had to model it in and say, "No, it's 12,000 feet above the landing site," and so that worked out good.

ROSS-NAZZAL: What sort of interaction did you have with people from USGS [U.S. Geological Survey] or Bellcom [Inc.]?

BENNETT: USGS was some of the scientist groups and everything and, like I said, they had their strong opinions about where they wanted to go and everything. But you were saying what, from

my standpoint, like I say, we could tolerate—once we'd got the accuracy down, we could tolerate these things if we modeled the terrain in and all like that and you didn't have a big cliff to go over, a big mountain to go over, on your way up or anything.

The Bellcom folks were sort of like a check and balance, and they would look over our shoulder and they offered other concepts and everything else, too, and I got along very well with them. I think some people worried about that, [looking over our shoulder], and I said, "Hey, if they've got to look at this and they find something, that's great, because it's got to be done right."

The night before we were landing on the Moon, my wife said to me, says, "What if they die?"

And I said, "Honey, we've done the best we can do," and that's all you can say, and we had.

Now, today, I don't think we—our risk [on Apollo] would be much greater than what we're willing to fly with today, but it's a risky business, and it was a dream for them to go.

I did climb up on top of the Saturn one time. I didn't climb up it; we went up, in other words, in the VAB [Vehicle Assembly Building]. And we got up there and looked down, and people looked like little ants. And I said, "This is like the Humble Building in downtown Houston, and you're going to light the fire on this thing? I'll go to the Moon on paper." [Laughs] And so they were gutsy people and brave people.

ROSS-NAZZAL: They certainly were.

Were there any sites that the scientists picked that from an engineering perspective you thought were too dangerous to get to?

BENNETT: Yes, like the Tycho crater. It was too unforgiving. I mean, it was a large crater and everything, but we could probably have done it later, but it was considered too risky. And other things like that when they—I said, "You look like you want us to land between a rock and a hard place here, and that's not good." So, yes. So they had to compromise on the sites they got, and they got good sites out of Apollo 15, [at] the place we did land.

ROSS-NAZZAL: Once a landing site was decided upon, how long did it take you to come up with the trajectory analysis?

BENNETT: We already had the trajectories, but we would have candidate landing sites, and five or six and that sort of thing. So we'd see what kind of trajectories we needed to go into each one, and sometimes it wasn't any difference. So we had to do that before the sites were selected and take that information to the meetings if there was any reason [for not going to that site].

I told Dr. Petrone that we were looking at four or five different sites for Apollo 17, and so I compared this one and this one and this one, and I said, "We can do all of these," I said, "But this is like a piece of cake compared to going to Tycho."

And he said, "Floyd, there's no lunar landing that's a piece of cake." So I used the wrong phrase.

I said, "Well."

He said, "I know what you mean."

ROSS-NAZZAL: How many individuals did you work with on designing these analyses?

BENNETT: We had about—oh, well, let's see, one other picture here. This is the names of the people that were in our Landing Analysis Branch. [Bennett shows another image.] I adopted this cartoon for our branch logo. [A cowboy going over a steep cliff on his horse.] And the guy was saying, "Whoa, you SOB! Whoa!" And I took the "SOB" out, but I told the astronauts—and Neil Armstrong signed this—I said, "This is the fuel optimum descent, guys." [Laughs]

So you can see there was about twenty of us in there, but that was just in our branch. You had to work with the navigation branches. They got very conservative on me when we picked Apollo 17 with, like I said, they had the mountains all around. So they gave me their dispersion equation, ellipse, and I looked at it and I said, "This is bigger than anything they've ever given me." And I said, "You guys, your conservatism is going to cost us in other areas here. You've got to get real."

And so I went down to their branch and took their sign down and put up "Lost In Space Branch." They got a little ticked at me, but anyway, I said, "I can't hit the Moon with this set of dispersions, much less the landing site."

So then they took out some of their fudge factors, and we were able to do it. But that's something in the lessons learned that we said, not just them, but any designer of the propulsion system or anything else, if they get overly conservative in theirs and make somebody else absorb their uncertainties, the system won't work. So you've got to be honest and say it like it is, and you've got to stand behind what you come up with. Got to do the best you can, as they say.

ROSS-NAZZAL: I also understand that you actually worked in some of the staff support rooms during the missions.

BENNETT: Yes, we had three or four of our fellows on the console, Willis [M.] Bolt, Dan [Joe D.] Payne, and Jim [James V.] West and [I've left someone out], Jim [James H.] Alphin. And they were in communication with the FIDO, Flight Dynamics Officer, for what's going on and everything. And the guidance guys were also in that room, MIT [Massachusetts Institute of Technology, Cambridge, Massachusetts] and Jack [John R.] Garman's group. And they were the ones that called that—I don't know if you recall. They had an error display, an error out of the guidance system during the landing. They had actually simulated that in one of the simulations, and that's what made them aware that this thing could happen.

The computer, I think it was like 64,000 words, which is you've got more in your pocket calculator now. But if you started getting updates from the landing radar or something else, and your computer has this duty cycle of going and doing things. And, I think, in this case, the rendezvous radar signal, I believe it was, somehow got into the flow there and started things getting real busy, and so it created an alarm. It says, "Hey, I'm not doing all these other functions. I'm just going to do the guidance right now." And so they were able to say, "Hey, it's still okay to go." And so we were in there.

And, yes, I was more there as advising and monitoring our guys, and they all did a good job. We were in Building 30 getting ready to go over to the control center from our administrative wing, and Jim Alphin and I got in the elevator. And he had all his books and everything like that. And I said, "Are you ready?"

He said, "Yes."

I said, "Well, you've got to punch the button, or we ain't going anywhere." So it was just a little nervous time, because he hadn't even punched the button to go down.

ROSS-NAZZAL: Can you tell us a little bit about the organization of the support rooms themselves, from what you remember?

BENNETT: You had various displays. Somebody was watching trajectory parameters. Somebody was watching the attitude and the guidance parameters, like if they were looking for various alarms and everything. So you just the TV monitors there and you could call up other displays.

The most disturbing thing to me was, not being a flight controller, everybody talking on those loops together. They could recognize each other's voice and not have to say, "Okay, who was that?" But, yes, [that] was a very good system.

And Gene [Eugene F.] Kranz came by and said, "Is everybody all right in here?" before we went down there.

We said, "Yes, just another sim [simulation]," but this one's going to be nominal, because some of the simulations you had put in a lot of errors and things, like you put in a low thrust. In fact, Jay [F.] Honeycutt was SimSup [Simulation Supervisor] in those days, and I was concerned about—I mentioned to you we couldn't throttle the engine up in the first phase of the flight where it's efficient. And so if the thrust was getting low, if the engine wasn't putting out as much thrust as it needed to put out, if it was beyond its three-sigma dispersions, the guidance equation would keep saying, "I need more thrust and I'm not getting it," and it would start pitching the vehicle [and] it would go into a loop and you would crash.

I mentioned that to Bill [Howard W.] Tindall. He was our [Deputy] Division Chief there. And so I talked to Honeycutt, and we put a simulation in where that happened, [very low thrust],

and it did exactly that. That got Bill's attention and everybody else's attention that that was a damned good display to have.

I had to insist on that display earlier before we did that, because when I came down here, [to Flight Operations Directorate (FOD)] I was in the Engineering Directorate, and there was some, like—what's the right word—some competition, if you want to, between the designers and the flight operations people. And so "You designers don't know how to operate," and, "You guys operating it don't know [how] to design," that sort of thing. But eventually everybody got the message and worked together, but there was some competition there.

I came over from Engineering Directorate, and we've got to decide on what displays you want to have in the MOCR [Mission Operations Control Room]. So we said the normal thing, you need the attitude and this sort of thing and what the thrust is. And I said, "I also need the thrust command that the guidance system's asking for," because of this problem I was telling you about.

"No, we want to have—." You were limited in what you could have, so they wanted what we called V\Gamma, velocity and flight path angle.

And I said, "Well, wait a minute. That's good for orbital parameters. You've got to know your velocity and your flight path angle to know what kind of orbit you're on, but you've already fired the engine and you're already suborbital. You're going to hit the Moon at this point, so why do you still need V\Gamma?"

And so they couldn't come up with anything else, so they said, "It's traditional."

I said, "Okay, I'm not going to argue with tradition, and you do need it for ascent, I agree with that, but I want this other one, too." So we were able to both get what we wanted. So that was very interesting.

ROSS-NAZZAL: When you were working in the staff support room, what were you thinking about the Apollo 11 landing?

BENNETT: Well, everything was fine. All systems were—everything was nominal and all like that. And then when it got down and took over and we kept watching his forward velocity and his altitude rate and, like I said, he was going around like this [gestures], but his forward velocity was still going forty feet per second forward or something, and you can't land at those speeds. And I said, "What is he doing?" We didn't know what he was doing. He didn't have time to tell us it was a rock field out there.

The call came up to thirty seconds to go on fuel, and I thought he was going to have to abort, I really did. And all of a sudden, he stopped and he found what he was looking for and he went down, so he was cognizant of it, too. But there again, the systems guys had put a little more pad in there. They had a little more fuel than they would say they would have. Now, you can be conserving a little bit. You don't want to have a hard line there. But the guy's got to know what he's got to work with. Yes, it was touch-and-go there at the end.

ROSS-NAZZAL: When Pete Conrad finally made that pinpoint landing on Apollo 12, what was your reaction?

BENNETT: Oh, that was great. That was great. I had to go over to the other [Lunar Surface Scientist's] staff support room and tell them where he was. When we did the simulations, like I was telling you, the snowman crater pattern, that big crater is what you could see, mostly. And

he would plan to land just upstream of that in what we called Conrad's Parking Lot. And it turned out he was little further along, and so he moved around and he landed up near the head crater. And so we were aware of that during all the simulations we did for the landings, but the scientists didn't sit in on those simulations. They started their simulations after he was on the surface and that sort of thing.

And so, "What's the parking lot?" And so I went down and showed them a map where he was, and then they put up a sign on their door that unauthorized personnel shouldn't be in there. They were a little embarrassed. But anyway, it all ended well, yes.

ROSS-NAZZAL: Did you receive any commendation for the Apollo 12 pinpoint landing?

BENNETT: Yes, I got the Exceptional Service Medal for that. That was neat. John [W.] Aaron and I flew up to Washington with the crew in the NASA plane to get our medals from Dr. [George M.] Low. That was very rewarding, yes.

ROSS-NAZZAL: Did you have any involvement with the Apollo 13 mission?

BENNETT: No. I went out there [to the control center] for a little bit. I'd gone home, was taking a shower or something, I think, and it came on the TV. And I came out to see if I could help with anything about using the LM systems, but I wasn't a LM systems expert, so the best thing I could do was get out of their way. They did quite a job on that. They really did.

ROSS-NAZZAL: You mentioned that the Apollo 15 landing was pretty complicated. What were

you thinking as they were landing?

BENNETT: Oh, I was glad that we had modeled that terrain and heard them say, "There's Bennett Hill." [Laughs] Yes, that was great. We were sweating that one a little bit from going over those mountains and all, but we kept thinking positive.

ROSS-NAZZAL: I understand in '72 you became the Manager of the Apollo Program Office within the MPAD [Mission Planning and Analysis] Division.

BENNETT: Yes, their mission office, yes, and that's when I was doing the site selection on 17.

ROSS-NAZZAL: Did you have any other duties or responsibilities?

BENNETT: Well, we were coordinating all of the trajectory planning at that time, and instead of just looking at the descent part, I worked with all the other branches for the navigation and the abort logic for translunar [trajectories] and that sort of thing. So I pulled together some of those, coordinated the effort there to get all those briefing packages together, and we did those for upper management and also did them for the press. That's when I met Jim Hartz with NBC. He wound up on *The Today Show* later on. I guess it was after Apollo 13 when I met [him].

Apollo 12 got very little news coverage, and then Apollo 13 woke up the press, "Oh, there can be problems," and this sort of thing. So they came out by the bunches for the next mission. They wanted to know what's going on and all this, so we started briefing them on all of this. I wasn't familiar with some of the other aspects of it as I would have been if I was working

on them, so I would get the right technical expert in that field to brief them. And we were typical engineers using our jargon, and I said, "Hey, you've got to talk English here." And I said, "When you say this, do you mean so-and-so?"

"Well, no, I mean this."

I said, "Okay." So we kept going that way, and I said, "Wait a minute. Let me ask you this." So we got through, and I turned to Jim Hartz and I said, "You got anymore questions?"

He said, "No, do you? You're doing great." [Laughter]

But we've got to speak English when we talk to people, because it's very important for them to know what's going on.

Now, Jules Bergman, you couldn't be as—what? Jules had his own agenda, and he was kind of difficult to work with sometimes. They gave him—"they," the news media—they had what they called—they called themselves aerospace scribes. AeroSpace Scribes, ASS. So they gave him the ["Big ASS"] award for looking for the story behind the story and missing the story, and he wasn't too happy with that. But anyway, he was always wanting to get in the simulators and all like this, and I think later on they did allow him to get in. But Jules did his homework, he sure did. He just was kind of hard to get along with sometimes. I'm sorry about—I think he died with a brain tumor, actually, so maybe he was having some difficult times.

ROSS-NAZZAL: How much time did you spend working with PAO [Public Affairs Office] on this material that you gave to the press?

BENNETT: That's what we did there and then went with those guys. We'd set up briefings with PAO, through PAO, and every mission we would do that. And then we were on call if they had

technical questions from the news media. They would say, "I know you're busy, but do you mind doing this?" And no, we didn't, because we wanted them to know as much—well, I hope they didn't know as much as we did, but I wanted them to know as much as they needed to know, so they could do the right story. It's very important that the press do that.

I thought Miles O'Brien did a good job on the [*Columbia*] accident [earlier this] year, and he came on like that and he had done his homework and he knew what was going on. So it's very important that we talk to the press so everybody's on the same sheet of music.

ROSS-NAZZAL: What type of questions did the press generally ask you?

BENNETT: Well, sometimes we chided them about the questions they asked. They didn't always ask the pertinent questions, I guess, but sometimes they did. And that was the thing you'd have to say is, "Okay, I don't really know the answer to that one, but it's not important because of this, this, and this. If you really want to know the answer, we'll try to get it for you," and try to keep them back on track of what the right questions should be.

But many times they asked intelligent questions, too, but you can't just go and answer every question out there, or you'd be there forever if it's not a pertinent question. So that's what we were trying to do.

ROSS-NAZZAL: I also understand that you were Chief of the Mission Integration Branch.

BENNETT: Right. That was when we were doing Apollo-Soyuz [Test Project] and Skylab. And there we combined our office with their office, and there weren't the long trajectory burns on

those, but it was similar work to what the folks had been doing there. And they were trying to show—get the right constraints for all their science that they were doing and that sort of thing on orbit.

ROSS-NAZZAL: What were your basic duties as chief?

BENNETT: Just coordinate all the guys together and be sure we had the right people on the right jobs there. I wasn't the technical expert in those.

ROSS-NAZZAL: Is there anything else you think we should know about your involvement with the Apollo Program or Skylab Program, that we haven't covered?

BENNETT: I don't think so at the moment.

ROSS-NAZZAL: Okay. I'd like to move on to the Shuttle Program, if you don't mind.

BENNETT: All right.

ROSS-NAZZAL: I understand that you were working in the Systems Integration Office for the Space Shuttle Program Office.

BENNETT: Yes, I went over to System Integration Office with Dick [Richard H.] Kohrs and Owen [G.] Morris. He was the chief of it then. I guess the Shuttle Program had already started

by the time I transferred over, and, in fact, I think they had already let the contract for the main engines and all. But we were trying to get a handle on the performance of the launch, and you had millions of pounds of weight there. And how did we know that we had weight control on everything?

So we had to write an appendix to our requirements to say, "External tank, you're limited to this type of weight." I forget what their weight was then. And the main engines, the solid rocket boosters, and the Orbiter. And if you start exceeding that weight, then you've got to come forward to the program. You have your actual weight and here's your control weight, and you've got to report what margin you've got, and you've got to come report any changes like this so the program office can know if you change your weight, you may be affecting somebody else, affecting the thrust capability.

And so we did what we call a weight and control and performance control and established all the requirements for that, and worked the interfaces between all the elements like when you mate, you've got to have a certain structural attachment and certain loads and that sort of thing. So we managed those requirements, too, and, "If you can't meet it, you've got to let us know. That's why we have the Program [Requirements] Change Control Board so that if you can't make it, we've got to see if it's affecting the other person, or you've got to stop and go fix it, one way or the other." So there was that type of work.

You got a bigger picture of the program, but at the same time, I had been used to being a designer in Engineering, and then in operations over in Flight Ops [Operations], and now I was in Integration, which I was trying to teach everybody to play in perfect harmony, I guess, as the song goes. But you weren't designing anything, you weren't operating, but you have to make everybody play together. So it was an interesting job. In fact, I'm still doing some of that with

USA [United Space Alliance] today in Systems Integration.

ROSS-NAZZAL: Can you talk to us about your work with the various contractors during the Shuttle Program, during the early Shuttle Program?

BENNETT: Well, it wasn't so much the contractors as it was the project offices of the NASA people there. One fellow over at Marshall [Space Flight Center, Huntsville, Alabama]—Marshall and JSC engineers were highly competitive, too. I'd never dealt with Marshall before when I worked on the lunar module. I didn't need to. But there was one fellow there when I needed to know what their weight was for the external tank. And we were going to a meeting and there was a change coming up, and I said, "I've got to have something here."

And he said, "Well, I've got to get this approved by my top management."

I said, "Fine, but we need them by so-and-so."

And he couldn't get it approved, and I said, "Well, stamp it preliminary and give it to me, it's better than me having to make up something." So okay, so he did, and I presented it. It was preliminary, and everybody got the message and it was fine.

So he called me after the meeting and he says, "I'm not giving you anything else."

I said, "What are you talking about?"

He said, "You used it."

I said, "Well, that was the idea. I told them it was preliminary." But he got very nervous about it.

So it depends on who your managers are, maybe, but overall, I think we worked quite well with them.

ROSS-NAZZAL: Were there any other difficulties that you encountered while working in this position?

BENNETT: It was kind of hard to get information out of Orbiter for some reason, because the Orbiter Project was reporting to JSC Center Director as well as the Program Manager, and so they wanted everything, maybe like the fellow from Marshall, cleared and everything like that before they would talk to us about some of the things. But it all worked out. But you had to treat them a little differently, I guess, is the word.

ROSS-NAZZAL: I also understand that you worked on computer systems integration for the Space Shuttle.

BENNETT: Well, that was in Systems Integration, and what we were doing was, it wasn't any flight computers or anything like that; it was pulling together a bunch of databases for all the measurements you had onboard the Shuttle. You had a lot of development flight instrumentation on the first few flights, and [by the way] we're going back to putting more [instrumentation] on now [for return to flight next year]. And so it was a massive amount of data in each project.

So each project had their own database for their sets of instrumentation, and you had to pull them together into one database so that everybody could work with it. And that was our job, and that was a little difficult, because there again, some of them were already in existence and the people didn't want to change and everything like that. Rockwell [International Corporation] had built the Orbiter data[base] and they were also the integration contractor, so we wound up

using their system, but it was kind of difficult there for a while to do that. And unfortunately, I didn't have any budget to control them with, so anyway, but we finally got it together. It could have been run a lot more efficiently, though.

ROSS-NAZZAL: I understand you were the Chairman of the Computer Systems Hardware and Software Integration.

BENNETT: Yes, that was that same role, right.

ROSS-NAZZAL: The same thing, okay. Okay.

What sort of interaction did you have with IBM [International Business Machines Corporation]?

BENNETT: Well, I went to San Jose [California] and took one of their management courses out there in [computer] systems, and that helped me an awful lot. They were involved in developing these databases as well. Very good, very good people.

ROSS-NAZZAL: Did you have any contact with Rockwell?

BENNETT: Yes. In those days, too, yes, Rockwell wound up building [the] database.

ROSS-NAZZAL: What are your memories of STS-1?

BENNETT: I guess I remember seeing the bird fly over here, [JSC], with all that tile missing before it ever flew and everything. The tile was really a nervous—well, I guess it was a very hard design and everything, and people really worked hard at doing that. And they came up with a good material and everything, but it was a worry, even on STS-1. I'm sure we had some missing pieces when we got back.

But I guess the main thing was the launch. The launch and entry are your most difficult dynamic phases of flight, and if something goes wrong, you've got [very] little time to react. I think even today we're all still nervous about aborts during the ascent to return to flight, because that's a very difficult maneuver, and you can only simulate it. We all think it'll work, but you never know. Things have got to go so quickly and just right.

So you sweat out the launch and then you sweat out the entry, and when you're on orbit, everything is sort of in standby and you've got time to do something usually there. I had worked with John Young on Apollo 16 before, so I knew him quite well. And Bob [Robert L.] Crippen, I met him during my Computer System days. We used to go to [flight] software meetings out at Rockwell all the time. Everybody was saying, "Who are they going to pick to fly? We know John's going to fly."

And so when I heard Crippen [was selected], I said, "Well, John wanted somebody who had that [on-board] computer background," and he did. "Crip" did a good job in learning all that stuff.

ROSS-NAZZAL: Can you tell us a little bit about those software meetings that you went to?

BENNETT: Oh, they were long, very long. Arnie [Arnold D.] Aldrich chaired those, and it was a

lot of various subjects to cover from one system to the other. Bob [Robert A.] Minor, Bob Minor was a software engineer out there at Rockwell in those days before he came here to Houston. He came in with a briefing one day and was about a couple inches thick. I said, "Bob, by definition, a briefing is supposed to be brief." So anyway, he did a good job, and I told him afterwards, I said, "You know, that was really a good job you did, and if you'd have been selling tickets on the *Titanic*, I still think I would have bought one even knowing the ship was going to go down." I don't know if he took it as a compliment or not, but I meant it that way.

ROSS-NAZZAL: Once the first flight had flown, what were your major duties?

BENNETT: I wasn't in operations then. I was planning for the next mission, I guess you'd say, but I had no real-time responsibilities during Shuttle.

ROSS-NAZZAL: Can you talk to us about planning for the next few missions? What was your involvement?

BENNETT: Well, again, it was to be sure that the performance, the weight and performance and all, was adequate and we had the right margins. One time Bob [Robert F.] Thompson was the Shuttle Program Manager and I said, "You're overweight in this particular area."

And he says, "No, we're not overweight. We have negative margin. We'll work it out." [Laughs] So that's when I learned the term negative margin.

ROSS-NAZZAL: I understand that you retired from NASA in 1982.

BENNETT: Right.

ROSS-NAZZAL: Can you tell us why you decided to retire at that point?

BENNETT: Well, I was fifty years old then, and I said, well, the Shuttle Program didn't leave me [any design or operational options]. I wasn't operating anything or designing anything, like I said, and so I said, "I think I want to go look around, and I'll be more marketable at age fifty than I will at fifty-five or a normal retirement age." So I went over to Personnel, and I said, "Is the early-out option still available?" Because they were getting ready to make me an inline manager, and prior to that I'd been an Assistant to [the manager].

And they said, "Yeah."

And I said, "For how long?" They said, "Oh, about another week."

I said, "Well, thanks for letting me know." So anyway, I decided I didn't want to be locked in, and so I retired.

But there wasn't much going on in the aerospace business in '82 around here, and I wound up seeing an ad. Oh, that reminds me of another—Ed [Edward I.] Fendell. I've got to give you an Ed Fendell story in a little bit. Everybody knows Ed. But anyway, he found this ad. He was from Connecticut originally, and Perkin-Elmer [Corporation in Connecticut] was advertising for a mission manager to manage a telescope that was going to fly on the Shuttle. It was a sun optical telescope. Perkin-Elmer was already building the Hubble [Space] Telescope at that time, and so they were looking for a mission manager to do that. And I wound up going up there with them for five years.

But after I got to Perkin-Elmer, I said, "Well, how's things going on the Hubble?"

And they said, "Well, now that you're one of us, we're over budget and behind schedule," and I think with all the problems they had with that program, the government never did [give] them the solar optical telescope, so I wound up coming back here to Houston with Rockwell [in 1987].

But the people at Perkin-Elmer were very extremely intelligent people and [made] a good product. It was a shame the Hubble had the [initial] problem, because they had evidence that there was a problem with it, but they couldn't believe they had made that kind of mistake. They did and were able to correct it and everything.

They would always—I mean, you had a set of minimum requirements, but they never [design] to the minimum requirements. They'd maximize. They would give you more than what you wanted, and sometimes that cost you more money. You can't buy a Cadillac for the price of a Ford, with the requirements of a Ford.

But I mentioned Ed Fendell, and this was also on Apollo 15, if you don't mind me going back a minute.

ROSS-NAZZAL: Of course not.

BENNETT: That was the first flight where we had the Rover, and they had the TV camera there to take the picture of the ascent. Ed was controlling this camera on the Rover from the control center, and so he wanted us to calculate what angle and rate he had to go to track this thing as it went up, so we ran the trajectory and where he was parked and that sort of thing, and gave him the data.

"Oh, it can't go that fast."

I said, "Ed, the result is done by the same folks that did the lunar descent trajectories and everything, and I have great confidence in them that they know what they're doing." I said, "If you don't want to use it, don't use it." I mean, it wasn't affecting my ascent.

So he didn't. So he cut the rates in about half, and this sequence of pictures taken off the camera [shows image] shows before the engine started, six-tenths of a second—two seconds. I lost this one. Anyway, at less than 3.7 seconds the ascent stage is gone, and he's still looking at the descent stage.

So on Apollo 16, he came around and wanted to know if we'd calculate it for him again, and I said, "Yeah, Ed. Are you going to use it?" [Laughter] And he did, and [he] tracked it beautifully.

ROSS-NAZZAL: He's a character.

BENNETT: Yes, he is.

ROSS-NAZZAL: You mentioned that you returned back to Houston and started working for Rockwell.

BENNETT: Yes.

ROSS-NAZZAL: What did you start doing for them?

BENNETT: It was systems integration work again on the Shuttle, but this time I worked with the Shuttle main engine, concentrating on that, and learned an awful lot about that machinery. That is a fantastic engine, the Shuttle main—Rocketdyne's [Propulsion and Power of the Boeing Company] engine. And there's no one person that seems to have designed it; it just evolved. "We've got to change this. We've got to change that," and it really is something else. And that was a very interesting system to learn about. We tracked the requirements on them. If they changed the weight or if they had some kind of a problem that would interface, would cause the Orbiter a problem, because the fuel system had to come from the tank through the Orbiter to the engine, so you had to worry about all those interfaces and work with them to keep track of those and say, "Yeah, you can do this. You can't do that. Or if you want to do that, you've got to come forward to the board and see who else you're affecting." So it's an interesting job, systems integration, really is.

For the last few years I've been doing that, but I've also done work on what we call interface control documents. These, again, are the interfaces, electrical, mechanical, whatever environments, between the various systems. Whenever somebody builds something new or you go to an upgrade, do I have to change this and that? And one of the biggest problems, I guess—I don't know if you'd call it a real problem, but, well, it's caused us to have a lot of waivers, is the platforms down at the Cape.

[These are] massive platforms where the workers get on to work on the Shuttle, and you don't want a large gap there [or] the guy could fall or something or he'd have to wear a safety harness and everything. So we have a general requirement of you can't be any closer than six inches because you could damage the vehicle. In fact, we've pulled the vehicle out and hit a door sometimes and that sort of thing. And we've had a lot of waiver conditions where there's

so many platforms and everything that the guys [say], "We're at three inches. We can't get six inches. We can't cut this thing back any more." And so we'd have to get a waiver for that while they go study it to see what else they can do or come back and say, "Okay, if you do these extra procedures, you can continue on that way."

But we then have to send it to the loads analysis people because the vehicle again is flexible. It moves, and particularly out on the pad, you've got wind loads and everything. So can you tolerate three inches at this point without hitting it? So you have to do those kind of analyses. But again, it's very complicated down there [at KSC], and they want to get their job done and not hold things up, but I think they were down to a quarter of an inch of the engine bell one time, and I said, "That's not a clearance. You're just touching at that point." So it's something you have to stay on top of, and they're working hard to change all the platforms and all to get the right stuff. But that's what I'm doing today.

ROSS-NAZZAL: Great. Good to hear you're still doing it.

I just have a couple more questions for you today.

BENNETT: Okay.

ROSS-NAZZAL: What do you think has been your most challenging milestone in your career with NASA?

BENNETT: Oh, it's definitely the lunar Apollo Program, yes. Like I say, with so many unknowns, and it's something mankind had dreamed about all their lives and even us as kids, and

we're able to do that, yes, to be a part of that team was really great.

ROSS-NAZZAL: I'm sure it must have been exciting for you, having that interest.

BENNETT: Yes.

ROSS-NAZZAL: What do you think was your most significant accomplishment?

BENNETT: Again, it would be the designing of the descent trajectory, because I was in a unique position of working on it when it was a future mission and then working in the design and development of the hardware that went on it to make my trajectories work right, and then to go over and to be in a part of operations and see it operating right. And I think I contributed that way. because the operations people had been doing rendezvous in Gemini and this sort of thing, and they didn't have a lot of expertise at that time in the powered flight maneuvers. They learned quickly, I'll say that, but I felt like I was sort of a tutor to them as well as the astronauts.

ROSS-NAZZAL: Before we close out today, I'd like to ask Sandra and Rebecca if they have any questions for you, if that's okay.

BENNETT: Okay, great.

WRIGHT: I had one for you. When you were talking about your Landing Analysis Branch and you showed us your picture, you had twenty of you working together. Can you share with us a

few more details—how twenty of you worked together, so many missions were going on at the same time, and planning, and how that was all coordinated and everyone had their own duties?

BENNETT: Well, yes, you had some people that were going to be in the backup rooms and others doing dispersion analysis, some doing the guidance logic, and—let's see. What else was in there?

They also combined us with the Entry Branch. Jon [C.] Harpold and Claude [A.] Graves. Claude Graves was my Assistant Branch Chief, and Jon was [section chief] over that. So you had a lot of them working the entry part of it, which I didn't. I did a hands-off on that. They were the experts on that, but there was probably about ten of us on the other side of it. We just worked the various disciplines, and I had some people doing only ascent trajectories. Like I said, we would have to have changes, and somebody wanted to change something. And I said, "Well, Jim, run the trajectory on that with this [change] in it."

"That's not going to make any difference," [he said].

Well, I still had my slide rule in those days, and I was able—I said, "No, it should change by a little bit." I said, "I know I'm not [as] accurate," but as the computers were coming along and they were getting stuff out to ten decimal places, and sometimes we got wrapped up in believing it. I said, "Your input is not that good."

And that's what Chris Kraft said to them, "I don't care what that 'GD' computer says. You tell me what it's supposed to do."

So we had to do that one time, and so he ran it off on the computer and came back, and, [said] "See? It didn't make any difference at all." I said, "Come on. It had to make some difference. Show me what you did."

So he says, "Oh."

I said, "What?"

He said, "I didn't change the input." So you can't always trust the computer, but the computer can get you a lot more than we can think through, but you've got to have the right input to it and be able to analyze the answer that comes out of it.

WRIGHT: You mentioned that you had, of course, all those years where you were planning for those landing sites and the twenty of you that worked. Did you have a lot of turnover with all of the long hours and so much work to do in such a short amount of time?

BENNETT: No. And in the early days, it wasn't the twenty of us. I was in E&D, Engineering [and Development], GN&C, Guidance, Navigation, and Control, and so you had navigation people and guidance people, and I had to interface with them to be sure that we could handle all the constraint that they had in their trajectories. But, no, we didn't have much turnover. In fact, we didn't do a lot of hiring either until I guess I got some new guys in in '66 when I went over to MPAD.

One of them, Gil [Gilbert L.] Carman, he's the one that developed that little rudimentary computer program for the window view, and he called me a few years back and said he had twenty-five years of service. And I said, "Man, I hired you." And now I think he's retired. I don't know if he's retired or not, but he's got about thirty years out there now.

But, no, there wasn't a lot of turnover. We did have our first RIF in those days, a reduction in force. This is just a little side story. I didn't know the fellow [engineer]. But anyway, they had difficulty; some people could bump somebody else and this sort of thing. And

this one fellow, he got RIF'd and he hadn't been one of the stars of the program, I guess. So he took the test as a secretary and got a job as a secretary, and he made a damned good secretary. He was filing great and everything else. They couldn't believe that—maybe found a better job for him. But that was about the only time we lost people, was a reduction of force.

WRIGHT: Thank you.

JOHNSON: I was just wondering, in 1962 when you came here, obviously the area has changed quite a bit since that time.

BENNETT: Oh yes.

JOHNSON: I was wondering about the neighborhood that you moved into with your family, if you're still in that neighborhood, how it has changed over time, and how you think that NASA has affected the communities around this area.

BENNETT: Yes, we got here in '62. Well, this area wasn't developed much at all. I'd lived in the country in Virginia, and I was enamored with the big city of Houston, so I wanted to get a little closer to town. We wound up, some new houses being built up by [William P.] Hobby Airport [Houston, Texas], and a large contingent of us moved in there. It was a very nice neighborhood, new homes and everything like that. I think they were about $20,000 or something in those days, and a very nice neighborhood. It's still a fairly nice neighborhood, but, unfortunately, it's surrounded and people have to go to burglar bars and that sort of thing.

But I lived there until ’77, I think it was, and then moved to Sagemont Townhouses on Sabo. I liked that, and I was there when I retired from NASA.

When I came back [from Connecticut], well, my wife had started working. With kids gone and everything, she went back to work [before we went to Connecticut]. I don’t know if I told you I got married in college. She put me through my last year of college. … [In Houston], she wound up as an office manager for a company in software, and they were five minutes away up near Gulfgate at the time, but then they gradually moved across town, out eventually to Dairy Ashford and I-10. That was a long hard drive for her, so when we came back from Connecticut, I said, “Do you want to go back to work?” She wound up working at Perkin-Elmer also, because the winters were so cold up there and [you could] get cabin fever up there in the wintertime.

She said, no, she was going to quit working.

I said, “Because if we are, I’m going to move halfway over to where you are, otherwise I’m going to move out to [the NASA] area.” And we did and moved into El Lago [Texas] for a while, and that was nice. And now I’m still here in this area, [Clear Lake City, Texas].

But it has changed quite a bit. When we came back from Connecticut, having been gone only five years, I couldn’t believe the growth and everything. The freeways were never empty. It used to be they were only full during the rush hours and everything.

But, yes, NASA was the only game in town out here for a long time. I don’t think it is anymore. I think it would hurt if it left, but I think it’s had a very positive effect on the area and the school systems.

ROSS-NAZZAL: We thank you so much for coming out here today and sharing these lovely photographs and your stories with us. We’ve very much enjoyed them.

BENNETT: You've helped me bring back things. And if you all want this to give to the place over there—[hands Ross-Nazzal some reports].

ROSS-NAZZAL: Yes, that would be fantastic. Thank you. Thank you so much.

BENNETT: All right. Thank you all.

[End of interview]