ORAL HISTORY 2 TRANSCRIPT

AARON COHEN
INTERVIEWED BY RON STONE
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STONE: So, you were born in Texas?

COHEN: Yes, sir. Born in Corsicana, Texas.

STONE: Went to school at—?

COHEN: I went to Texas A&M University, class of [19]'52.

STONE: And then into the Army.

COHEN: Then I went to the Army for about 2 years. I was in Korea, and then when I got out, I went to work at Radio Corporation of America [RCA].

STONE: What did you do at RCA?

COHEN: Actually, very interesting. I started my engineering career and I had the opportunity my first day or first week there to work on something called a microwave oven; and I worked on the early magnetrons that went into a microwave oven. I didn't know what they were talking about. They said, "We're going to design an oven that you can cook a roast in, in a few minutes." I went home and told my wife, I said—she said, "You don't know how

to cook." I said, "No, but we're going to design an oven." So, I worked on magnetrons, which is the main tube in a microwave oven; and then I worked on color television at RCA.

STONE: How does one make the skip from microwave ovens and color television—?

COHEN: Well, it's still electronics. Electronic tube is basically what it is. I worked on the magnetron, which is a part of the electronic tube; and then of course the colored television is basically an electronic tube. So, basically that's the same—that's the theme. It's electronic systems.

STONE: But the move into General Dynamics took you—.

COHEN: Well, that was an interesting thing. I got interested in the space program just by reading what was happening in the paper. And it turns out that General Dynamics was interviewing in New York City; and, of course, I was working in New Jersey. And I took the train across to New York City and interviewed with General Dynamics, and I got a job. And so my wife and I moved to San Diego [California] to work for General Dynamics Astronautics [Corporation] and—.

STONE: What was your job? Your first job at General Dynamics?

COHEN: Well, my first job was working on the Atlas [rocket]. And actually I was doing heating of the Atlas, aerodynamic heating. And then I got into guidance, navigation, and control. And then when I was—after I was there for a while, we worked on the Atlas. It was stated that these people from NASA were coming—and I didn't know what they were talking about—NASA was coming to launch a space capsule on top of the Atlas. And, of course, if

you know how the Atlas is built, it's basically what they call a balloon structure. The skins are very, very thin on the Atlas. It because it's pressurized—it's actually structurally stabilized by having pressure in it. But we had to put a belly band around the station 502 (and I remember the station) so you could mount the capsule to it.

And so we worked—and I don't know whose idea it was. After talking to people, I don't know if it was NASA's idea or General Dynamics' idea, but I was working on that belly band because they said NASA was coming the next day to talk to General Dynamics to see if we could launch one of their spacecrafts on it. So, that was really my first encounter with NASA, which I—and I didn't know I—at that time I didn't know I was going to work for them. But that's what I did at General Dynamics. And then I got into the area of guidance, navigation, and control and worked on the Centaur vehicle, which is still flying today as an upper stage. And then, interestingly enough, I worked on General Dynamics' proposal for the Apollo Program.

STONE: You make it sound like it's an easy skip from microwave ovens to rockets and guidance. That to me, that seems like a huge jump!

COHEN: Well, it isn't a big jump. And it *is* a big jump and it—they are different types of engineering. But basically, as I've learned and as I've—(actually, I've learned this when I started teaching) basically it's the same process. If you understand what the customer wants, understand what the requirements are, usually with an engineering background you can make your changes in the different disciplines or different projects. So, in that regard I was very, very fortunate to have worked on a broad spectrum, which I think gave me the benefit that led me to be able to do what we call systems engineering.

STONE: So, General Dynamics says, "We want you to write a proposal to NASA. We want this Apollo contract."

COHEN: Right.

STONE: And you set about doing that.

COHEN: Well, I was working on the team that set—

STONE: Yes.

COHEN: —about doing that. And we worked on the contract—we worked on the proposal to NASA for the Apollo spacecraft, Apollo mission. And, of course, we didn't win. And then after that, I decided, well, I still wanted to—I got very interested in Apollo and decided I wanted to go work for NASA. And that's when I came and worked for NASA.

STONE: Do you remember hearing that speech that [President] John [F.] Kennedy made?

COHEN: Yes, I do. Of course at that time, I believe that was (what?) in [19]'60, '61—

STONE: '61, '62—

COHEN: '62.

STONE: —somewhere like that.

COHEN: I joined NASA—I think I was at NASA—I got enamored with the program before the speech, I believe. And that was when we were still working on the proposal. And—but I do remember the speech. Yes, I do.

STONE: But do you remember thinking, "Wait a minute. I'm not sure we can do this?"

COHEN: You know, I guess maybe I—No, I didn't. I didn't really think that. Now you know, talking to some of the other people like Chris [Christopher C.] Kraft [Jr.] and maybe Gene [Eugene F.] Kranz or Glynn [S.] Lunney, they may've thought that. I really didn't think—I probably wasn't smart enough to think that. I probably thought it was an engineering problem. And not really recognizing what all the issues were, just decided that we could do it. Now in—at that time—the early times of the Apollo Program—I was primarily focused on the guidance, navigation, and control and the reentry heating, the thermodynamics of it, which were two big technology efforts you had to overcome. But that's really what I was working on in the early days of the Apollo Program.

STONE: When you went to work for NASA, did you immediately come to Houston [Texas]? Or did you go to Langley [Research Center, Hampton, Virginia] first?

COHEN: No, I went to Houston. I went—I came directly to Houston. In fact, we worked—I came to work at—on the freeway, off the freeway, Gulf Freeway—.

STONE: Farnsworth Chambers building?

COHEN: No, I was—

STONE: No?

COHEN: —I was in the Office City building, right on the Gulf Freeway.

STONE: On the Gulf Freeway. Okay.

COHEN: Yeah.

STONE: Okay.

COHEN: In fact, that's where I came to work. That's where I worked.

STONE: As I recall, back in those days, there were all these bright, young men—

COHEN: Right.

STONE: —mostly men at Farnsworth Chambers.

COHEN: Right.

STONE: —And all these bright—

COHEN: That was—

STONE: —young people over at the Gulf Freeway.

COHEN: —yeah. And Office City. So, Farnsworth Chambers was like the headquarters building—

STONE: Yeah.

COHEN: —and I was in the engineering building. There was another one—there were several other buildings.

STONE: Yeah.

COHEN: The Houston—there was a little petroleum building on the freeway. And then there was a—

STONE: Yeah.

COHEN: —there were a couple of other buildings that I don't recall the names of. But Farnsworth Chambers was like the headquarters, and the Gulf Freeway was what—where the Apollo Program Office was.

STONE: Somebody described that as an extremely heady time for engineers. It was like you were looking for the Golden Fleece and knew you were going to find it.

COHEN: Well, as you know, when you think about it—when you think about it, you said, did I think we couldn't make it? That's a very interesting question because if you really look back on it, there were not any textbooks written of how you were going to do that. We

didn't—couldn't find a textbook of how you were going to do the aerodynamic heating. How were you going to do the guidance, navigation, and control. How you were going to build the structures. How you were going to design an environmental control system. How you were going to design the landing system. So, there were not any textbooks. So, we almost had to write the textbooks as we were going on. And as I tell my students today, I said, "You know, don't think you can't do something. Because you can." We didn't know how to do it. So, your question was a good one: did I think we couldn't do it? I think the answer to that is I didn't really think about that. But when I think back now and try to teach my students, I do relate to that type of problem that, you know, you're given a problem; and don't think you can't do it. Because you can.

STONE: Was this a heady time for all of you? Or just a busy time? How do you recall it?

COHEN: I think it was a busy time. In fact, it was so busy and I—it was so busy you really lost sight of what your family was doing. You really lost sight of what—you had to have a good home life, because you had to have somebody there to take care of the children and be patient with you. But you really were dedicated with your work, almost 24 hours a day. You were—you didn't mind working around the clock, coming in Saturdays and Sundays, because you knew that what you were doing was really something that everybody wanted and you were interested. And the question you asked (I'll go back to it; it was a key one): could you really do it? After it was done, after we had accomplished it, then I started thinking: could we really do it? I mean—.

STONE: Your initial job, I think, was a structures and materials engineer. What does that mean?

COHEN: Well, I was really working in the—when I first got to NASA, I was working in the structures group which was looking at the thermal protection system, the heatshield, for the Apollo vehicle. So, I was working on the heatshield, which is—was the ablative material built by—made by AVCO Corporation, which is with the heatshield to go on the outside of the Apollo spacecraft for reentry.

STONE: And there again, we're breaking new ground.

COHEN: Breaking new ground. You know, very new ground. The aerodynamic heating, how did you calculate the aerodynamic heating? How did you attach—what kind of material did you use? What—how did you test the material? How did you attach it? So, it was all very, very new and very different. But I don't think we really thought we couldn't do it.

STONE: This is 1962, and somewhere about that time you transferred to the Apollo Spacecraft Program—

COHEN: Program Office.

STONE: —Office.

COHEN: Right.

STONE: What led to that?

COHEN: I really wanted to get in more directly into the guidance and navigation control area.

As I said, at General Dynamics I had a little bit of aerodynamic heating and a little bit of guidance, navigation, and control; and I was really more interested in the guidance, navigation, and control. And my entrée to that was to work in the Apollo Program Office, which basically was doing the guidance, navigation, and control and, at that time, working with the MIT (Massachusetts Institute of Technology) Instrumentation Laboratory. And I was—I got involved with working with MIT Instrumentation Lab on the guidance, navigation, and control system. And that was really my desire. That really was what I really wanted to do.

STONE: The pat question that's written down here seems all too simple. It's got to be more complex than this. But, what were the challenges in developing [a] control and navigation system in those days of spaceflight? I mean we could take the whole 90 minutes for that I suppose.

COHEN: Well, that's right. That's right. And, of course, I think that probably is one—in my mind was one of the key technological issues. Because here you are on Earth, and you want to hit something in a pinpoint accuracy 240,000 miles away, and you had to hit it at the right time, at the right angle, at the right position. And how were you going to do that? And so, there I had the opportunity to work with the people at the MIT Laboratories who had started working on something we call inertial guidance (and that was under Dr. [C. Stark] Draper at the MIT Instrumentation Lab). People like Dick [Richard E.] Battin and Phil Felleman and Norm Seers and these type of people that were working at the Instrumentation Lab.

And basically, to get a little technical, an inertial navigation system is composed of a computer, an onboard computer. It's composed of something we call an inertial measurement unit, which allows you to determine the attitude of the vehicle in space, and a star tracker, that'll allow you to, like the old sailors of years gone by, measure the angles

between stars. And from that, you can determine your position and velocity in space and know where you are. And so that's basically an inertial guidance system. And then you had your control of how you controlled the jets that moved you around the center of gravity. So, with that system we were able to guide, navigate, and control to the Moon. Now later on, we did decide to use aid from the ground, from the Deep Space Network to get ground information. So, with all that we were able to guide and navigate to the Moon. And it turns out it was a very, very sophisticated system. The thing that's interesting: if you look at the computer we used on the Apollo vehicle—

STONE: Not much of a computer.

COHEN: —it's not—it has—your PC at home is much, much more powerful than that little computer we used. And it was a wire rope memory, where you actually had to—actually wire the zeros and ones in that made up the computer memory months before you decided to fly. And we had a little bit of erasable memory. So, it was a—to me, it was one of the big achievements. And really it was the forerunner, in all honesty, of many of the things we're doing today, both in spaceflight, aircraft flight, and commercial uses of computers.

STONE: While you were working on that, Mercury and then Gemini were going on.

COHEN: Right.

STONE: Were you learning things from them or not?

COHEN: You know, we—I tell you what. And I guess—I was really not involved in the Mercury Program or the Gemini Program. The big offshoot of those two programs, though,

were primarily, especially in the Gemini, was learning how to do rendezvous. Rendezvous, that was one thing. And, of course, how to really design your electrical power system with fuel cells and your environmental control system. So, those were the helps that those programs gave us.

STONE: How did you change jobs? Why were you promoted to Technical Assistant to the Chief of Systems Engineering Division? What does that mean?

COHEN: Well, what happened is we started going along. We found that there was a bigger job in terms of—which—a bigger job in how you integrate all the systems into the spacecraft. So, you know it wasn't just guidance, navigation, and control, which is a subsystem. It was how do you put all the systems into the spacecraft (the environmental control system, the guidance and navigation control system, the—all the systems that made the Apollo vehicle work)? And so, I was promoted to that job, to see how we could get the system to work.

There is an interesting—a very interesting point in my career at that time, which probably not too many people know about. It—Joe [Joseph F.] Shea was the—at that time was the Manager of the Apollo Program Office, and Joe and I became very good friends. We used to play tennis every Saturday morning together and became very good friends. And I was doing the guidance and navigation control work; and he said, "Aaron, there's a bigger job in understanding how you resolve all the interfaces. And that's—there's a very important document called [the] interface control document," which every system has today. He says, "How do you get all the interfaces worked out between the command module—

STONE: Yeah.

COHEN: "—the service module, the lunar module, the launch complex, all the hardware that went in it?" And it's very complicated, because interface control documents cannot be developed until you design. You can't design until you have the interfaces defined. So, I was given the job to resolve the interfaces; and that was probably one of the biggest jobs and one of the best jobs and one of the most important jobs I ever had. And I was—I mean, at that point in time I didn't recognize the significance of it. But if you couldn't resolve those interfaces, you couldn't put the vehicle—I think there was like 1200 interface documents to resolve.

STONE: Does this mean you're running interference between all these contractors, trying to get—?

COHEN: All the contractors, all the—between Marshall [Spaceflight Center, Huntsville, Alabama], Kennedy [Space Center, Florida], and all the contractors. We were trying to put the thing together so we could actually bolt things together, have wire runs complete, have the functions complete. The interfaces are electrical interfaces, mechanical interfaces, functional interfaces. They all have to fit. And you have to do that before you can build a vehicle. And they have to be resolved; so one person knows what has to go on each side of the interface so they can design it.

STONE: Did the contractors have trouble getting together on this?

COHEN: Oh yeah! And one person's got something designed. Another's got something designed. And as simple as a bolt hole pattern, wouldn't work. I'll give you an example: If you go to change a tire and if your tire doesn't fit on the rim—

STONE: You're in trouble.

COHEN: —that's a simple interface.

STONE: Right.

COHEN: And so, all these interfaces had to work. And—.

STONE: So, how'd you ever get them—?

COHEN: Well, it's an interesting story. They gave me about 10 people. We had about 1200 interface control documents, and we had to get them resolved or we weren't going to get the [Apollo] off the ground. So, you know, that was a very, very important part of it. So, Joe Shea—in fact, I remember Joe Shea taking me to Marshall Space Flight Center, and he took me to see von Braun. He introduced me to von Braun, and he said, "This is Aaron Cohen. He's going to resolve all the interfaces." And of course, I felt very, very good about that until von Braun says, "What's an interface?" So, I knew then I had a little problem with it! But the way we did it is, we identified all the interfaces. And then I had a big meeting at Cape Kennedy. I got—

STONE: Got all the contracts—

COHEN: —all the contracts together in the big firing room. And I said, "We're going to stay—" and we broke down into teams, and I said, "We're going to stay here until we get all the interfaces resolved." Well, of course, that was an overstatement because there was no

way you were going to do that in one meeting. But at least—we stayed there about a week, and at least we got them all defined and found out what the issues were so everybody knew what they had to go back and work on. And then we periodically had a meeting; and I guess that over a period of 4 to 5 months, we were able to resolve it. And that to me was one of the biggest achievements I think I made and one of the biggest contributions I made to the space program in getting the interface—not many people really recognize the significance of it. But—

STONE: Well, the mythology always is that everybody was in lockstep. That everybody was doing exactly what they were supposed to do.

COHEN: Yeah, right. Right.

STONE: In fact, they were not.

COHEN: They were not. And not by any maliciousness. It's just that—

STONE: No.

COHEN: —people were going off and doing their own thing, and somebody had to bring it together so that when this bolt hole pattern was made, the other person's bolt hole pattern would meet that so you could bolt them together. That's as simple as the electric wire—the wire runs and how you'd bolt the lunar module to the command and service module, and so forth and so on. The launch vehicle. So, that was, to me, the—one of the—I was very young at the time, but it—to me, it was one of the highlights of my career. From going from the

guidance and navigation. So, we went from microwave ovens to color television to guidance and navigation and control to interface documents on the Apollo vehicle.

STONE: There again, nobody told you couldn't do it. So, you did it.

COHEN: That's right. And we did it in about the time schedule they gave us, too.

STONE: Was there—speaking of time schedule. Was there a feeling of tremendous pressure on everyone at that time?

COHEN: I think there was, yes. I think time was really—I think your—I keep going back to your question: did we think we couldn't do it? I don't think technically, even though we didn't know exactly what we were doing,—I don't think technically we really had an issue. I think the time was really the thing that was bothering us the most. And I think that's where people like George [M.] Low—then when George Low came in and Chris Kraft came in and George [E.] Mueller really made that schedule happen in my mind.

STONE: There is a question about hardware or software, which was the most difficult to work out?

COHEN: Well, that's a tough one. I think the software at the time—the software at the time was probably the most mysterious, you might say, because we weren't in the computer age really as we are today. You know, if I look at what my students could do—my students can do today with software, it's amazing. I mean, they could do things we couldn't do, that we didn't know how to do. So, I think in that time period, software was probably—whether it was harder or whether it was more mysterious, it probably was a little bit of mystique about it

because a lot of people didn't know how to do it. So, I would say software probably was harder in some regards. You'd have to say software.

Because hardware, you know, whether you'd be—you know, you have aluminum. You have composites—we didn't have composites at the time. We really dealt mostly with aluminum and that type of material, which was conventional material. Environmental control systems were of interest, but if compared—for Apollo, the environmental control system really wasn't that complicated, and the thermal protection system was evolving. And it was pretty robust. So, I would have to say that it was software in that time period. And that's why I go back to the guidance and navigation and control system. It was probably the most sophisticated system with an onboard computer, using a computer with the software; and the Mission Control software really probably was the—

STONE: Now MIT was the original contractor to do this sort of work. Am I right about that?

COHEN: For the onboard system, yes, they were.

STONE: Now, did the other people who were also building components get in—try to get into the guidance business as well?

COHEN: Well, the guidance business was composed of the following: MIT at first was the major integrating contractor and did the software and designed the inertial measurement unit and the optical system and the computer. But as we went along, we found that MIT probably—it was too big a job for MIT to produce anything. So, we gave the job really to AC Spark Plug [Division of General Motors Corporation] at the time, which became more the integrating contractor for the guidance, navigation, and control system; and they actually did the production build of the inertial measurement unit. Raytheon [Company] built the

computer; and Kollsman Instruments [Corporation] built the optical system; and MIT did all the software. And it basically was put together by AC Spark Plug. So, that's how it was really done.

STONE: Do the American people realize that AC Spark Plug built that thing?

COHEN: Probably not. But that was part of General Motors at the time.

STONE: Right. I understand.

COHEN: Yeah.

STONE: But it just seems funny to say, well, AC Spark Plug—

COHEN: Well, that's right.

STONE: —is going to take care of that.

COHEN: We called it "AC Spark Plug," and it was really a—of course, it was part of General Dynamics at the—General—

STONE: General Motors.

COHEN: —Motors, excuse me.

STONE: What are your impressions of the people you worked with at the MIT Instrumentation Lab?

COHEN: Well, of course, I've got the highest regard for them. I really feel that the people at the MIT in the guidance and navigation were one of the key people in getting the Apollo Program accomplished. Dick Battin and those people, Norm Seers, Phil Felleman, Milt [Milton B.] Trageser, Ralph [R.] Ragan, all those people to me were really key. And they had a lot of lot of their expertise came from graduates of MIT right into the Instrumentation Lab. And of course, the whole Dr. Draper activity of inertial guidance to me was very, very important. So, I have to give them a lot of credit. Now that's my own personal feeling on it. I think that the MIT people really did a fantastic job for the space program.

STONE: Somewhere along the line, Wally [Walter M.] Schirra [Jr.] is credited with saying, "I'm sitting on top of this thing, each part built by the lowest bidder." I don't know whether that's his original line or not—

COHEN: Yeah. Right.

STONE: —or whether he stole it from somebody—

COHEN: Yeah.

STONE: —but how bad is, in fact, what we're talking about? How difficult was it to work with all of these people and keep them on track?

COHEN: Well, you know, if you go back to that point in time, if you really look at the key people in my perspective at the Johnson Space Center [JSC, Houston, Texas], of course, we had the command and service module [CSM], which was at that time North American Aviation [Inc.]. And if you look at their leader was George [W.] Jeffs, who was extremely motivated person to get the job done. If you look at Grumman [Aircraft Engineering Corporation] of Joe [Joseph G.] Gavin [Jr.] and Tom [Thomas J.] Kelly. And if you look at MIT Instrumentation Lab of Dick Battin, all of those people were very, very, very motivated to get the job done. And even though they may have had differences and they may have gone off their way, they really all were very motivated. Then if you take the Marshall Space Flight Center with their people, it was the same thing. You know, people like Ludie [G.] Richard at the Marshall Space Flight Center who was in charge of their guidance, navigation, and control system, which was done by IBM [International Business Machines]. Those people were all motivated. And the same thing with the Cape [Canaveral, Florida—later named Kennedy Space Center (KSC)]. So, really it was a very motivated team that everybody wanted to get the job done.

And then if you look at our leader in Washington [DC] at the time, George Mueller. You know, George has a way of pulling everybody together. He's got a fantastic reputation. When George had to make a decision—in fact, when he had to make a decision on how you were going to do the way we were going to do Lunar Orbital Rendezvous [LOR] or Earth Orbital Rendezvous [EOR] or go direct, George Mueller—and there were a lot of differences of opinion, and George Mueller used to get those people together and keep them together Saturdays and Sundays until they were able to make a consensus decision on it. So, George had a way of getting people to agree to do things and come out with a consistency of decision processes. Even though some people were unhappy with it, they still agreed with it.

STONE: Still there was not a blank check that you were working with. There were budget constraints. You were trying to use as much—as many products off the shelf as you possibly could, and obviously you had to make a lot from scratch. But how much did that enter into the whole thing?

COHEN: Well, it did. I do think, though, you have to start at the fact that we did have a very clear statement from President Kennedy. And I look at that as—when I teach today, I say, "That's a need statement." He said it very clearly. "We're going to send men to the Moon and return them safely within a decade." And that's a very, very simple statement. He didn't tell you how to do it. He told you what he wanted done. And from that—with that, when the leader states that, it makes it pretty clear in what you're going to do now. Your point is that you do run into constraints. Constraints always are dollars. And dollars become very, very significant. Now in the Apollo era, though, the dollars weren't as significant as we go to the next program, into the Shuttle Program.

STONE: Yes.

COHEN: The dollars became much more significant. Time was really the constraint. Because if you listened to his need statement or his general requirement, "We're going to send men to the Moon and return them safely at the decade," he didn't say anything about dollars. Now, dollars are always there. So, we had a number of reviews that tried to get the dollars back into a box; but, actually, we did have dollars to do the job for the Apollo Program.

STONE: Nobody worried about the budget, is that what you're telling me?

COHEN: No, I didn't say that.

STONE: Okay.

COHEN: I didn't say that. No, they were worried about the budget because they had a constraint. But the dollars were there to do the job. And we still had to go explain why we were spending money, how we were spending money. But the dollars were easier during the Apollo Program than they were during the Shuttle Program.

STONE: In 1966, you became the Assistant Chief of the Systems Engineering Division. What were your responsibilities there?

COHEN: Well, that was the systems engineering organization was the organization to basically do all the systems aspects of it; to be sure, again, that everything played together and that we were ready to go to checkout and deliver the vehicle. So, my job was to be sure that all the analysis was completed, all the systems; when we looked at the structural analysis, the thermal analysis, all the detailed guidance analysis, that it all played together. And that was my job in that organization.

STONE: You set up a flight readiness review program—

COHEN: Flight readiness review.

STONE: —at that time.

COHEN: We did a flight—we did what we called an FRR (flight readiness review). First we did a—first we—of course, we did a critical design review. Then we did a flight readiness review for each mission, and we had 2 weeks to get the vehicle through that.

STONE: What was a customer's acceptance review?

COHEN: Customer's acceptance review is when you basically get together and go through all the documents and look at all the designs and be sure the design meets your specifications. And you essentially buy off on the vehicle. The customer, which is NASA in this case, basically buys off the vehicle from the builder of it. So, you look at basically what they've accomplished and what your requirements were. And you buy off the vehicle.

STONE: At this point, you—you're—everything's on schedule—

COHEN: Right.

STONE: —going along. Then there's that tragic fire. And everything comes to a grinding halt. Where did you hear about the fire?

COHEN: Well, that was interesting. If I go back and think about it, they were doing a countdown demonstration test, and I was listening to the—I can't remember if I was listening to the results—or listening to the test, or was in a room where we were getting the results. And I think, in all honesty at the time when I think back on it—and, of course, sometimes your memories become a little bit—I think George [W. S.] Abbey and I, who's now the current Center Director, were in a room together. George and I were listening to the results

together at the time. And we—something went awry. Something went wrong. We didn't know exactly what because we couldn't tell. But that's our first indication. And, of course, we got a later report. I was in Houston [Texas] at the time—

STONE: Yeah.

COHEN: —I was in Houston listening to it on a hookup—

STONE: Yeah.

COHEN: —in a—actually, I wasn't in the—even in the Control Center. I think we were in an office. I think we were just in an office listening to—because it was a fairly routine test. I mean, you know, we didn't really think that it was going to be a, you know—a countdown demonstration test is not a significant test. It's a minor test in many people's minds.

STONE: As I recall, the next day there was a deep, dark, black cloud over NASA. Everybody just—it was awful. Not just the loss of those three men but what the future might hold for the whole program.

COHEN: Right. Well, that's right. And, of course, there was a lot of uncertainty. A lot of "Why did it happen? How did it happen?" And then, of course, then you go through that investigation, which is very traumatic, and you find the results. Then you go through what corrective actions you have to take. The thing that's interesting, though, is that there were black clouds; but people did feel very motivated to fix the problem and continue on. And there was no question about the fact that we wanted to fix the problem and continue on. The

astronauts, the management, and the country—the Congress and the country—wanted to fix the problem and move on.

STONE: When Frank Borman called you and said, "I want you on the Tiger Team." (I don't know whether he called you or not.) But when you—

COHEN: Right.

STONE: —how did you feel?

COHEN: Well, I felt very good. Actually it was George Low who called me.

STONE: Okay.

COHEN: George Low who called me. It was—Frank was actually—George Low actually set up the team.

STONE: Okay.

COHEN: And, of course, I was elated to do it because I felt it was a way that I could really get involved in getting the vehicle ready to fly again. And that's what I felt was important, is to get the vehicle ready to fly again. So, I was elated in some respects. I was a little bit—then I really felt the problem that you asked me: could you do it? I was really concerned: could we really get the vehicle ready to fly again? Because it was so important, and we had to overcome all the issues that were there.

STONE: At Downey [California—the North American plant], things—there really was a black cloud over things at Downey, were there not?

COHEN: Yes, there was. Yes, there was.

STONE: Tell me what that was like.

COHEN: Well, the issue—unfortunately, whenever you have an accident or a bad problem, you go through the fact of: what happened? Why did it happen? And then unfortunately you start thinking: whose fault was it—

STONE: That's right.

COHEN: —this thing?

STONE: Fingers start being pointed.

COHEN: Fingers start being pointed. Of course, that really doesn't help solve the problem. But that's the type of thing.

STONE: That's right.

COHEN: Whose fault was it? Why did this happen? Why did that happen?

STONE: Yeah.

COHEN: And that is really the—something you have to overcome before you can really get going again. Once you get going, though, you forget that part of it. And so, we got over that pretty quick. The team—I think that's where the team was really important. With Frank Borman's charisma, with his dedication, with his can-do attitude, him being out there overcame that problem. I think that, in my mind, was the biggest thing that Frank was able to do, which was monumental. He already—he was able to focus on the fact we wanted to get this thing flying again. He had a team to do it. He wanted—we needed Rockwell to do it. Or North American Aviation at the time.[1]

STONE: Yeah.

COHEN: We needed North American to do it, and so Frank saw that. And he had the blessings of George Low and Bob [Robert R.] Gilruth to get that done. And so, with Frank as the leader, I think we were able to accomplish that. So, that was the big thing, was to overcome this finger-pointing.

STONE: You started, though, at ground zero all over again—

COHEN: Exactly.

STONE: —and rewired that thing, reconfigured it.

COHEN: Yeah, in fact we did even more than that. What we did is, we started and we went through system by system, subsystem by subsystem, system by system, to find out, even if it

[1] North American Aviation, Inc. became North American Rockwell Corporation on 22 September 1967.

had nothing—not a thing to do with the failure, we went through each point and tried to see what type of corrective action did we have to take to fix it so it was as good as possible. Now, in later years, I found out after the *Challenger* [51-L] accident there's a saying that "A ship in the harbor is safe, but that's not what ships are built for." So, you could not make this perfect. And we knew we couldn't make it perfect. But we certainly could make it better than it was within the time, money, and schedule and dollars constraints we had, and make it essentially safer. And we did do that. But we went through every system, point by point. And that's where George Low had meeting after meeting, where we—each person brought up issues they had. The flight control people did, the engineering people did, the contractors did, and we addressed each problem. We didn't fix everything everybody wanted us to fix. But we—but when we didn't do it, we let them know why we weren't doing it and then the job we really had in the [time] was to get those things implemented and get the spacecraft built again.

STONE: Tell me about how the decision was made on the oxygen blend.

COHEN: Well, in fact I was out at Downey during that time with the Borman team and I got a call from George Low. And he said that "The testing's that being done by Max [Maxime A.] Faget's people with the materials we have will not allow us to use the oxygen atmosphere we have. So, we need to—there is no materials that will be self-extinguishing." That was a criteria. The materials that, once ignited, had to be self-extinguishing.

STONE: Right.

COHEN: And, of course, what is a fire? A fire is oxygen; it's fuel, which is material; and it's some type of ignition source. In fact, this room right now has ignition sources in it.

STONE: Sure.

COHEN: I mean, it has a fire—but in a spacecraft where you 100% oxygen and you have electrical wiring and you have a fuel, such as even metal, you've got to do something to correct it. And they couldn't find any way out. So, he said, "Would you please—would you take it—I want you to have a design team and come up with what you could do." So, I had a design team that was one person from Rockwell, Dave [David S.] Levine, John Zacarro was on the team, Joe [Joseph P.] Kerwin, who was a medical team and later became an astronaut for Skylab, and myself. [We] actually went about seeing what we could do, and we came up with a 60% oxygen, 40% nitrogen on the pad, which in testing the materials became self-—could itself self-extinguish—the materials were self-extinguishing. And we started that out at 14.7 psi. Now the next thing we had to do was figure out how we could get this back to 100% oxygen—

STONE: Get rid of it, yes.

COHEN: —at a reduced pressure, and without tearing the vehicle apart. And we found, interestingly enough, a penetration of the vehicle that had a nozzle on it, and you could open the nozzle. The nozzle was very much like your garden faucet. You could turn it. You could put a—essentially a fixed penetration of the vehicle, so we could vent it down and then have the regulator—oxygen regulator resupply the oxygen. So, by the time we got on orbit, we were at 5 psi, 100% oxygen, which also was self-extinguishing. So, we were able to do it without any changes to hardware or software; it was just procedures. And, of course, that was a really an interesting way. And they flew every mission that way. They flew every mission that way.

STONE: But had it not been for that fire, you never would have figured that out—

COHEN: That's right.

STONE: —and the fire was just an accident waiting to happen—

COHEN: That's right.

STONE: —somewhere, was it not?

COHEN: Yeah, well, that's right. And there are a lot of reasons for it. People have varied reasons. But we were 100% oxygen at 16 psi. You can go back in history why we were at that way. There were reasons why.

STONE: Sure.

COHEN: Whether they were right or wrong, there were reasons why we got to that point, which obviously was not the right place to be in hindsight. But it's like many things, you can correct things in hindsight that you couldn't do beforehand.

STONE: Take you to 1968 and you're the Chief of the Command and Service Modules Project, Engineering Division.

COHEN: Right.

STONE: What does that mean?

COHEN: That's getting each vehicle—it means getting each command and service module ready to fly. So, we would get each vehicle from Downey; ship the command and service module from Downey to the Cape; and then once at the Cape, get it ready to fly. And then once it's flown, you get the next one ready. So, our job was to—and then actually take it through the flight readiness reviews. Take—to take each vehicle through the flight readiness reviews. So, that was the job. That was a (you might say) was a detailed engineering job but more of an operational engineering job of getting a designed vehicle ready to fly.

STONE: I have some friends who work at NASA who swear to me they never read the paper and there was no race with the Russians involved anywhere. They were racing with themselves doing all sorts of things. But all of a sudden, were you one of those people who's looking at the paper and wondering what the Russians are doing or not?

COHEN: Well, you know, I'm not sure I really was at the time. I guess I was so busy doing what I was doing that I'm not sure I really paid too much attention to it, although probably more than I recognized. But I really wasn't paying too much attention to it.

STONE: So, were you taken aback when someone calls you in and says, "[Apollo] 8's going to do—"

COHEN: Well, that's—of course I feel that—you know, I talk about important things in my career. That was probably the highlight of my career, Apollo 8. Again I got a call from George Low. And I said that we wanted—he said, "I need you back in Houston. We need to

review Apollo 8—to be sure that we can get Apollo 8 ready to go to the Moon, that's spacecraft 10[3]. The nomenclature was spacecraft 10[3]. And of course, each vehicle was supposed to be designed to go to the Moon, but you really don't know until you go through the—all the flight readiness reviews and everything. So, I remember very distinctly. I came back to Houston. I brought a gentleman with me by the name of Ed Smith. And Ed Smith is—was my counterpart at that time at Rockwell—at North American. He was a head of the engineering for North American Aviation. And we did a review of every drawing, every discrepancy report, all the wiring to see: could spacecraft 103 (or Apollo 8) do a lunar mission like we designed to be?

And I remember we did that. We spent about 2 or 3 days doing it, and we had a lot of, you know, a lot of teleconferences back to Downey, looking at records, having records sent in. And we were able to complete the review. And I remember typing up the report in—my wife and I took it over to George Low's house the night before he was getting ready to leave to go to Washington [DC] to meet—to get approval for Apollo 8. So, I had that memo I gave him. I had that memo prepared, and after the flight I gave it to—I asked Frank Borman to sign it. So, I still have that. I still have that letter with Frank Borman's signature. He says, "You were right, Aaron. This was a good spacecraft."

STONE: So, there again, no question in your mind as you and your wife typed up this report—

COHEN: My wife didn't. But I have the signature. We delivered it.

STONE: —you know, as you type up the report and you and your wife took it over to Mr. Low—

COHEN: Right.

STONE: —no question in your mind that it could be done.

COHEN: No. No question. No.

STONE: Never looked back?

COHEN: Never looked back. I felt it was—that was what it was designed to do, and there was no reason to feel that the design wouldn't work on all the systems we had, including the guidance and navigation system. I remember the one issue Frank had. You know, we changed—one of the big changes after the fire, which we didn't talk about, was the fact from an inward opening hatch to an outward opening hatch. Because Apollo had—on the fire had an inward opening hatch—

STONE: Yeah.

COHEN: —primarily because of Gus Grissom's flight [Mercury-Redstone 4, *Liberty Bell 7*], which caused the outward opening hatch to cause the failure. So, we went back to an outward opening hatch. It turns out, on the pad, you're safer with an outward opening hatch for escape; but in space, you're safer with an inward opening hatch because the pressure tends—the pressure inside is higher than outside and it tends to seal. And an outward opening hatch, it tends to want to blow it open. And that was Frank—one of Frank Borman's biggest issues. He wanted us to be sure that thing wouldn't open on him. And it was

designed like a vault anyway, so it wasn't going to open. But that was his biggest issue, I think.

STONE: Around you other people at NASA, as I recall, seemed to be terribly surprised that things were moving at this kind of Mach speed, that you were going to do—that 8 was going to do what they thought 9 or 10 was going to do.

COHEN: Right, right.

STONE: Did you have a lot of explaining to do to them, or—?

COHEN: Well, I didn't personally. No, I just felt that 8 could do the job. We did what we had to do. 8 could do the job, and—which I didn't really have any problem with. I think the issue was, again, the guidance and navigation was going to work. The heatshield was going to work. The environmental control system was going to work. We looked at all the wiring—any potential problem with the wiring and the structure, and we saw no issues with the parachutes and the recovery system. So, we didn't see any issues with it. Everything was tested. Everything had been tested. The thrusters had been tested. The engine had been tested.

I guess the one issue, the one real issue in the mission was an interesting one was that we were having a problem with the service propulsion system. Not a problem with it, but we found that you do have to make some corrections (what we call midcourse corrections) on your way from the Earth to the Moon based on the information you get from the guidance and navigation system to put you back on course. And, we found that, of course, you have one service propulsion system, which is used to get you out of lunar orbit; and so it's a very, very important engine.

STONE: Yeah.

COHEN: But it also had to be used to make the midcourse corrections. And we found, by doing some tests, that if you—there were two feed lines or two banks, we called them, in one engine. But if you fired that engine with both banks dry before you had wetted them, you got a pressure spike which could cause the engine to explode. And the Mission Rules called for the midcourse corrections to be made—excuse me—to go into orbit with both banks, because you wanted to be sure you burned into orbit correctly. Now the question was: how are we going to get both banks wetted before you got in orbit? So, I remember they brought me that problem—the engineers at JSC and North American brought me that problem. And—but they also—but we also had a solution. And the solution was to fire one bank on the way to the Moon and go out of plane, so you didn't disturb your trajectory; and then a little later, fire the other bank—

STONE: Bring you back.

COHEN: —bring you back, so you didn't disturb your engine and you'd have both banks wetted. Well, I had to call George Low and tell him that—and tell him that problem. Now the thing about George Low: he was one of the kindest gentlemen you ever wanted to meet. I mean, he really never got excited. Never, never raised his voice. You knew, though, when he was mad. So, I had to call him where it's about 2 days before launch. And they had all the Mission Rules written, and Frank Borman had gone through all this.

So, I called—I was the one who had to call him and tell him of it. So, he really got very mad at me. I mean, he didn't give me a chance to give him the explanation of the solution. I mean, it was uncharacteristic of George, but he did get very mad at me. He says,

"Why are you telling me this so late in the count during the mission?" I said, "Well, George, I just found out about it myself. But I've got a solution." So, once I could give him the solution, we were okay. And how that's how we flew every mission basically. It was basically a solution that we had. So, the lesson I learned there was: always be sure that when you told your boss a question, be sure you had a solution for it. But we were able to work out a solution for it.

STONE: That also brings up an interesting point. The assumption was that all things like that had long since been figured out.

COHEN: Well, that's right. And this one came up very, very late. And that's another thing we learned: we learned that that was going to be mission after mission. It was always something late in the count or late in the mission that was going to come and surprise you. No matter how good you designed it or how well you did it, there was always going to be some kind of surprise that you had to work on.

STONE: That had to be scary. I mean, you know.

COHEN: Yeah, it was scary. Yeah, there was—

STONE: Did the astronauts realize this was happening to them, too?

COHEN: I think they did. I think they knew that. And I think that's of course where our good operations people came in. Because I think our operations capability with people like Glynn Lunney and Gene Kranz and Chris (at that time) were able to help resolve those

operational issues even though the system—you know, I was more into the design part of it. They were more in the operations part of it, and I think—

STONE: Yeah.

COHEN: —that's where it all came together really.

STONE: Do you remember that Christmastime when 8 went around the Moon—

COHEN: Yes, I do.

STONE: —and we lost them for a while?

COHEN: Right, right.

STONE: And we didn't know—I mean, I guess you knew they were going to come back the other side. But sheer mortals didn't know it was going to come back.

COHEN: Well, I knew they were. But it's just—it's no matter if you knew or not knew, you knew physically they could. But of course, whether the communication was going to come through was another question.

STONE: Yeah.

COHEN: Of course, that was always a very tenuous time, when you're behind the Moon.

You can't do much about it until you come to the other side, and you hope you're going to re-contact with them. But, yes, it was very—I won't say it was scary. But it was very tense.

STONE: When Apollo came home, did you feel like you had had done it all? I mean, that you'd done everything that they brought you to Houston to do?

COHEN: Well, you mean Apollo 11 or Apollo 8?

STONE: No, when 8 came home.

COHEN: Well, I—no. I still felt we had to do Apollo 11, and that's really what we—

STONE: But from a guidance standpoint—.

COHEN: From a guidance standpoint, we really did what we had to do. And from the heatshield—

STONE: Yeah.

COHEN: —from the two things that I was really, you might say—from a subsystem point of view, interestingly we did, but you also have to recognize that then I became, as you pointed out, in my career—I became more involved with all of the systems. And so, I really—until the parachutes came out and the bags came out, and we got the crew out of the vehicle, it was not over.

STONE: In 1968, you became the Chief of Command and Service Modules Project, Engineering Division.

COHEN: Right.

STONE: What does that mean?

COHEN: Well, that meant that I really was doing the—almost the same thing, but just had the title, really is what that meant. I was really doing the same thing as I did in the Project Engineering Division.

STONE: Then in [19]'70, you were the Manager, Command and Service Module.

COHEN: Service module, right. Then I took over the total job and that's when I became manager of the total project, including the resources, the schedule, the resources, and the vehicle. Right.

STONE: You are the manager of the command and service—

COHEN: Service modules.

STONE: —modules for a program that is winding down.

COHEN: Right.

STONE: Was it difficult to keep the enthusiasm up after 11?

COHEN: Not really, no; it really wasn't. I didn't have that problem. I mean, I think the enthusiasm for Apollo was there. And I think people did recognize the significance of it. And I do think people knew that each step along the way was important. And I think George Low left us with a legacy of understanding the detail, working on the details, and paying attention to details. So, he taught us that. And with that type of a legacy, you pay attention to details. So, yes, I think it wasn't hard to keep the people's—at least I don't think it was hard to keep people's interest up.

STONE: The day Gene [Eugene A.] Cernan took that last step on the Moon and started coming home, did you go home that night and say, "Well, you know, this—" I mean, did you feel the historic significance of this? Or did you think there would be lots of other people going back to the Moon?

COHEN: Well, I thought that—I thought we would have a continuation—not necessarily to the Moon, but some continuation. Although the Shuttle was in the horizon, and that's where I was headed towards. Of course, we did have one—we did have this interruption of Apollo 13 in the middle of all that. And of course, that was an interesting story in my perspective of what happened on Apollo 13.

STONE: Was—this is a stupid question. It was a surprise, obviously. But were you surprised that what happened to 13 could happen to 13?

COHEN: Yes, I was. And it turns out that I was just in the transition. You talk about the

head of the command and service module. I was in the transition of just taking over the command and service module. I'm not even sure the announcement was out yet, but I was really the project manager for the command and service module on Apollo 13. That was really the—my first mission. And it turns out the problem with Apollo 13, in my perspective when you go back and look at it, was again a very interesting circumstance, the situation.

We were again doing a countdown demonstration test on Apollo 13. And as you know, what you do is you load all the consumables, the cryos, and the oxygen tank, the liquid oxygen, liquid hydrogen. You load all the propellants, and you count down to zero and then you stop. And then, of course, you have a successful test. The crew gets out and goes home, and then you offload everything. Well, we did that; but we could not offload the oxygen out of oxygen tank 2. We got the hydrogen out and we got the oxygen out of oxygen tank 1, but we couldn't get the oxygen out of oxygen tank 2.

So, we had an—and I was the manager of the command—I had just took over as manager of the command and service module; and we had a teleconference between Downey, the North American people, Beech Aircraft [Corporation], who made the cryo tanks in Boulder, Colorado, and the Cape people and our subsystem manager, who was also at the Cape at the time. And we said, "Well, we can't get the oxygen out." Now there's really no reason to get the oxygen out, other than the fact that it would boil off and you'd like to get more pure oxygen in so—because you're not going to launch for about a week. So, we—normally the way we get the oxygen out is you actually pressurize—you have a port in the tank where you pressurize it with nitrogen and you cause the pressure to flow the oxygen out through another port.

STONE: Okay.

COHEN: And we couldn't do that. I mean, it just didn't work. We looked at the X rays in

the tank, which we had, and as the records show, that had been in one—another vehicle and had been taken out and was dropped. And in dropping it, there's a union—a little union that connects the port—and it was dislodged. So, there was not a continuous flow path. Now that did not have anything to do with the timing. No operation of the tank was at risk. In fact, the only problem with that port is you couldn't take the oxygen out.

So, we decided (all of us decided, the North American people, the Beech people, the Cape, and the Johnson people) the right thing to do was to turn the heaters on in—the tank had heaters and fans; heaters so you could cause the liquid oxygen to become gas so if you go to the fuel cells, and the fans, so that you could stir the oxygen in zero g so you didn't have a void. You had a continuous system. So—and it also had a capacitance probe, so it did have electrical circuits in the oxygen. So, we decided to boil off the oxygen, turn the heater on. Now—and we said, "Well, that's really not going to be a problem because oxygen—cryogenic oxygen, its temperature is –270°F, so that's pretty cold.

And we also had a thermostat, and with a thermostat with a relay that if the heater got at the—heater got higher than 80°F, the thermostat would open and take the power off the heater. And we also had strip charts in the Control Center to watch the temperature. So, we decided that we'd do this to go boil it off. Well, we did; and it was very successful. And we boiled it off, and there was no problem. And, of course, what we didn't recognize were a couple of things that were very, very interesting later is that: the thermostat did not operate, did not take the heater element off. As a result, the temperature of the heater element in the probe got to about 1000°F and, of course, took the Teflon insulation off the wire of the heater element. And the reason why is because there was a very subtle change made after the fire on the pad, where we went from a 28V DC system to a 65V DC system so we could pressurize the tanks easier. And the 65V DC system would've been all right; except, when you kept it on for the period of time we kept it on, the relay was not compatible with it; and it essentially locked in place so that the thermostat didn't work.

STONE: Yeah.

COHEN: And, of course, we didn't recognize that until after the flight. And when you then get to turn the heater on during flight, as they did—as Jack [John L.] Swigert did—he really turned on the—they said he pushed the circuit breaker in for the fan, but and also the fan and the heater were on the same circuit. The heater element got hot and, of course, that's when you had the explosion. So, in retrospect, we knew exactly what the problem was. It was a—several changes that were made that really were not recognized at the time. And why? I guess I never did know clearly why in the control room they did not measure the temperature and see the temperature. I guess that whether it was off the scale or whatever, but that's what happened.

And, of course, we are able to—and I was with Jim [James A.] McDivitt. I spent a lot of time with Jim McDivitt on the accident investigation in preparing for the hearing in the investigation. And the biggest issue they hit us on was have—be sure you understand your hardware and understand the changes you make to your hardware, which we—and I was—I remember very clearly, that was recommendation number 9. And they beat us up on recommendation number 9 because we did not clearly document the fact that we went from 65V—from 28V DC to 65V DC. And that was really the change. And I use that—in all honesty, when I lecture in my classes, I use that as an example of how you need to pay attention to detail, you need to communicate, and you need to have teamwork. And it was a very subtle problem.

STONE: You move in [19]'72 to Manager of the Orbiter Project Office. The Space Shuttle Project Office. That's—it seems to me like that's almost like jumping from microwave ovens to guidance again. This seems like a big jump to me.

COHEN: Well, it was. Of course now I'm responsible for the design, development, and operation of the—

STONE: You're going to start and build the whole thing?

COHEN: Right. We're starting with a viewgraph. And we're starting with all over building a Space Shuttle. And the Space Shuttle Orbiter was—is basically three systems. It's basically a launch vehicle; it's a spacecraft, because it stays; and it's an airplane. So, you're designing three systems in one. And in the system complexity, the Orbiter is so much more complex than the Apollo vehicle. I mean, it's just—the mission is not as complex but the systems are so—I mean, it's just a so much more complex. And at that time I also had the responsibility of the integration of the system. When we first started out, Bob [Robert F.] Thompson gave me the job of the Orbiter plus the integration, so I did have also the integration of the system engineering integration.

STONE: What is the lead Center management structure?

COHEN: Well, the lead Center management structure is a way of managing the vehicle. And—when you have a very complicated system like the Shuttle and you have various centers operating it, you want to have some Center in charge, or you could have one—some Center in charge. The Johnson Space Center was given the lead Center, and systems engineering and integration was given to the Johnson Space Center; and that was under Bob Thompson. And then the Orbiter was responsible to Johnson Space Center. And the main engine and solid rocket boosters and tank was the responsibility of the Marshall Spaceflight Center. And then the launch was the responsibility of the Kennedy Space Center.

And the lead Center was at the Johnson Space Center under Bob Thompson, which integrated that total activity.

STONE: When they gave you this job, did they tell you they wanted a reusable Space Shuttle, as it were?

COHEN: Yes, they did. They said they wanted a reusable Space Shuttle.

STONE: Why that instead of like what the Russians were doing?

COHEN: Well, because the whole idea—the whole thought process that, in order to make spaceflight more economical—

STONE: Yeah.

COHEN: —and more readily usable for commercial activities, you wanted something that could be reused time and time again and not throw away the expensive guidance and navigation system, environmental control system, for the basic structure. So, that's why they wanted a reusable system. And I think in that context, the Shuttle has proved out to be very, very successful.

STONE: Are you one of those kind of people who sits around and doodles on a piece of yellow foolscap? Did you draw some designs of that just in your mind?

COHEN: No, I really didn't. I—in all fairness, there were several configurations that came out of it that had been done previously, and we—I came in when—the point when we had

proposals from the North American, Grumman, and Lockheed [Aircraft Corporation], and Martin [Marietta Aerospace] (at the time). And basically, all had had a very similar configuration.

STONE: Didn't they have big wings at one time?

COHEN: That—well, they had fly-back boosters, if that's—they had fly-back boosters.

STONE: Okay. Yeah.

COHEN: But the point there was that the fly-back booster—see, you had several problems with the Shuttle. Now you become very much—you have a cost constraint to get to the point that you—

STONE: No blank check this time.

COHEN: —no blank—it said, "You're going to build a reusable system." The need statement or the top requirement, "You're going to build a reusable system," and didn't give us a time constraint on it, but that had to stay within a cost constraint of so many dollars in a given year. I think it was [19]'72 dollars. And—'72 year dollars, because we accounted for inflation. And so, you were fixed now. When we went to a fly-back booster, it—you went out of the development box. It became too expensive. So, that's why we had to go without the big wings on the booster. And so, that's why we gave up the total—the fly-back booster and stayed with the system you see today.

STONE: Can you talk about how much the Department of Defense [DoD] entered into this whole thing?

COHEN: Well, the Department of Defense entered into several factors. They drove basically the size of the bay of the Shuttle, because they had some payloads they wanted to fly. So, they drove that. They made a very—and they also drove the amount of (I'll use the term) cross-range. How much out-of-plane maneuvering the vehicle could take for purposes. And that drove the wings, the type of wings we had. So, when you look at what the Air Force really did, their requirements for—to satisfy the requirements drove those two things. And the Air Force was very, very important in helping get the Shuttle really sold to the government.

STONE: You built it to stay up for a month, I guess?

COHEN: Well, the original requirement—the original requirement was for—let's see. It was really a—what we called a 28-day mission—

STONE: Okay.

COHEN: —it was 4 people for 7 days. That's a 28-day mission. And then later, it was stated that we wanted to be able to stay up for 30 days with the number of people. So, we really had a design that could do that, but we never really—and that sort of drove the problem. But, yes, that's what we had, is the—

STONE: So, that one that's flying right now is basically that same kind of design?

COHEN: Right. It's basically the same.

STONE: But they don't stay up that long.

COHEN: No, they don't stay—well, we really never did design—we never really did stay up 30 days. We never did really stay. The—they—it was—

STONE: But did you have to compromise the design because of that?

COHEN: Yeah, you had to compromise the design; but we—it was really, in all honesty,—it was more of a soft requirement. That was a soft requirement than a hard requirement. To see what you could get with a goal of 30 days. It was really never a hard requirement to make a 30-day mission. But actually, it's done—it's—we've had 7 people up for—we've sent 7 people up for 14 days, so that's—let's see, that's 98 day—that's a hundred—that's a 100 man-day mission, you might say.

STONE: You said when it was designed, it was designed to be—or when it—when they started talking about it, it was going to be a reusable thing that would really make space travel efficient and inexpensive. And they were talking about sending up two or three of these things a month. Is that ever going to happen?

COHEN: Well, I think it probably will. But I think there's got to be some changes in technology before it happens. It—you know, first of all, how are you going to make it cheaper? And let's talk about that. How are you going to make space travel cheaper? I think you have to some way reduce the effort in terms of the amount of people working on it

to get the turnaround to go. I think that's number one. Number two, there are things such as single stage to orbit, which they're trying to do, or two stage to orbit, which they're trying to do; and that technology is coming along, but it's not quite there.

I think the biggest thing in—to get to the flight rate you're talking about, I think we've got to simplify the systems quite a bit in the Shuttle. The Shuttle system will not allow that type of high flight rate. I think you're going to have to simplify the systems. Now I say that, and I think that's left to the engineers to design it. I'm not sure exactly how you'd go about doing it. I think eventually it will come. I think eventually it will come. I think the NASA would like to reduce the cost a pound to orbit to more of the 100 dollars per pound rather than the $1000 or $5000 a pound. So, I think eventually it'll come. But it's—and it's needed to come before we really can take advantage of spaceflight in the commercial world.

STONE: It's amazing. If we go back to the time when you graduated from high school in Corsicana, Texas, the thought of going to the Moon was not even—I mean, you know, you couldn't even think about that. So, in a reasonably short period of time, we've done a great deal. Do you see that kind of—

COHEN: Well, I think—

STONE: —warp movement within the next 25 or 50 years?

COHEN: —well, I think so. If you look at 1903, the Wright brothers flew—

STONE: Oh yeah.

COHEN: —their plane, and it was the length of the external tank. So, you know—so, and

now we can fly—we can keep a vehicle in orbit for, as you point out, 30 days. And Space Station and actually send probes, unmanned probes, to Mars and Venus. And eventually, I think we will send human probe—or human vehicles to Mars—in, that's what my students are working on—but we'll send them back to the Moon and on to Mars. I'm convinced of it.

STONE: Are the guidance problems solved? I mean, that part of the—

COHEN: I think the guidance problems are solved. I don't think that's an issue. I think now the issues are more: can we make the propulsion systems more efficient? Can we make the structure more efficient? Those are the type of things. Can we get more efficient—really for interplanetary travel, can we have a closed-loop environmental control system so you can actually recycle all your waste products and that type of thing? So, you're now looking for things like that. And can you take advantage of resources on other planets? Can you get propellant? Can you get oxygen out of the lunar soil or the Martian soil? These are the type of technologies that you're looking for today.

STONE: The Space Shuttle design was an exercise in compromise, it has been said. In a perfect world, what would it have looked like?

COHEN: Well, I think—

STONE: If you hadn't had to make all those compromises?

COHEN: —well, I think in the perfect world, in my mind, of course, I'm a—I sort of feel like the father of the Space Shuttle Orbiter, so I'm not going to be too critical of what my offspring—

STONE: You shouldn't be.

COHEN: —looks like. But I do think if you—in a perfect world, you probably would have a fully reusable Shuttle. By that I mean, you wouldn't have to throw away the external tanks or let the solid rocket boosters go, even though we recover them. You would have a fully reusable system. As you pointed out, you'd have more of a fly-back booster. That would be the perfect world. Of course, is the development cost—and that's where they talk about the compromise. Is the development cost warranted in that in making up for what the operations—reduction in operations cost? So, how do you balance development cost to operations cost? And that's what—that's would be when they talk about compromises, that's where the compromise is.

Do I think that's a major compromise? Probably no. I do think there are things we could've done better had we had some of the tools that our young engineers have today, such as computer-aided design systems, CADS systems, systems that are more automated in design processes rather than drawing on a drafting board and a T-square, as we did in the olden days. But that's to me where you can make your benefit of it. And I think eventually it'll come along.

STONE: Has your baby been everything you thought it was going to be?

COHEN: Yeah, it really has. I mean, I'm very proud of it. And I think it's really been very, very good. I—and I think it's going to fly for a long—I think it's going to fly for a lot longer. I think one of the things we did is: we picked up technology that, in the'72 time period, that still stuck with us. In fact, they're making modifications now. They're changing the cockpit. They're upgrading what the cockpit looks like. The so-called glass cockpit,

where we do go away from the electrical mechanical devices to more electrical devices. So, I think the Shuttle will be upgraded. But it will be flying a long time. And I think successfully. I wish there would be ways to make it to reduce the cost to orbit. I—and I wish they could do that. But it's a complicated—the other thing is, we try to do—is we try to do a lot of things for a lot of different people, and that does make the flight a little bit more expensive.

STONE: Can you tell me what your gut felt like the day *Challenger* blew up?

COHEN: Well, that, to me—that really—I think I recognized—I was in the Control Center—in fact, I was sitting in the Control Center with Chris Kraft. We were sitting in the Control Center together. I'd just got back on a trip. I was head of—when that happened, I was head of research and engineering. And I was really not working on the Shuttle at the time. I was working off on Space Station and advanced technology, and I'd just returned the morning I saw it blow up. And I guess, in that point in time, I recognized the—I recognized what the problem was.

I mean—I shouldn't say that. I didn't know it was the solid rocket booster. I thought it was—everybody thought it was the main engine, the liquid engine. But I did recognize the significance of what happened. I knew there was no way, with that type of activity—there was no way we were going to save the crew and we've got a big rebuilding now. I did think, though—I guess what I did think, where I was wrong—I did think after living through the Apollo accident—tragedy that this was going to be an easier problem to fix, because once we recognized it was the solid rocket booster that was a pretty simple thing to fix. In my mind, I mean, because I—we—you could analyze what the problem was. I mean, it was a bad design that could be fixed. But I guess in retrospect, we did very much like we did in Apollo. We went through every system and made every—and looked at

everything we could do to make it safer so we could get it safe again. And it took us longer than I thought. But it—but we were able to fix it. But I did recognize the significance right away.

STONE: Mr. Cohen, there was—there's a vast difference, I think, from a public perception, from the Apollo fire and the *Challenger*. After the Apollo fire, people wanted us—we still had a goal. After *Challenger*, there was some serious talk in Congress and among other places that, "Well, maybe that—maybe we just don't need to be doing this. There's no reason to do this."

COHEN: Yeah.

STONE: Did that—were you aware of that?

COHEN: Yes, I was. And, of course, that's where we really coined that phrase "A ship in the harbor is safe, but that's not what ships are built for." My deputy—I became Center director about that point.

STONE: Yes.

COHEN: And my deputy was a great guy named Paul [J.] Weitz. He was an astronaut. And Paul and I had the job of trying to figure out how we were going to get the astronauts and how we were going to get the [Johnson Space] Center going again. And I think when you really got down and started talking to people, they really wanted to fly again. The people at the Johnson Space Center really wanted to fly again. And that's what the business we were in. And we felt we did have a mission to do. We did have satellites to put up. We did have

research to do in orbit. We did have things that we felt were good for humankind that we could do in orbit that we couldn't do on the ground, and that the Shuttle was the place to do it until we had a space station, until we could get a space station going. So, I think in that context, we were able to convince ourselves and we were able to convince the people at the Johnson Space Center. As a result, I think we were able to convince Congress and the public that was what we wanted to do.

STONE: But that must've been an extremely trying time because—

COHEN: It was a very hard time. Yes, it was.

STONE: —you had essentially two jobs. You had—you were in charge of rebuilding that Shuttle—

COHEN: Right.

STONE: —and at the same time, you got a—you've got all these people whose heads are hanging low—

COHEN: That's right.

STONE: —and you're trying to build them up.

COHEN: Yeah.

STONE: How'd you do that?

COHEN: Well, I really went back—what I did is I—again, I took the lessons from people I learned from, like George Mueller, George Low, Chris Kraft. And I took things—and Frank Borman—things that I learned from them, and I went back—I used the analogy very much to when a football team or a baseball team is having problems. You go back to your fundamentals. You go back to paying attention to details. What is your goals? What are you trying to do? How do you fix it? And we just went back paying attention to our details. Trying to see how we fix the things that were wrong and with a motive of how we got things going again. And as a result, everybody jumped in and we had teamwork again.

STONE: And how did you feel when the Shuttle flew again?

COHEN: Well, I was quite elated. I've got to be honest with you, that was very—that was probably the most nervous I've been in a long time. But we had a great crew and a great operations team. And I think—and a great contractor team that helped us get the vehicle ready to go again.

STONE: One of the things you did to stabilize the Center was have each directorate report directly to the head as opposed—tell me about that. Tell me about that organizational method you used.

COHEN: Well, what we did is, we had—the way we operated is that I would have meetings with each directorate that reported to me. We would have one-on-one meetings once a week. If they could come in—like a Gene Kranz could come in and tell me what was his problem. Each person could come in and the head of the Flight Crew Operations Division and the Astronaut Office, and each group would come in and tell me what—(excuse me)—what

issues they had. What they thought ought to be fixed. What they—what their complaints were. And I clearly stated to them, "I'm not going to be able to fix everybody's problem. But if I can't fix it, I'll tell you why I'm not going to do it." And I think I became very successful. Now, I—to be honest with you, that wasn't original with me. I learned that from Chris Kraft. But that's—but it puts more of a human touch, so people really could contact me and work with me on a day-to-day basis. My door was always opened and we would always listen to people's problems.

STONE: There was a larger public relations problem, though, with the people outside the space center. People just, like, didn't care anymore. I mean did that—did you find that shocking or—?

COHEN: Well, I did a little bit. But I think what—let me tell you how I worked that. I worked that—I got a very great deal of help from the Greater Houston Partnership, from the people at the—in downtown Houston. People with—you know, with Jim Koehler and the people there—

STONE: Yeah.

COHEN: —were very helpful in keeping the interest of Houston up. And the people in the—in Houston helped me with the—at the national level. So, I had a great deal of support from our congressional delegation, whether it be Democrat or Republican at that time, and also from the Greater Houston Partnership. So, I had a lot of support. And I interacted with them quite frequently. I was a member of the Greater Houston Partnership. And I used to go downtown quite a bit and spend time with them, and I had just a lot of support from them. They were very helpful. They were very supportive. And then, of course, we became a—Dr.

Debakey became very, very helpful to us and we became very helpful to Dr. Debakey in some work that he wanted to do. So, we had a good relationship with the people of Houston and with our congressional delegation.

STONE: Did Space Center Houston come about because you needed to change your image or what?

COHEN: Well, Space Center Houston was—we wanted Space Center Houston for several reasons. One, we were—felt that we were inadequate in what we were doing in allowing people to share with us what was going on at the Johnson Space Center. And over and above that, there became a security issue. If you recognize how we used to do—there was a lot of issues with it in letting people wander around the Center.

STONE: Yeah.

COHEN: I mean, that became a real security issue. I mean, when you looked as Center director and you saw what was happening—and I'd look out the window and see all these people wandering around the Center, not knowing who they were or what they were—you became a little bit concerned: "Are you going to have a safety issue?" Now the result was to build Space Center Houston, which now the issue was: you had to charge people, because we had to pay for it; so, that was an issue with people. But in all honesty, we did it for several reasons. One, we weren't satisfying what we thought was the public need; and two, we did have a real security issue. So, with those motives, I was convinced that we needed to do something different. And that's really how Space Center Houston came about. The idea came about, I should say.

STONE: What do you think NASA could do to improve its public relations standings now? Or are the standings good now?

COHEN: I think the standings are good. I think that the biggest problem NASA has is being able to explain what they're doing to the lay person. In fact, a little history on that. And I got burned by that a little bit. The Greater Houston Partnership said, "Aaron, tell us why the—" And some very important people were there. "Tell us why the space program is important?" So, we put some documentaries together. And when you look at the documentaries, they look like a Ph.D. thesis. And so, I took that—I didn't recognize that myself. And I took that to the Greater Houston Partnership, and they said, "This won't help."

STONE: Yeah.

COHEN: They said, "You're talking to—you—you've got a Ph.D. thesis put together. You didn't put together what the public needs to know." And I think that's probably one of the hardest thing for a technical organization such as NASA to do. They know so much technically and they're concerned about how they—they're concerned they don't want to give you too much of a soft—of a hard sell, but as a result they tend to do it more technically and don't—and do not communicate accurately with the lay person. I think that's the hardest problem for us to do. The information we do have, the research we do, the knowledge we do is—the knowledge we have obtained for people is fantastic. And if we could only explain it to them a little better. It's easier said than done. I mean, NASA tries to do it, but it's easier said than done.

STONE: Well, that's why they need to teach speech across the street over there as well as engineering.

COHEN: Well, that's right.

STONE: To understand—so you can understand those things.

COHEN: Yeah. But it's—you know, it's just very hard to do. It's not easy to do.

STONE: In 8—in 1989, you wrote the *Report of the 90-Day Study on Human Exploration to the Moon and Mars*.

COHEN: Yeah, right.

STONE: 10 years ago. What's happening?

COHEN: Well, I think a lot's happening. I've got to be honest with you: that was another great point in my career, to do that study. It turns out it was probably a little bit more expensive than people wanted it to be, so it didn't go over too well. But in all fairness, I think it was better than people accepted. Because our—the way we costed it was really a long-range program that was going to do—it was where we were going to go back to the Moon, this time to stay, and on to Mars. That's what President [George H. W.] Bush stated that we wanted to do. And when we priced that out, it became very expensive; but if you really looked at the missions, they weren't that out of the ordinary when you compare it to the Apollo cost. I think the framework was good. I think there have been studies since then.

I think the time probably was not right for it. I think there were other circumstances within the country, such as the problem with the monetary system in the Savings & Loan. So, I think things really weren't right—

STONE: Yeah.

COHEN: —for us to spend that money. But what's happening is—I'll tell you what's happening under Dan [Daniel S.] Goldin, which is very positive. We are sending robotic probes to Mars, to other planets. There are studies to see how you would send humans to other planets, essentially Mars. And I'm convinced that that report is a forerunner; and I'm convinced that all this will come to pass. I'm convinced that students of mine will—if they desire to become astronauts, will be able to walk on Mars. So, I'm convinced that is going to happen.

STONE: Mr. Cohen, we probably would not have gone to the Moon when we did had there not been a Cold War going on that required—

COHEN: That's true.

STONE: —the missile gap to—

COHEN: Right.

STONE: —catch up. So, is it going to take something like that now to propel us on?

COHEN: Well, I'm not sure it's going to take that. I do think, though, your point's well

taken. The—you know, you go back and why was the space program started? It was not started for science or technology or economics. It was started because of the Cold War. And so, you're absolutely right. But I do think that there does have to be a need, a need that causes the public to see the importance of it. Now what's that need going to be? I don't know.

STONE: That's my question.

COHEN: I don't—.

STONE: What is the need for you to go to Mars?

COHEN: Well, I think there is going to be a desire of understanding the existence of the solar system. Just a—just to give you what little things that have been found out to date. If you look at what the Hubble Space Telescope has found out—and I'm plagiarizing a little bit from what I've heard people say—but the people that have looked at the Hubble Space Telescope say they've discovered billions and millions of—

STONE: Yes.

COHEN: —galaxies. In these galaxies, you have billions and billions of solar systems. And in these solar systems, you have billions and billions of planets. The universe as we know it has been in existence for 10 billion years. And so, are we going—is there someplace—something out there that has life or culture equivalent to ours or above ours? I think that is going to be something that people are going to want to know and to find out, especially with some of the discoveries that have been made at the Johnson Space Center. And the other

thing I think that's important, that I think you'll find, that people are wanting to know why the ecology has changed on Mars and what could that do to—what could we learn from that? In fact, as I was doing the *90-Day Study*, I was working very closely with [Dr.] Carl [Edward] Sagan. And we used to talk about what is it that we're trying to prove or trying to find out? And that was his thought process. That was what he said. That we ought to find out what—why did Mars change? What changed in Mars?

And the other thing I think we have to recognize, the biggest problem I think this world (not the country but the world) faces is our lack of energy. We are not going to be able to rely on fossil fuel. In our lifetime, there's not going to be a problem. But in the lifetime of our children and our grandchildren, fossil fuel is not going to do it. With the Third World countries wanting to come up to our standards, with the population increasing, we're going to have to have another source of energy. Whether it's solar energy or energy from another source—such as helium-3 from the Mars—from the Moon—I don't know. But I think energy and the ecology is going to cause that need. Not a Cold War.

STONE: You moved up to Washington, D.C., in 1992. So, is the view from the top much different than the view from—?

COHEN: Yes, it is. It is. You become a little bit more humble. You become a little bit more humble. You know, at Johnson Space Center we felt we were ruling the roost; and when you got to Washington, you understood that there were other people that had to look at to see what you were doing. But I enjoyed that very much. I did learn a lot. And I felt I contributed a lot. I was there in the latter days of [Richard H.] Truly's—I was Acting Deputy Administrator for Dick Truly. And then when Dan Goldin came, I was his Acting Deputy Administrator for about a year. And so, we did a lot of budget hearings; a lot of going to Capitol Hill and the White House. So, I did learn a lot. And I think I contributed quite a bit.

STONE: Did you also not realize or find out that dealing with these people in Congress makes you feel like maybe we haven't gotten our message across as well as we should have?

COHEN: Well, you know, I think that's—it varies. I think there are some people that are extremely, extremely supportive. And I think there are some people that really don't care. But I guess that's true in many things. I think I can say this, though, very clearly: the Texas delegation while I was there was as supportive as anybody you can want. Democrat, Republican, you really had a fantastic support from the Texas delegation, which would help you sell your story. And there were people in other places that you might think didn't have interest in the space program, such as people from Wisconsin, such as Mr. [F. James] Sensenbrenner [Jr.], who were very, very supportive of the space program even though you might say their States did not have a direct benefit from the space program. So, I think it varied. It varied quite a bit. But I think, all in all, at least in my perception, we had a great deal of support from the Executive Branch and from the Legislative Branch.

STONE: You are not in the business of being a prognosticator. But look down the road 50 years from now. Will there still be a Johnson Space Center? Will there still be a NASA?

COHEN: Oh I don't think there's any question about it. I think there will always be a NASA. I think there will always be a Johnson Space Center. Of course, always is a long time. I do think the mission of the space program is about three different things. First of all, I think we touched on a couple of them. One such as launch vehicles. I think we need to do better in launch vehicles; and I think eventually they're going to have to have a replacement for the Shuttle. What that is, single-staged orbit, two-staged orbit, we're going to have to have some way of getting payloads and people into space with less expense than we do today. I think

we got to work on some kind of propulsion systems, whether it's ion propulsion systems or plasma propulsion systems. I think that's got to happen. And I think exploration will take place. I think we will explore.

STONE: Do we all—do we still have to have men and women out there, though? Or computers are getting smart enough that we don't have to do that, do we?

COHEN: Oh, I—no, I think you still—I think there's a place for both. I think you do need a robotic missions. In fact, I've been on the Mars Architecture Study at the Jet Propulsion Laboratory [Pasadena, California] where we've looked at the robotic missions. But even the people that are very interested in the robotic mission are very firm that you do need men and women in space. There is no question in their mind, the robotic missions are the precursors. But eventually to do the job, you do need men and women. And I think you get very much in support from both the people doing the robotic missions that humans are going to be a very intimate part of the exploration program.

STONE: Why'd you leave NASA?

COHEN: Well, I left NASA because I felt it was time for me to do something else. I always had the desire that I wanted to teach. I've had that desire—I never taught before. I always had the desire; I wanted to teach; and an opportunity was coming to me at the—at several places. One at MIT and one at Texas A&M. And, of course, I'm a graduate of Texas A&M and I felt that it was a good time for me to go. I didn't want—I—but leaving NASA was very hard. I mean, it was very hard; and it was—they treated me very well. I enjoyed it. I had a wonderful career. I couldn't think of anything I'd want to do more than I did. But I did want to teach. And I had an opportunity to come here and teach senior mechanical

engineering design, which is something that I can use my talents on. A lot—many of the things we talked about today are examples how I get my students and teach my students. In fact, we design projects very much like what we're talking about. The futuristic projects, these students do that. So, I had the opportunity to come teach; and that's why I left. And I—

STONE: Your students still want to go to the Moon or go to Mars?

COHEN: Yes, they do.

STONE: Is this still a—is this still something that engineering students are interested in?

COHEN: Yes, they are. And it—well, of course, it does challenge the engineering in terms of structures, materials, guidance systems, propulsion systems, environmental control systems. So, it really taxes them on their technology and their advancement of the state of the art. So, they're very interested in it. And I'm very fortunate to teach here at Texas A&M because I do get a lot of rejuvenation myself, you might say, in working with the students.

STONE: You could've stayed making microwaves. Are you glad you came to NASA?

COHEN: Oh I can't—I mean, yes, I'm very happy. I'm very happy I came to NASA. Yes, I am.

STONE: At the time you did, it must've been terribly exciting.

COHEN: It was extremely exciting, and I'm—I feel very, very fortunate to have worked with

the people I had the opportunity to work with and the things I had to work on. It was just a wonderful, wonderful career for me.

STONE: 8 or Moon landing or the first time the Shuttle flew? The biggest moments of your life?

COHEN: Well, let me give it to you in sequence.

STONE: All right.

COHEN: First of all, I have to say the most significant event in my career was Apollo 8, as we talked about. I think that because humans left the influence of the Earth for the first time. And that had to be a very, very significant event. The second most important thing in my career was the first flight of the Shuttle. Because that to me was the most complicated vehicle we ever flew. And the second most—the third one was actually the second flight of the Shuttle, because that showed we had a reusable vehicle. And the fourth one, which although was very, very important, was the Apollo lunar landing—was the fourth one in my estimation. So, that's how I rate my goals and my—

STONE: It's interesting that everybody's making lists—

VOICE OFF CAMERA: Ron, I'm sorry—

VOICE OFF CAMERA: And we're recording.

STONE: If you look at all those lists that people are making now at the—as we come to the end of the 20th century about great events of the 20th century, Apollo 11 is way up there.

COHEN: Yeah.

STONE: 8's not even there.

COHEN: Well, I think that's right. And I think when you—like the National Academy of Engineering is—which is the most prestigious engineering organization in the country came up with their list and they actually have Apollo 11 as one. They don't mention Apollo 8.

STONE: Yeah.

COHEN: You're absolutely right.

STONE: Yeah.

COHEN: And I think that's probably right from a perspective of the country and of the world. But if you really look at the engineering and what you—as you pointed out, what you were really trying to accomplish, Apollo 8 has to stand out. And I've got to tell you: I don't think today that you could make a decision on—to do Apollo 8 like we did. I mean, this was something George Low thought was important; for whatever reason, he thought it was important. He was able to put it together. He was able to sell it. And we were able to do it. Could you do something like that today? I'm not sure you could. I mean, I'm not sure that you could because there are a lot of risks. I mean, talk about risks! There were—you said,

you asked me and I passed it off, like, "Yeah, it was easy." But there were a lot of risks in doing Apollo 8. And—that's something that not too many—

STONE: There are debates going on to this very day as to whether you all really were ready to do what you did with Apollo 8. Obviously it worked! But the question is: were you really ready?

COHEN: Well, you know, I really think so. I mean, I really think we were. You know, at some point in time you've got to do what you set out to do. And we set out to leave the Earth and not stay around in low Earth orbit anymore. We said we were going to go someplace.

STONE: Did that mean you'd learned so much on those previous flights that it was just—you just didn't need to do the same thing over again, or what?

COHEN: Well—yeah, I think that's right. Well, I—whether you learn, I think you accomplish what you set out—

STONE: You—yeah.

COHEN: —to do. And I don't think you were really going to learn much more—I mean, you know, you couldn't study—you can't study forever. And—

STONE: So, somebody was too conservative in 1968 or '69 when they started building up all of this stuff?

COHEN: Well, I think we looked at various plateaus. And I think if we'd have had some

problems in those, you probably would have regrouped. But I think it's like anything else, we were successful. I mean, what were the things were the biggest issue, I guess, and I think the—Frank Borman probably said it best. Somebody said, "Frank, what's going to happen if once you get into lunar orbit and you can't fire the service propulsion system?" You know, that's the one engine—the one single engine we talked about—that gets you out of lunar orbit; and if you can't fire it, then you're going to stay in lunar orbit. I mean, there's no way to get out. There's no way to be rescued. There's no way to get out. And Frank says, "It's a bad day." Well, that's right.

It would've—if you couldn't have fired that service propulsion system to get out of lunar orbit, you were—it was going to be a very, very bad day. And that was the biggest risk. So, the service propulsion system probably was the single most questionable item of, "Was the mission going to be a success or not?" The guidance system, we felt was good. The environmental control system, the hatches, the so forth was—were we going to be able to get out of lunar orbit? And of course, that is a very testable system. I mean, we did a lot of testing. And ground test versus in-flight test is not going to accomplish very—different. So, we were very, very, very, very satisfied that we had a very, very good propulsion system. A sound propulsion system. So, in that context I don't think we were nervous. I mean, well, I shouldn't say "nervous." We were nervous. But I don't we had any technical issues that we were going to learn anything more about.

STONE: We're in the business of history here today. Not romanticizing something.

COHEN: Yeah, right.

STONE: And I'm not trying to do that. But I am curious, as historians may be in the future,

as to whether people like you and the actual astronauts who flew ever discussed the possibility that these things wouldn't work? I mean, really sat and talked about it.

COHEN: Well, I've got to be honest with you. I wasn't involved in the real, you know, like, what if it didn't work from a point of view of a more of a sociological problem. I was involved in discussing it more from a technical problem. What did we have to do to be sure it did work? What gave us the confidence it worked? I didn't talk about the social problems or the society problems if it didn't work. And when we came to the details of (really) the engine design, the engine testing, that's where we felt very, very comfortable. Because we had a very, very sound test program. There were no shortcuts taken in the test program. There were no shortcuts taken in any anomaly or discontinuity in the test results. And we were able to really correct everything we felt was a problem. So, we felt very comfortable about it.

We did a—in fact, I remember doing a very detailed review of all the propulsion systems for Apollo 8 to show that we were good. And we put together a large notebook for George Low on every test we did, every discrepancy we had in every test, and what was the fix for every discrepancy and how we validated it. So, you know, I think we did as thorough a job as we could do possibly—humans could possibly do. But I never was involved really in "what if this didn't happen?" It would've been very dire—it would've been very bad.

STONE: Did you ever ask yourself whether you were asking man to do more than man could do? I mean, your machines are going to work. And all these things are going to happen right. The is man the wild card in all this?

COHEN: Yeah. Well, I think you have to be sure in your design that you don't ask the man or the human (shall we say?) to do more than they can do in a given period of time. And

I think in Apollo 13—and if you look at the depiction of what happened, I think—and with all those failure modes, we may have been asking the humans to do more—or probably more than they should be asked to do. But, of course, that was a very abnormal situation, and they did overcome it. And, you know, I have to say from my point of view of Apollo 13, in my mind the hero of Apollo 13 was Fred [W.] Haise [Jr.]. Because I think Fred probably knew—I mean, I know Fred very well and I've worked with Fred. In fact Fred, in the early days of the Shuttle Program—Fred was on my staff in the Shuttle Program—I mean, the Orbiter Project Office. And Fred probably knew more about that vehicle than anybody else, and probably had it all figured out before anybody else could tell. So, Fred—but I think you do have to be careful you don't ask humans to do anymore than what we did. And I think we do take that into consideration, because astronauts and operations people are part of our design review boards. And they sit in. So, they don't allow us to do that.

STONE: But those people, those astronauts, if they are the kind of "right stuff" people that fiction makes them out to be, will say, "Oh yeah, I can do that. No problem."

COHEN: Well, I think, you know, you'd be surprised. You'd be surprised. If you sit in these meetings, in these change boards, they speak up. These people do not—are not potted plants. I mean, if they don't like what you're doing, they let you know in no uncertain term. A Frank Borman's going to let you know, in no uncertain terms, he's not going to do that. Or a Gene Cernan will let you know. Or any of the astronauts today. Rick [Frederick H.] Hauck. A Rick Hauck is going to let you know that that's not what the right thing to do is. So, the astronauts of today, the astronauts of yesterday, are not going to sit back. They're no shrinking violets. They're going—they're not going to sit back and not tell you what they think. They're not doing that.

STONE: That Space Station out there—that's out there, or going to be out there—or—

COHEN: Yeah, that's right.

STONE: —we—the Russians made us feel like everybody had overstayed their time there and men were—men and women were doing more than they really should do and could do. And that got to be a situation where I think the American public began to ask a lot of questions about whether this was wise or not.

COHEN: Wise, and should we participate? Should we send astronauts back to the *Mir*? Well, I think that's right. I think anytime—you know, it's easy anytime you have a potential failure or a failure that becomes life-threatening, you question it. So, in this question, I think we gained an awful lot from going to the *Mir* and working with the Russians. I think today, if you look at the Space Station (and I've got to be honest with you, I'm not that much—I'm—I've been away from it a while, so I'm not really an expert) —

STONE: I understand.

COHEN: —but if you look at what—where the Space Station stands, I feel firmly that if the Russians don't participate with us, there's ways we can get around it. On the other hand, I think if they can participate, we probably would do it faster, maybe, with a little less money. But I do think we can handle it without the Russians.

STONE: Which brings up the whole point of international cooperation that's going on now. Is there really that much or—or not?

COHEN: Well, I think there is. I think, you know, there's Russians and—we're talking about Space Station in particular. There are the Russians. And of course the—you've got to recognize, there are the Japanese, there's the European Space Agency. So, I think the international cooperation's very large. There's also a lot of international cooperation in the robotic missions, the missions the Italians are playing a big part in, in sending robot—the unmanned missions to Mars. So, are the French; the CNS. And I think—I really think that space, since I really feel space is an international enterprise, I do think international cooperation is extremely important. And I don't think it's really going to be a success unless you have true international cooperation.

STONE: We are—we're in the middle of 1999, as this is being recorded. Are you surprised that there has not been more of a commercialization of space? That—?

COHEN: Well, I wish there was more. I think in some regards the [commercialization] of space has been very good. If you look at the communications satellites, I think it's been very good. I think the real issue has been primarily the lack of launch vehicles, commercialization of launch vehicles. So, I'm a little concerned about that. As you may or may not know, I'm doing some consulting with a company [Kistler Aerospace Corporation] that is trying to do a commercial reusable launch vehicle, with George Mueller, who again is one of the key players in the Apollo Program. (He was head of the Apollo Program.) And I think that it's inevitable that we will eventually have a commercial reusable launch vehicle. But I—and I think it's needed.

In fact, that's one reason why I got involved with George Mueller, is because I saw the need for a commercial vehicle that's built purely with commercial money and asked—and do not—does not ask the government for any funds; and that's what we're trying to do.

We're not asking the government for any funds because I do think that's going to be step to commercializing space. And I think it will happen. But I think industry has to change. Industry has to be a little bit more, you might say, willing to take a risk rather than having the government always come to its rescue funding. And so, until that happens, I think we're going to have a problem. Also—but also, they've got to see the return on investment so that their stockholders will be satisfied with what they're doing. So, it's a give and take. But I think the market's there, and I think eventually it will come.

STONE: Thank you, sir.

VOICE OFF CAMERA: Clear.

STONE: Okay.

[End of Interview]