ORAL HISTORY TRANSCRIPT

MARLOWE D. CASSETTI
INTERVIEWED BY CAROL BUTLER
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BUTLER: Today is December 21, 1998. This is an oral history with Marlowe Cassetti for the Johnson Space Center Oral History Project. The interview is being conducted by Carol Butler in the offices of The Boeing Company in Colorado Springs.

Thank you for taking time to speak with me today.

CASSETTI: You're welcome.

BUTLER: To begin with, let's start briefly with your career working at Langley [Research Center, Hampton, Virginia]. What were some of your responsibilities there? What were you involved with?

CASSETTI: Well, when I went to work for Langley in June of 1957, I was hired in at NACA [National Advisory Committee for Aeronautics] Langley Research Center as a—I think my title that they hired me was an aeronautical research intern, and I was at a program which then, six months later, they categorized me as an aeronautical research engineer.

I worked primarily through most of the time I was at Langley at the sixteen-foot transonic wind tunnel, mainly doing aeronautical and propulsion research that included testing a lot of the military and NATO [North Atlantic Treaty Organization] airplanes such as the B-70. Many of the projects I worked on were in conjunction with NATO, so I've worked, surprisingly, on a number of British airplanes.

There was a very unique airplane called the Swallow. It's a curiosity because it was never built and flown, but you might see some designs of it around. The thing that was unique about it is it had a variable-sweep wing at a time when there was no such thing as—there was one variable-sweep research airplane that had been built right after World War II. But the Swallow was basically a flying wing with a variable sweep. Also what was notable was that it was designed by Barnes Wallace, a very famous British aeronautical engineer. He was the main feature in the movie called *The Dam Busters,* where he was the guy who thought up the bouncing bombs to bust up the German dams in the Ruhr Valley.

Anyway, I worked on a number of projects that were airplanes, a few missiles. At the sixteen-foot wind tunnel at Langley we did a lot of tests and designed and built engine simulators that were really small hydrogen peroxide rockets in the wind tunnel that simulated the jet exhaust. So we worked on that and, as a result, I also spent a lot of my time out in the rocket test area, where we would test out these engines that, ultimately, us engineers would design. That kind of led me in good foundation to get into the space program.

BUTLER: Absolutely. It seems like a natural transition to move in. When did you actually hear about the efforts for the space program?

CASSETTI: Well, I came to work in the summer of '57, and, of course, a few months later, in October, the first Sputnik was launched [by the Soviet Union], and then the U.S., of course, had its own rocket program, or satellite program, with rocket, which was the—I believe it was the [Vanguard] Program. But in '58, of course, there was a lot of concern in this country that all at once the Soviet Union was out in front of us and that we were not proceeding very well. So the National Space Act was declared in 1958, and all at once we went from being NACA to NASA [National Aeronautics and Space Administration], and sort of at the stroke of a pen, all at once, everything was—titles were a little different.

Of course, that was all going on, and from my world it was really an amazing thing going on, the fact that—it wasn't too amazing that the Russians had beaten us into orbiting the first satellite. I think that was very—very much in awe that they had done that, but also very much disappointed that they were out in front of us, because we were talking about 1957, 1958, and we were at the height of the Cold War. It was a pretty serious business, and it really was very difficult to accept the fact that we were behind.

BUTLER: Was that a reaction felt around the [Langley Research] Center, do you remember?

CASSETTI: Yes, I think so. In our office conversations, certainly, a number of my office mates were—of course, they were all older than I, but many of them had gone through World War II flying B-17s and B-29s over Japan, and many of them were in front-line battle and so forth, and they were all very much shaken by it, maybe not visibly, but in conversations they felt the same way, I think.

BUTLER: A disturbing challenge to the nation. As you moved into the space program, then, to face this challenge, how did your job responsibilities change?

CASSETTI: Well, I was perfectly happy and feeling that I was making an impact in the area I was in, which was mainly testing airplanes, having to redesign. One of the airplanes that I worked on that was through the NATO arrangements that we had was the predecessor of the Harrier. It was called a Hawker P-1127, and it looked very much like the Harrier. It was built by the Brits. It had an aerodynamic stability problem, and I worked pretty intensively on that and ended up redesigning the horizontal tail, which, in contacting the folks back in England, they were not happy because the airplane was starting production. It was in production. They did not want to have to go back and retrofit the tails on them. So they basically said, "Oh, your test results are interesting, but our pilots can fly this thing without that fix."

And then later on I found out, after I left the aerodynamic part and went into the space program, in my contacts I learned that they had experienced—I think they had lost one airplane with the pilot, and then they went back and retrofitted. So, after about, I think, the first five airplanes they went to my tail design, which is still on the Harrier today. It has the Cassetti tail on it. [Laughter]

BUTLER: That's great.

CASSETTI: Actually, I was perfectly happy doing what I was doing in research. I really enjoyed research, but I could see that there was a whole world kind of passing me by with the manned space program. By that time the Space Task Group was formed at Langley. The Space Task Group was formed by NASA, and they were originally supposed to go to the Goddard Space Center [Greenbelt, Maryland]. That was the foregone conclusion, that they were building this new Space Center outside Washington, D.C., and this group was just temporarily housed at Langley to eventually move there.

I saw all this going on, and I just really bit the bullet and contacted a friend of mine who was working at the Space Task Group that used to be working in our section, a gentleman named Chris [C.] Critzos, C-R-I-T-Z-O-S, I think it is. He was like the executive officer, or the executive at the Flight Operations Division. So I contacted him, and he said, "Oh, we're hiring like crazy. Come over." Within a couple of weeks I had transferred over there.

I guess because of my dabbling with rockets, not big rockets, they were small rockets, but, nevertheless, I had had my hands in rocket fuel and the hardware, with that as a background, I was put into flight operations in the Mission Analysis Branch. I interviewed with John [P.] Mayer, who was the branch chief, and John felt that my background—I had about five years' experience at NACA when I made the transfer. So with my background, he put me in a section which did a lot of the launch vehicle, the trajectory work, mainly trajectory and analysis area, a little bit away from the fields I was used to, but everybody was learning, and we were learning to use large full-scale computers to do the trajectory analysis.

So I worked with a few guys who had been doing it a bit longer, and we got ready for our first launch, which was MA-[4] [Mercury-Atlas 4]. It was the last of the unmanned Atlas launches before John [H.] Glenn's [Jr.] flight, which was MA-[6]. We did a number of things. In particular, one of the first jobs I had was putting together a statistical summary of the performance of the Atlas vehicle in terms of lifting the Mercury capsule into orbit, so it involved working with the Air Force people who were involved in the Atlas and their contractors and then working with the spacecraft people to get a best estimate of what would be the weight at launch, including whatever last-minute stuff they put on.

And then I would do a statistical analysis, mainly with a calculator, desk calculator, and paper and pencil kind of thing, get it typed up, slap a "Secret" cover sheet on it, because everything that involved the Atlas performance, since the Atlas was at that time our first line of strike in our nuclear forces, everything on the Atlas was highly classified. So that was one of the jobs I had.

Then as in other duties assigned, we had a back-up Computer Center at Langley for the missions. So the first couple of Atlas launches, MA-4, -5, and -6, I worked in the back-up mission Computer Center at Langley. We did all the computations that the main mission computers did, and we backed up. So every time they got a solution, we got a solution, and sometimes they didn't get one and we got a solution, which was generally figuring retrofires to land at certain points and so forth.

In those days—people don't realize, but in the early sixties, computers were tremendously unreliable. Very poor in terms of meantime between failures, so even though we had several computers in the main Computer Center, something could go wrong. And we were very much dependent on using our computers to calculate exactly when to fire the rockets and at what angle to land to come close to the carriers that picked up the Mercury capsules out of the water.

BUTLER: Absolutely. It is amazing what was able to be done when you look back at the computers, as compared to what we have sitting on our desks nowadays.

CASSETTI: Yes. Exactly.

BUTLER: As you were involved in these early Mercury missions—in fact, going back a step, actually, right after Alan [B.] Shepard's [Jr.] mission, President [John F.] Kennedy challenged the nation to land on the moon by the end of the decade. So you remember that announcement and what the reaction was?

CASSETTI: I do, and I think we were all just rather stunned by it. It was like here we had the job of putting a U.S. astronaut into low Earth orbit, you know, just a few miles up, really, comparatively a few miles up, and all at once the President is saying that we're going to go to the moon, with men, and bring them back. It was just absolutely—we were just incredulous. To say that we were surprised, I think, was an understatement. I mean, we can't figure out how to get the Atlas to work, and we're going to have another whole new rocket?

It was not that we didn't believe it; it was just that it seemed like such an overwhelming task. It was not a simple thing to do, and it took tremendous resources. But I think it was just incredulous, that at that time when we were struggling with the baby steps, it's like, you know, I can think of a toddler taking a first couple of steps and being unsure, and then you say, "In a couple of years, he's going to run a marathon." [Laughter] It was like, "Wait a minute. We just try to navigate right now."

So it was not that we were saying that it was impossible to do. I guess we all felt that we could accomplish anything, but, on the other hand, the tasks that we had to do at that time were difficult enough.

BUTLER: Absolutely, and then they were difficult tasks. You mentioned the Atlas and that it was having some problems and you always had to keep it pressurized to keep its integrity intact, and it had difficulties on launch. Can you talk a little bit about some of what was going on with that?

CASSETTI: Yes. At that time, after I got involved in the Mercury Program, I had a lot of visits out to the Air Force facility in California, where they were doing the project management on the Atlas, and we would have endless meetings. A lot of it had to do with things that were being done to either upgrade or make the Atlas vehicle more reliable. Of course, the Air Force really were quite helpful in supporting NASA. They really played a large part that I don't think they really got much credit for.

In the meantime, they were also trying to get this country to have a nuclear intercontinental ballistic missile [ICBM] program going. Probably one of the biggest factors in the 1960 election was the so-called "missile gap" that was a big political debate about how much we were behind the Soviet Union, and there were people that were really disputing that we were behind. So, the Air Force folks that I dealt with were right in the middle of all that, so they tried, and, of course, we tried to have the very safest thing that we could possibly come up with and yet still be able to pull off the program, and I think we ended up doing that.

But the one thing that did amaze me is about once every month or so I would get a 16-mm film from Los Angeles [California] on all the Atlas launches that had gone since the last time, and they were doing a lot of test launches. I don't remember exactly what the failure rate was, but there were an awful lot of film clips that I saw that just—you know, tremendous explosions. I would summarize the film and then one thing I did not report on, but I kind of made a mental note is, what if we had a Mercury capsule with an escape tower on top of it? Could it have survived? The feeling, too, we had not launched a man yet into orbit, and the feeling was, "Boy, that's going to be a real chancy thing." Of course, we had proven test pilots that were now called Mercury astronauts, and I'm sure they knew full well the risks involved.

A lot of times we would go review the Atlas. A lot of the Mercury astronauts would be involved in that. There were several of them that were always there in those reviews and so forth. I never talked directly with them about the risks of flying on the Atlas, but they could draw their own conclusions.

BUTLER: Sure. Well, it's good that they were involved in the process.

CASSETTI: Yes, they were. Very involved.

BUTLER: They could see what was going on and make their decisions, and obviously they did launch safely. There weren't any problems with the vehicle with the Mercury astronauts on board, and that shows a lot for the people pulling the program together. So that's good. It all came together.

Moving into the flights, John Glenn's was the first orbital flight on the Atlas, and so he got up safely, and everything seemed to be going fine, but then he had the problem with the indicator on the heat shield. Were you involved at all in decisions on that?

CASSETTI: I wasn't involved in the decisions on it. I was involved in the back-up Computing Center at Langley, where we had access to all the voice loops, and, of course, we heard the Capcom [Capsule communicator] loop where they were talking to John, we heard John's voice replying, we heard the flight director's loop and the FIDO [Flight Instrumentation Dynamics Officer] loop and all the various loops, so we knew full well what was going on there. We also had a commercial television on in the background to hear what the public was hearing. It was very interesting, because in those days the public never heard any of the stuff that was going on in real time. There was a conscious decision made that the guy who was head of the public affairs, John [A.] "Shorty" Powers, was the one who was doing all the commentary, and so he was basically relaying what he was hearing, and then the news would pick up on that and sometimes would broadcast that.

So a lot of times there were—I don't remember exactly. It was obvious that something was wrong with the heat shield or the heat shield indicator, and it turned out it was the indicator. It wasn't that the heat shield had deployed. It just really underscores in those days we were battling a lot of problems with the technology of the day. Nowadays an indicator comes on in the dashboard of your car or your airplane or your boat, you're pretty sure that there's a problem there, but in those early days, sometimes the indicators failed more often than the real hardware did, which is a problem in that regard.

BUTLER: Gives a little more respect, even, to accomplishing what everyone was able to at the time with this with those.

Well, John Glenn came back safely.

CASSETTI: Yes, he did.

BUTLER: And has come back safely again, in fact. The next flight up was with [M.] Scott Carpenter. You mentioned that you were involved with the trajectory and analysis and such, and then he had some problems with the fuel, whether it was from him or maneuvering or whatever, but he did end up coming down off course.

CASSETTI: Yes, about 250 miles downrange or—downrange, I think it was. Yes.

BUTLER: Do you remember any of the discussions around that time?

CASSETTI: Yes. My boss, my section head, was Carl [R.] Huss at the time, and Carl was also the retro officer, and it was Carl's job, in real time basically, to give the commands of, "At this time, at this attitude, fire the retrorockets to get down." I have heard Carl's story on why they missed, and I've also heard other stories. Carl's story was, basically, either through inattention or through misunderstanding or what, Carpenter fired in the wrong—I think, if my memory serves me right, he may have been doing something else and all at once the time to fire came up and he missed the time by many seconds. And traveling at 11,000 feet per second, a few seconds and you go winging around quite a few miles off. Fortunately, that was not life-threatening.

I remember hearing his interviews after the mission and also reading the reports. He just basically rode it out, got out in the dinghy and rode in the sea and waited for several hours for him to be found. But I think there was a lot of concern that they knew he had fired late, and they did not have good tracking on him after retrofire, so it was fairly problematic about them finding him. Fortunately, through beacons and the airplanes, they were able to locate him. I don't really know any more than that. I know Carl and Scott got into a very heated argument some days later when they were doing the post flight analysis on what happened. There were a lot of people that were very concerned that that had happened.

BUTLER: Sure. Well, when you're wanting to get your astronauts back safely and you are relying on limited equipment or—of course, at the time it was top-of-the-line equipment, but still only had limited capabilities—it's logical to have concerns. So there wasn't a lot of calculations, then, after he fired off to find his trajectory and where he came down?

CASSETTI: No, there was. What happened, in those days we had no on-board guidance at all, so we only relied on—NASA had a number of worldwide tracking stations, but, really, when you looked at the coverage, they weren't spaced all that close together, and so from one radar site you get a vector from tracking, and that vector, then, you're able to fit a trajectory to.

What you'd really like to do is have several tracking stations and sort of have them all kind of agree on where the trajectory is going. As I recall—I may not have this right, but I think that his post retrofire that we had a relatively good handle on where he had gone, but the thing that was perplexing was why was it telling us that it was not going to be close to the carrier. Why was it telling us it's 250 miles downrange? So there was a lot of concern that, well, we had bad tracking data. We didn't know at the time, really, in real time, that the retrofiring had been off as much as it was. So that was it. So we had a relatively good idea of where he was within maybe a fifty-mile or thirty-mile radius.

BUTLER: Enough to be able to track him down with the beacons and all.

CASSETTI: Yes, enough to send an airplane down there or a helicopter. I think at first it was a rescue plane, and then a helicopter got down there.

BUTLER: Yes, from everything I've heard, he just floated around, waiting. [Laughter] He knew he was fine and eventually he'd be found. And he likes the ocean anyway. He's gone into the nautical and the diving stuff.

CASSETTI: Yes. One thing to say about Scott Carpenter, one of the first times I had gone down to Cape Canaveral [Florida], which was a chore, because in those days the government was not too wild about you flying on commercial, so we had a NASA airplane we flew from Langley to Cape Canaveral, and it took forever. It was an old, dilapidated, two-engine prop-driven—I think it was a Martin 404 or something, made barely 200 miles an hour.

Actually, I got down to the Cape and went into a meeting where we were briefing the mission team, and I met Scott there for the first time. What impressed me about Scott was he remembered my name after the meeting. So he was very gracious. I did not give a briefing, but I had something to contribute to the meeting, and after the meeting was over, he called me by name and asked me to explain something to him. So I was pretty impressed that he—

BUTLER: That's good.

CASSETTI: But in my association at NACA on the airplane end, I had several friends and associates who were test pilots, and they always very much impressed me in terms of their grasp. I think just about all of them were full engineers, and they were flight test engineers, and they knew as much about aerodynamics and stability and control that I did. They probably knew a lot more than I did.

BUTLER: I'm sure it's important to know some of those details when you are up there flying a test aircraft, and if something starts to go wrong, having that background would give you some knowledge to be able to decide what to do next. Definitely a unique group of people. You mentioned Scott Carpenter. Did you work at all with any of the other astronauts?

CASSETTI: Mainly in the context of reviewing what was going on with the Atlas Program and what we were doing on that and getting into debates sometimes. After the meetings, we'd go over to the local watering hole. To me, it was very difficult, with the guidance systems that we had, to get the spacecraft into the right orbit, because there was very little margin of error, really, between putting them into a low Earth orbit and being on a suborbital trajectory that comes back down to Earth. So there was very little margin for error.

I remember getting into an argument—I think it was with Alan Shepard and Wally [Walter M.] Schirra. They were both saying that they didn't need one of these guidance systems, all they needed was a stick and a throttle and they would get into orbit just fine. [Laughter] I said, "Wait a minute." I couldn't believe that. I said, "No, you guys don't know what you're talking about." So we got in a pretty heated argument about that. I remember it was at a bar in Los Angeles. [Laughter]

BUTLER: That sounds a bit like them, from what I've heard. Well, you obviously used the guidance system and it worked.

CASSETTI: Yes. In fact, one of the things that was very interesting, and I often tell this to people, we were at a meeting where we were talking about different upgrades to the Atlas to make it more reliable or to make it a little lighter weight or something along that line, and the discussion in front of the group was the guidance system on the Atlas at the time was a radio guidance system, and that's what we used throughout the whole program, is that you would have a radar station on the ground communicating with the rocket through a two-way link that would track the rocket, and then a very rudimentary computer would figure out what the steering commands and send it back up to the Atlas.

Well, it turns out that that initial guidance system was powered with vacuum tubes. It was a tube-type, and it weighed about sixty pounds, the guidance system on the Atlas. Sixty pounds was an awful lot of weight. I mean, we'd kill for sixty pounds. So the discussion on the table was to put in a transistorized guidance system, because they had developed a transistorized system to replace it. We got in this big discussion about whether it was good to get rid of the tubes and go with the transistors. I remember there was a general officer there said, "Oh, these transistors aren't very reliable." He says, "I bought my daughter a transistor radio, and the first day she took it to the beach, it didn't work anymore and brought it home." He says, "We don't want that kind of stuff on there." So it was decided we would keep the tube-type system. So it was interesting what decisions—I thought to myself, later—

BUTLER: All based on a trip to the beach.

CASSETTI: Yes, a trip to the beach. She probably got saltwater in it or something. [Laughter]

BUTLER: Oh, how funny. Well, it was a new program at the time, and there were several points where, I've read in a couple of books, you needed a part and you ran down to the hardware store. It was such a small group and they were trying to get things done in such a short time, that you did what you had to.

CASSETTI: Oh, yes. Exactly. The Space Task Group was just a few hundred people. I remember if you needed to take a trip anywhere, in my middle desk drawer I had a book of government travel vouchers, and all I did was just rip one of these—it looked like an IBM punch card, kind of a stiff cardboard thing, pull it off. Go down to the airport, they would fill it out, and I would sign it, and they would give me an airplane ticket in return.

BUTLER: Wow. That's great.

CASSETTI: And then when I'd get back, I would take my receipt of that and whatever else—travel was much more simple. We didn't have all these travel offices and many levels of signature and everything. It was just like that was my job and—

BUTLER: You needed to do it, and they trusted you to do it.

CASSETTI: Yes. And the other beautiful part of it was, when you traveled for the government in those days, it was sixteen dollars per day per diem. So that's all you could spend, was sixteen dollars, I mean, as far as the government was concerned. Sixteen dollars was to buy a hotel room and to get your food. So you would go down—there was a cashier's window, and you would go down there with—you would have to have a signed set of travel orders. So I'd get the secretary to type up some travel orders, and generally she would sign them, because the guy we worked for was never around. And she knew how to forge his signature just as well as he could write his own signature. So I would take that.

In those days, things like Xerox machines were not usually available, so you would take this thinnest piece of tissue paper, which was the tenth carbon copy of something that you could barely read, and I'd take it down to the cashier's window, and she would try to see how many days I was traveling by holding this thing up to the light, and then for each day I was traveling, she'd count out sixteen dollars. So if I was going on a two-day trip, it would be thirty-two dollars, and that's what she would hand me, and I'd be off on my trip.

BUTLER: Now, I'm not all that great with the conversion factors, but that certainly doesn't seem like a whole lot of money for—

CASSETTI: Well, actually, it wasn't. In fact, I'm surprised that nobody got wise to this, but in those days you could never afford to go on a trip, even to Los Angeles. We used to go to

Boston a lot on the Apollo Program and stay in a room where it wouldn't cost a lot more than sixteen dollars a day. So the trick was to take a buddy with you, and you would share a room. So you'd split the cost of a room, and then you could—

BUTLER: You could eat. [Laughter]

CASSETTI: You could eat. Yes. Otherwise, you were having to subsidize the government on the room and board kind of participation.

BUTLER: Things are a little different.

CASSETTI: Exactly. In fact, I remember on a couple of occasions—we had, I remember, a trip to Boston, which was extremely expensive, where we had three guys staying in a room, and we had a roll-in cot, and we split the room three ways.

BUTLER: Wow. Well, it worked out, I guess.

CASSETTI: It was not a lot of fun.

BUTLER: I'm sure if somebody snored pretty loudly, too, that might be— [Laughter]

CASSETTI: Yes, that was always a problem. [Laughter]

BUTLER: Well, from the Mercury Program, you then moved into Gemini.

CASSETTI: Yes.

BUTLER: Based on all these missions and the various things you were learning along the way, what sorts of lessons were you able to transfer into the Gemini Program?

CASSETTI: A lot of what we did on Gemini was basically a takeoff of what we were doing on Mercury. So there was not a lot of—I won't say there was a lot of innovation, or not a lot of innovation, but it was really just sort of a transfer of what seemed to work, what seemed to do right. And for me it was an easy transition, because I was working on, really, almost a liaison function with the Air Force on the Atlas Program and then doing the liaison with the Titan II on the Gemini Program. So a lot of the same people I worked with in Los Angeles.

Some of the contractors were different, of course. I was working with General Dynamics out of San Diego [California] on the Atlas and then started working with the Martin Company out of—actually, it was out of Baltimore [Maryland] at the start, because they were transitioning to their Denver [Colorado] operations at the time. But a lot of the Titans were built in Baltimore at the time.

BUTLER: You mentioned that you were liaison with the Titan. Was this basically a continuation of your same responsibilities, or did those change?

CASSETTI: Yes, except there was a change in the program management, and I was given a dual responsibility. I kept working in flight operations, and by that time I had worked up into a position of a section chief, and I had a section of about, I think, eight people. But in addition to that, Chris [Christopher C.] Kraft [Jr.], who had become the Director of Flight Operations Division, had asked me to work in a capacity in the Gemini Program Office. Actually, I didn't work in the Gemini Program Office. They had formed teams, and they generally had a Gemini Program Office person in charge of the team, and the teams were a whole variety of different teams.

There was one team that Chris asked me to lead. I wasn't a Gemini Program Office [GPO] person, but that was okay. He and Chuck [Charles W.] Matthews, who was the GPO head, had agreed to this. So I took over a team called the Gemini Launch Guidance and Control Team. So I was doing that, and that involved a lot more of integrating the spacecraft, the launch vehicle, and the ground launch system all into something that all worked together and worked right.

There was a concern that Chris had in particular, was that the Gemini vehicle did not have a launch escape tower, and it was to rely on a lot more redundancy than we had with the Atlas. We had back-up flight control system, which we didn't have with the Atlas, and we had ejection seats like you have on a high-performance military fighter plane, but there were a lot of people that were concerned that that would not be as effective as an escape tower.

So that took a lot of my time, but in our section we still were working the Mercury Program, we were working the Titan Program, and started working on the Apollo Program, because by the time, really, Gemini got into full swing, we had already moved to Houston. So we had all these programs going at that time.

BUTLER: You mentioned the move to Houston. Did that come as a surprise? You mentioned earlier that everyone thought you were going to go to Goddard.

CASSETTI: Yes, that was an interesting thing. When I went over to the Space Task Group, I was told, and fully expected, to move to the Goddard Space Flight Center when it got developed, when it was ready to move, because it was really being built for us, as I understood. However, somehow that fell through, and I've heard many different stories. One of them was that since [Goddard was] so close to [Washington, D.C. and] Congress and they were doing so many special projects of their own, that they had already filled the place up with their own people and their own work. I don't know. That's kind of the story I had heard, that there was no room for us to move to.

Anyway, I think after the announcement by Kennedy of the Apollo Program, in essence, of going to the moon, it was decided at that time, sometime after the announcement, that they would build a new space center dedicated to manned space flight, and Goddard would have its own role and so forth. When we heard that, then, my first question was, "Well, gee, where are we going to move to?" Of course, that was the question on everybody's mind. It turned out the site selection was really interesting. We had a guy in our group who was somehow close to that site selection. I don't think he helped personally, but somebody in his carpool or some associate of his, and it turned out that he came in the office and said, "Well, I know where we're moving to."

And we said, "Where?"

He said, "Berkeley, California."

And we said, "Berkeley, California?" We all scurried to a map and said, "Where the hell is Berkeley, California? Never heard of it." It was almost that way. Of course we had heard of it.

Well, it turned out that the three places that were under consideration were Berkeley, California—for the new space center, it had to have deep-water access; it had to be close to centers of learning, academia, universities, and so forth; it had to have a ready work force and so forth and so on. It had several criteria. And apparently Berkeley was the choice of the site selection committee.

Number two was close to McDill Air Force Base in Tampa, Florida. Third was—I'm not sure whether Houston was third or another site was third and Houston was fourth. So we were all faced with moving from Virginia all the way over to California.

BUTLER: A long move.

CASSETTI: A long move. Then, as I understand it, Lyndon Johnson was the chairman of the Space and Science Committee, and he had final veto. And, of course, Berkeley, California, was not in Texas, so it lost out. So then we find out that, hey, we're moving to Houston, Texas, now, or outside Houston, Texas.

Then shortly after they made that announcement, there was a weather phenomena called a hurricane, and Hurricane Carla hit that area. So here we had hurricane-tracking maps on our walls. Of course, we had all these trajectory maps and everything, so we were plotting that thing as we got reports on the hurricane moving in there.

It was interesting, a lot of people were not that wild about moving to Houston. I didn't have a problem with it. I thought wherever the space center would be, that's where I would move to. But there were people there that had some attachment to Virginia or that area, or the East Coast. There weren't a lot of my colleagues who had families and were raised on the East Coast and they were not moving halfway across the country to Texas or to California. So we lost quite a few people when we moved, and I was surprised how many did not join us. There were a number of people that did. I think the majority did move [with] the Space Task Group, but there was quite a few that did not move. A number of the people I worked with did not move.

BUTLER: It's a tough decision.

CASSETTI: It was a tough decision. It really was.

BUTLER: When you did move down to Houston, do you remember—of course, when the [Manned] Space[craft] Center first moved down, offices were scattered all over town.

CASSETTI: Yes, they were.

BUTLER: Do you remember where you primarily worked out of?

CASSETTI: Yes. There were buildings scattered generally around the southeast part of Houston. Our offices in the Houston Petroleum Center, which was right on the Gulf Freeway [I-45]. The other offices were scattered around generally in that area. Our big thing was, the computers were located at the University of Houston, and as a result—and they were not the University of Houston's computers. We had a building in the University of Houston that had our own NASA computers there. So we did a lot of commuting back and forth between the Houston Petroleum Center and the computers.

During the Gemini Program, I also had to work with the Gemini Program Office. That's where we had all our team meetings and so forth, and that was located in downtown Houston. I don't remember exactly where it was, but somewhere in the older part of downtown. I remember we were in some old building there. So we spent a lot of time driving around. NASA did have a taxi service, which helped out, especially making runs over to the Computer Center.

Computing was really Stone Age, when you think about it. We had to have cards punched up. You'd take a bunch of cards, you'd jump into a taxicab, you'd drive to the University of Houston, you'd carry them in there, you'd submit them to a dispatcher, and then basically you don't get any results till the next day. Then you go back. You know, just an incredible time.

Like I said, I was a section head at the time, and I think virtually all the folks that worked for me were involved with trajectory computations running on the computers, and, you know, half the offices were empty because the people were commuting over to where the computers were or waiting for runs. Sometimes when a run would come back, the answers weren't quite right or you'd have to check, so people would be sitting around spare desks or tables trying to figure out what they had had.

There was a high failure rate in those days. You'd punch one number wrong into a card, and you got a bunch of wasted paper, a big printout of garbage. So there was a lot of wasted time. It's incredible. I can imagine how it would have been had we had the kind of computers that are available today. Just even desktop computers could easily do the job.

BUTLER: Quite a difference.

CASSETTI: Yes.

BUTLER: I guess one good thing about all the travel time is that at least Houston doesn't have weather like today. [Laughter]

CASSETTI: Well, I'll tell you, there have been some gully-washers there that I remember driving to get to the Computer Center, and the water was gushing out of manhole covers with such force they were lifting the iron manhole covers off.

BUTLER: Wow. Okay, they have their different brand of weather.

CASSETTI: That's true. The weather was a little more cooperative.

BUTLER: How long did you stay in that situation, do you recall?

CASSETTI: In the temporary buildings? I think we moved there in early '62, and I forgot when our building was ready at the Space Center. I believe it was not till '64 or '65 that we moved. We were one of the last groups to move down there, and I don't know why. It was around that time frame that they moved us from there to the new Space Center, the Manned Spacecraft Center, the MSC.

BUTLER: And the new Space Center came up to speed, really, early in the Gemini Program, or at least got the Mission Control Center up to speed.

CASSETTI: Yes.

BUTLER: With those new missions, now, you had two people in the capsule, a new rocket. You mentioned the escape system instead of the launch tower, and there was some debate about that, as you mentioned. What was the drive to put in the escape seats and some of the discussion?

BUTLER: You know, I've got a very different view on a lot of that. The Gemini Program was, in a way, done at a transition between the Mercury Program and the Apollo Program, and I think the main emphasis and attention of NASA in the main was on the Apollo Program. The Gemini Program was run by some good people, but I think there were some people in the Gemini Program who felt they could actually jury-rig a system to fly to the moon, and I don't think there's too many people today that are aware of this subculture that was existing there.

When you have an escape tower on top of a vehicle, it's a real performance penalty. Ejection seats don't weigh much. An escape tower weighs an awful lot and robs performance from the vehicle. I think that was one of the reasons why the designers of the Gemini wanted that. There was a lot of things that were very innovative on the Gemini Program. One of them was that for a long time baselined in the program was the parafoil landing system. They were going to get away from the water recovery, and they were going to land anywhere on the Earth where it was relatively flat. They had a landing gear system of retractable, deployable skids and a parafoil, and it could come gliding in.

There was also a connection there with the Air Force. The Air Force was really interested in doing that, as opposed to the water landings that—you've got to have a fleet of ships out waiting for your return. I saw a lot of things going on from my perspective and talked to people who felt that, given the right resources, they could beat the Apollo Program to the moon. It involved rendezvousing with and lashing up a couple of Agena second-stages, to use those to get the necessary velocity to go to the moon, and then having a beefed-up heat shield, being able to come back, and then using some fairly simple techniques for navigating to the moon, to be able to at least circumnavigate the moon.

So I think there were a lot of things that were going on in the Gemini Program that the foundations of that were really—like I said, I think there was a hidden agenda there of, if the Apollo Program falls flat on its face, then they could step up and say, "Make these changes and we'll get you to the moon. We're not going to land on the moon…We don't have a lunar module, but we can at least go fly around it like an Apollo 8 mission."

BUTLER: Interesting. It would have been a long trip, I think.

CASSETTI: Well, it would have taken about the same length of time as Apollo 8 to do a circle eight around the moon, and that's basically it.

BUTLER: In the Gemini Program there were several important first steps—

CASSETTI: Yes, there were.

BUTLER: —to get to the moon. They included EVA [Extra Vehicular Activity], rendezvous docking, and extended stays in space. I guess the first question is, how were you involved in each of the missions and to what extent?

CASSETTI: Well, by the time Gemini was getting going, we had developed a lot of the rendezvous techniques of: How do you track and find the target? What are the maneuvers that you make? There was a lot of thought done in that whole process of doing those rendezvous maneuvers. I think that was one of the things that Gemini certainly did help us with, is the development of the procedures, the techniques, the many ways from a trajectory standpoint to rendezvous two objects in space. It's not that it hadn't been done. I think the Soviet Union had done a rendezvous before we got there with the Gemini, not manned, but they had done an unmanned rendezvous if my memory serves me correctly.

One of the things that we in the flight operations were very mindful of, and one of the things that Mercury told us that we needed to do, is keep things pretty simple. In other words, when we did a retrofire burn, it was scribed marks on the window. You put the marks on the horizon, maneuver the vehicle to where those marks are on the horizon, then fire the rockets. That's pretty simple. It sounds pretty crude, and I guess from a purist theoretical standpoint it's probably not the most efficient maneuver, but it's one that if all else fails and you lose contact with the ground and everything else, an astronaut, on his own, can line up that mark with the horizon, and he's got a stopwatch or he's got a way of measuring time, so he knows it's just time and attitude and pull the switch to fire the rockets.

The Gemini rendezvous maneuvers were very much done that same way. It was done with the thought of seeing the other vehicle, keeping the maneuver sequence simple enough so that you can arrive at solutions that make sense from a crew standpoint, from a ground monitoring, and so forth. The thing that we were still constrained with in figuring out the trajectories for that has to be the limited number of ground stations we had that could track between the various maneuvers so that we could update the trajectories for that solution. So I think that Gemini taught us a lot about that, that were used certainly with the procedures that were developed for the moon and the landing and then the re-rendezvous in lunar orbit.

You know, early in the Apollo Program there was a big debate on whether there should be an Earth-orbit rendezvous and a lunar-orbit rendezvous, and it finally ended up making sense to go the way we went, but there was also a big force within NASA at the time that wanted us to assemble everything into Earth orbit and then send one vehicle to the moon, that did the landing on the moon, and then returned to Earth, and that method lost out to the other method.

BUTLER: You mentioned the rendezvous. During Gemini, several different methods of rendezvous were tested. Can you explain a bit about what those were each meant to accomplish and some of the differences between them?

CASSETTI: Boy, I really can't. I was involved in more of a peripheral sense on that, and I really don't recall. One thing, though, that was very interesting was the fact that one of the early meetings that we had down at the Cape on Gemini, we had been developing Gemini as a program, and we had some flight operations concepts generated, and we went down to the Cape to brief the people at the Cape, the launch team and the NASA management on there about what the Gemini Program was all about. Also, as it is today, the Air Force is responsible for range safety, so we had people from the Air Force also heavily involved. Not only was it their launch vehicle, but their operations there in Florida.

One of the charts that I put up showed that in order to rendezvous with the Agena rocket, we had to constantly—we had a launch window where we constantly would vary the azimuth of launch, depending on when our actual launch time was. I remember somebody jumped up and said, "You can't do that."

We said, "Why?"

Well, the guy who was talking was from the Range Safety Office and said, "No, you've got to fire on a fixed azimuth because that's the way we do our business. We will not accept the fact that you can have any launch azimuth you want to." So that was quite a shock, because here I had a five- or six-chart presentation on how we were going to do the actual launch-day operations, and here's a guy who says, "Can't do it."

We finally got that straightened out, but I'll tell you, there was some really difficult battles that we had to face. I mean, we were up against the range safety people, who had the ultimate say. They had King's X. And we were not at all well received in that camp. They finally conceded, and we made a lot of concessions and so forth, and we got out and did what we wanted to do, but it was difficult. Basically, instead of having a five-minute launch window, no, they would have limited us to just a couple of seconds' launch window. So it would have been a very difficult time to be able to accomplish that.

BUTLER: Just had to find the ways to work it out together and pull it off.

CASSETTI: Yes. I think during those times, probably I became much more of a negotiator than I had been in the past. [Laughter]

BUTLER: Developed your diplomatic skills.

CASSETTI: Yes. I probably could have gone into the diplomatic corps following that.

BUTLER: In the Gemini Program, several of the missions, while successful to a certain extent, they experienced various problems, be it with how do you work in space, how do you keep yourself in place to work, and then some problems even with the Agena on one not having separated—

CASSETTI: Yes, the masking tape on the shroud. Yes.

BUTLER: After each mission, as these problems would arise, how would you look at these? How would you evaluate for the future missions?

CASSETTI: Well, a number of things. The one that I was closely associated with that was on the very first manned launch with—let's see, it was GT-[3], I think. [Virgil I.] Gus Grissom and John [W.] Young, they got right down to the last final seconds and they had a shut-down on the launch pad, which was caused by a guidance switchover, which was my area that I was supposed to be leading the team. So needless to say, that produced a lot of work.

I think that the lessons we learned on that is in a launch sequence—in fact, it was something that we—let me backtrack a minute. When we first started the Gemini Program, as I was saying, I was involved in a launch-vehicle part of it, one of the things that Martin [Company] had proposed—and let's face it, this was a vehicle that was being also used in the ICBM program, and so we weren't learning everything new all the time; there was a foundation to build on. But in the launch hold sequence, there were several hundred parameters and votes that had to be made, and we in NASA were really looking at the whole program and saying, "If we can't get off on time, we're not going to have a program, because we're never going to be able to rendezvous."

The same thing with the variable azimuth problem that we had to work out. We just felt, and one of the people that was very much involved in this, he was kind of my overseer in a lot of what was going on in Gemini, was Bill [Howard W.] Tindall [Jr.]. Bill was very vocal about it, that checking several hundred parameters and voting on it in the last ten seconds of launch, although it was done with computers—not with computers, but with an automatic sequencing system, that he just felt that that was way too many.

And we set off on a course of really reducing that. And we did. We reduced it down to like twenty parameters. So we got an order-of-magnitude reduction, and so we felt that we had a system that we could ensure that we had a good launch vehicle to go with and yet we're not risking the crew.

So that is when we had this launch anomaly where we held up the launch and went back and looked at what the cause of it was, and it was something that was wrong in the hydraulic system that caused the switchover, and it was probably something that was just one of those failures. It was not inherent in the system. It was somewhat maddening. You know, when you take that and some of the other problems we were having with the spacecraft, the masking tape left on the fairing on the rocket, just pointed out that we just had to do our job more thoroughly and do it harder and better and so forth.

So I don't think there was any "Eureka!" kind of thing that we said, "Oh, this is the way to do it," but I think we found that working as teams, that teamwork was certainly a good formula for success, and one of the lessons learned that I think was from, some degree on the Mercury Program, certainly on the Gemini Program that was brought over to the Apollo Program, was that we started forming teams of diverse disciplines and start working out problems, start working out "Okay, here we are, we've landed on the moon. What do we do next?" kind of thing.

Bill Tindall was extremely instrumental in this, and he led a team that was called a Data Priority, which doesn't mean anything to anybody, but it was basically, how do we do what we have to do? You go through the same process when you develop flight rules, but that generally is when you have systems already built and designed. This was really doing it earlier. Bill did a marvelous job of bringing people from all diverse areas to work out these problems.

It really was an outgrowth of—I'm jumping ahead to the Apollo Program, but it was an outgrowth of the flight where we tested the LM, the lunar module, in orbit, and because somebody didn't put the right number in the computer, the mission was not a full success. And somebody chimed up later, I don't know who it was. I heard the story sort of after the fact that said, "Well, nobody asked me what the right number was, and I knew the number all the time" kind of thing.

So the computer had a number that told about the characteristics of the engine, and it apparently didn't have the right data. I thought, "Jeez, if we're going to go land on the moon, we'd better have this thing worked out much better," because, in a way, we had people that were doing the engineering and the design and then development, and we had another group of people doing the flight operations, and there was certainly a disconnect between the two areas, and this brought a lot of that together.

So I think we learned those lessons in Gemini and then really started reinforcing it. I think the teamwork on the Apollo Program, certainly on the Gemini Program, was good, but on the Apollo Program it was—I don't think there's ever been an activity that I've been involved in where the teamwork really—it was just instilled in people. It was, "We have to land men on the moon before the Soviet Union does. No doubt about it. They're working on it. They're going to do it. If we don't get there first, they're going to be there first."

You would see people who would try to build empires, who would try to be obstructionist, and they would be just absolutely steamrolled by this team. I saw it time and time again where there was this intense feeling of teamwork. It wasn't always smooth, but it was like, "We've got a common goal." There might be redundancy and waste and other things going on, but there was still that single purpose that I don't imagine—maybe in the Manhattan Project there may have been that same sort of thing.

I was involved in the Shuttle Program, and I saw certainly good teamwork there, but by then NASA was pretty much of a mature program and it was pretty well structured along its own lines. Some people were called bureaucratic, but I think there were organizational lines and so forth and there was more of a sense of "We know what we're doing" kind of thing. But in the Apollo Program, we were still pretty young and still pretty immature in our manned space flight and the technologies we were dealing with.

BUTLER: That's wonderful. That's great. Talking about that teamwork, it obviously did make Apollo very successful in that, at the beginning of the Apollo Program, of course, there was the tragedy with the fire, but the recovery after that was very quick. Apollo 7 went up and the command module worked perfectly, essentially, and then right after that, they sent Apollo 8 to the moon, which was quite an outstanding decision, a challenge.

CASSETTI: It was super. They did a lot of, I think, really outstanding decisions. For example, it was always planned early in the Apollo Program—and I remember the plans—that we would test each vehicle incrementally. In other words, the Saturn V would fly with the real first stage and dummy second and third stage, and then you would keep working your way up until you matured. Now, unfortunately, with that we couldn't have landed within the decade and still proceeded along that way, so the first Saturn V flight had to be an all-up fight with all stages working. As a result, when you think about it, there was a lot of what might seem like high-risk decisions made, but they were really faced with the constraints that they were up to, they were rational decisions. They may not have been as methodical as some people would have liked.

Let's face it, the majority of the Apollo Program, as well as Mercury and Gemini, are really being run by engineers. There's not a lot of people there that are looking at the economics. You don't have a lot of MBAs involved here or so forth, and so there's always a tendency of engineers—and I'm one, so I can speak to that—is they tend to be much more methodical and want to be much more sure of the answers. They want to take all the time in the world to do things and then be precisely right. Well, unfortunately, you just don't have the luxury or the resources to do that. So sometimes you have to rush to the next stage without having 100 percent assurance. It's just part of the business of doing that under a high-pressure situation.

But I think because of the team, we were able to recover the program. There was enormous changes made to the spacecraft. I was really concerned that the country would lose the resolve once we literally killed three people, that people would say, "Well, wait a minute. This is kind of risky. We're going to take men and put them on the moon? We're losing them on the launch pad." But I didn't see that. It seemed like we had great backing from the administration, we had great backing from Congress. I think that the American people were pretty unwavering in their support for the program, so I think at that time we did recover pretty well.

There were a lot of changes that were made. It just pointed out the fact that the risks of manned space flight are considerable. I think until the *Challenger* disaster we really didn't face—it's very difficult for us to face up to the fact that we're putting people on top of rockets, and those things do explode, and they do contain an awful lot of bad stuff in them, explosive material.

BUTLER: Those first rockets in the early programs were meant to be missiles, meant to explode.

CASSETTI: Yes. In fact, when I heard of *Challenger*, the flashback was seeing those Atlases blow up on those movies that I would get. It just brought me back to the feeling that, "We're going to lose somebody one of these days through no fault of our own, really."

BUTLER: You've just got to make it worthwhile and continue with the goals, which, hopefully, that's what they would want.

CASSETTI: Yes.

BUTLER: Apollo did achieve its goals through all the hard work and landed men on the moon by the end of the decade. Do you remember where you were and what you were doing when they actually landed?

CASSETTI: When they actually landed? I was in the Mission Control Center there at Houston. My offices for many years were in Building 30 in the administrative wing right next to Mission Control Center. Where I sat was—well, you're down there. You know the part that's—I call it "the dragon teeth" between the windows there?

BUTLER: Yes.

CASSETTI: Well, my office was up on the third floor there, and I got a chance to go over to Mission Control Center for the landing, and put the headsets on and listen to the whole thing, and it was a singularly exciting and memorable—probably I'll never forget that event, mainly because I had a special assignment for a couple of years prior to the first landing, and that was, there was a problem that the Apollo Program was facing as it was proceeding toward the first manned landing, and that was that the performance of the vehicle was falling short and the weight of the lunar module was growing. So if you looked at all the numbers, it looked like we couldn't get there from here.

So, George [M.] Low, who was head of the Apollo Program Office at the time, asked Chris Kraft to look into this, and Chris turned to me and said, you know, "Figure it out." So at that time I was a branch chief, and we had Consumables Analysis in one of my sections, and so mobilized a couple of us to go figure this problem out.

The net result was, through the analysis we did, that it appeared what was happening was—and it was generally the contractors who were responsible for delivering the hardware from one contractor to the next to the government. They were giving a guaranteed weight or guaranteed performance. So when you add all those worst cases up, sure, it's never going to happen.

So we did something rather unique. We're talking about a time in computing history that was still Stone Age. The late sixties were no better than the early sixties or mid-sixties. Yes, the computers were a little faster, but, still, one run a day is all you got. I happened to be over in another area of our building, and somebody had brought in a teletype machine, and it was hooked into a time-share computer. I started looking over this thing and said, "Boy, what a great device." I mean, this is before you had a four-function calculator that you could add and subtract, I mean, you know, a pocket calculator. This was something that just absolutely blew me away.

So I did everything I could, and within a month or so I got one of these—I think it was called an ASR-33 teletype machine. It was a tabletop model that we had in our branch. You called up over a modem. You called up on the telephone. You put the telephone on the teletype machine, at thirty bits per second. It would communicate with a time-share computer in downtown Houston, it would allow us to write FORTRAN programs, compile them. We could do runs in somewhat real time. It would be slow.

We then set up a program, wrote a program in FORTRAN which basically modeled the propellant usage and the performance and the delta-V for the lunar module landing and takeoff, ascent and descent. With that, we were able to simulate all the dispersions. We were able to simulate different failure modes. There were several failure modes that were of concern. They had to do with the engine malperforming or still be able to take off or land, and then were able to do the statistical analysis.

From that, I was getting ready to brief George Low and Chris Kraft at a meeting to give them the results. The results basically were, we don't have a problem. So I came in one day. One of the guys that worked for me and I came in one day to finish up our analysis, and we came in there and we found out it was Memorial Day and the whole place was shut down. We had no power in our building. So we were stymied. And I thought, "Wait a minute. I've got a telephone at home. I've got electrical power. I can take this machine home, although it weighs a ton." [Laughter] So this guy, Pete Peterson, who worked for me, he was an Air Force lieutenant, he was on loan to NASA, he helped me get this machine in my car. We had to talk the guards in the building to let us out. He took down everything, but he finally relinquished, you know.

We took this computer, took it home, cleaned off my dinette table, which was the closest to the telephone, and had this thing running, and we worked there all the day until we got off our final results and then got the results plotted up and briefed.

What was very interesting, George Low had said that he would pay up to $30,000 a pound to remove any amount of weight from the lunar module to be able to make the mission, because one of the reasons we were going to the moon is we wanted to take some rocks back, so we were also performance-limited on how many pounds of rocks we could take back.

So this is a long-about answer, but when I was in the Mission Control Center and the lunar module was descending, when they called out "low level light," I said, "It can't come on this early." I thought, "Oh, my God. I did something wrong. I didn't take everything into consideration."

There was an interesting reason why that light came on. It was really due to fuel slush, and it wasn't that we were low on propellant. It's just that it was sloshing around in the tank more. A very interesting phenomenon, one that we didn't realize, or one that we didn't fully comprehend, and that is when you're hovering in one-sixth-G gravity on the moon and you have a propellant with fluids, it has much higher tendency to slosh around in the tanks than when you're doing the same maneuver in Earth gravity.

The other thing, too, was the fact that as they were coming into the lunar landing area, it was strewn with boulders that they hadn't anticipated, and, as a result, they had to fly further manually downrange to get into a clear space, with the consequence that it took more propellants to get there. It was a cliff-hanger for me. Of course, everybody gave me hell for it. "Marlowe, what did you do? I thought you said we had enough propellant."

BUTLER: Oh, my. That must have been quite a bolt of adrenaline, too. [Laughter]

CASSETTI: Yes, it was. It was really that. In fact, it was funny, from the Control Center I got a printout, and I had kept it for a number of years. I was looking for it recently and can't find it. I hope I didn't throw it out. But I had a printout from one of the consoles on the heart rates for the three crew members. Mike [Michael] Collins, in orbit, his pulse rate was sixty beats a minute or something rather normal, and Neil [A.] Armstrong and Buzz [Edwin E.] Aldrin [Jr.], theirs was up, 180, three times higher than that, I think. Of course, they were pumped up a lot with adrenaline, too. Just the elation.

And that was basically the crown jewel, almost. We hadn't returned them yet. They hadn't gotten out on the lunar surface, but all the things flashed through my mind, that at the last minute people were worried about—somebody had done a study from the radar signatures from their moon and thought that the surface of the moon was twenty feet deep in talcum powder and that you couldn't land on the moon, you would just sink like quicksand for twenty feet. And other things.

Yes, there were some surprises, but sometimes your worst fears are not realized. But we had certainly good equipment that worked flawlessly. I can't think of too many things that went wrong on the first lunar landing. And, really, throughout the Apollo Program, except for Apollo 13, which was, of course, almost a catastrophic—or it was a catastrophic failure, almost a fatal failure, things went well. Again, I think we had these teams working the problem, sharing information, not working in vacuums, and airing this, that we were able to solve a lot of rather knotty problems.

Again I have to compliment Bill Tindall's data priority he worked out, but the team worked out, all the procedures to update the guidance system so that the anomalies of the gravitational field of the moon, which we found out quite by surprise because of the mascon effect on the moon, that we had to update the computers just prior to landing with tracking data from the Earth, tracking radars from the Earth, to be able to land precisely at the landing sites that we wanted.

BUTLER: In fact, Apollo 12 was to test that precise landing system.

CASSETTI: Yes. And that worked flawlessly. When you think about landing with that kind of precision, it's incredible.

BUTLER: Absolutely, especially as we've talked several times about the computers and the possibilities. It's great. Of course, your career has gone on with Skylab and the Space Shuttle. I don't want to take too much or your time today, however. So looking back over your whole career, would you have ever imagined where it would all lead you?

CASSETTI: No, not at all. I don't think anybody does, really, unless—like I said, I was perfectly happy testing airplanes in wind tunnels. I'm glad I decided to go into a different direction, a different way, but I think the career I had at NASA was certainly very fulfilling. I had great assignments on the Skylab Program. I had the opportunity to appear on the *NBC Today* show, interviewed right after the first launch and the Skylab series, and interviewed on that show. I got many fan letters from that later. Surprising.

BUTLER: Oh, that's great.

CASSETTI: School kids, a few, yes, and adults.

The Skylab Program was a real challenge, and, again, we had great teams of people and got involved in the early days of the Shuttle Program and the design of the Shuttle and worked on some of the early concepts on the Shuttle Program that's been really quite a successful program.

The last assignment I had with NASA, JSC [Johnson Space Center] was trying to get the Air Force to have their own Shuttle Operations and Planning Complex, which was going to be located right outside of Colorado Springs. That, unfortunately, fell through for a number of reasons, but mainly because of the *Challenger*, that the Air Force decided not to pursue that. But that was a challenging assignment in itself.

But, no, I would have never predicted. Although when I was in eighth grade—I went to grade school at the time when you went to eighth grade then you went to high school, so you graduated from eighth grade, you graduated from grammar school, and in my class prophecy, my prophecy was I would be sending rockets to the moon.

BUTLER: Wow!

CASSETTI: So, talk about predictions, grade-school predictions that were right. That was in 1949.

BUTLER: That's great. What sparked your interest back then in—

CASSETTI: Well, I don't know who wrote the prediction, but I was very much just taken up by airplanes, not rockets necessarily, because there weren't really, other than the German V-1 rockets, there weren't really many rockets. But rockets had my interest, and I did a lot of reading on that. I was very active in model airplane building and flying and competing, and I was very engrossed in that. I read a lot of science fiction and so forth, so I can see where probably someone would have predicted that for me.

BUTLER: That's pretty neat.

CASSETTI: Then I read an article in a magazine about scientists testing out new airplane designs in wind tunnels, and I thought, "My God, they pay you to do that," which is kind of an interesting reaction, because many years later during the Apollo Program, after the Apollo had made several flights, there was a problem we were working on having to do with the performance of the Saturn V and the command and service module and everything. We had a simulation that we were running, and we couldn't get run time during the day, so I could go in in the evening and we could run the computers and get results back.

So one time I brought my son in. He was either in junior high or high school, early high school or late junior high, and I thought, "Well, I'll show him what I do," so I snuck him into our building, and I gave him some graph paper, and we were getting the results off the computer, and he was plotting the results. We were trying to find out where the curve shifted, and I was explaining to him what this meant, what that meant to the Apollo Program, too. We got through—I mean, he was very serious about it. And he was into that kind of stuff. His favorite subject in school was physics and math.

So we got through with it, we were driving home, and he was real quiet, and I thought, "Well, maybe he's bored," so I said, "David, what did you think of all this? What did you think about this?"

He says, "I just can't believe it."

I said, "What can't you believe?"

He says, "That people really get paid for this. This is so much fun and they get paid for it." And that was exactly my reaction. I remember thinking back about when I saw this article about scientists doing this research and people really get paid for that.

BUTLER: That's really neat, especially for him to think that of what you're working on.

CASSETTI: Yes. And now he's an engineer, a chip designer for Intel Corporation, doing very well.

BUTLER: Wonderful.

CASSETTI: I'm hoping a lot of that was an inspiration to him.

BUTLER: It sounds like it was. It sounds like it was.

CASSETTI: It was, yes.

BUTLER: Looking back again over your whole career, even the areas we haven't talked of, what do you think was both your most challenging time and maybe your most significant contribution?

CASSETTI: Well, I think—boy. There were a lot of engineering challenges, trying to figure out whether we had enough propellant to land on the moon and whether we had too much weight or not enough performance or what. That was certainly a great challenge, and that was something that I took on as a personal challenge and led that, and it was probably one of the toughest challenges. But also, I think working with people, trying to get consensus, trying to negotiate. I know that's sometimes more difficult than solving an engineering problem, is bringing together people with diverse opinions and thoughts and trying to get a team consensus and, hopefully, the right solution.

I think that's been sort of one of the major challenges, of motivating people to come to a consensus and sometimes having to give up on their ego a little bit and make concessions and so forth. I know that's been probably the most difficult. I've had people storm out of meetings and say, "I'm going to write a minority opinion," or, "I'm going to report you to your boss," or, "I'm going to send you a poisoned pen letter." It's not always easy to do that.

But then again, there were a lot of difficult challenges from engineering and analysis standpoint, and certainly I think the other aspect, as I always—I didn't have to force myself, but I always learned. I always tried to keep up with the technology. I didn't want to be somebody still seeped in the sixties when I was working in the eighties. So I always took it as a personal challenge to find out what was the latest technology and be knowledgeable and so forth.

As I got into the private industry and got away from engineering and more into marketing and program development, business development, I found that diverse background that I had learned really was a good foundation for that new change in my job and my career.

BUTLER: Wonderful. I want to thank you for taking the time today to talk with me. It's a great contribution to the project.

CASSETTI: You're very welcome. Thank you.

[End of Interview]