ORAL HISTORY TRANSCRIPT

ROBERT E. "ED" SMYLIE
INTERVIEWED BY CAROL BUTLER
BETHESDA, MARYLAND – 17 APRIL 1999

BUTLER: Today is April 17, 1999. This oral history is with Ed Smylie at the Marriott in Bethesda, Maryland. The interview is being conducted for the Johnson Space Center Oral History Project, by Carol Butler, assisted by Rebecca Wright.

Thank you for joining us today.

SMYLIE: Thank you for inviting me.

BUTLER: To start with, let's talk about how you became involved with NASA. How did you find out about the opportunity? How was the interview? Along those lines.

SMYLIE: I was working for Douglas Aircraft [Company, Inc.] in Santa Monica, California, at the time that NASA was formed. That was probably a little bit after NASA was formed. This was in the late fifties, early sixties. I was working in environmental control for the DC-8 airplane, ended up there because my brother worked there. When I finished my master's degree at Mississippi State, I went to California to work for Douglas, a fantastic engineering organization, a very, very good company. I was very happy there, but when they announced the Apollo Program, Douglas was late getting into the competition. They teamed with G.E. [General Electric Company], lost to North American [Aviation, Inc.], and it appeared that Douglas would have no significant role in the Apollo Program. I very much wanted to be a part of it.

Also they announced the move to Houston [Texas]. I had worked in Houston when I first graduated from college for almost two years. That's where I met my wife. She was

from Texas. So we decided that maybe we would try to join NASA [Manned Spacecraft Center] in Houston.

NASA was building up very rapidly. They announced interviews in Los Angeles in, I guess it was early '62 or late '61. I went to interview. The person who interviewed me was the manager of the NASA resident office in St. Louis [McDonnell Aircraft Corporation, Missouri]. For the life of me, I can't remember his name. Anyway, he interviewed me.

Within a week or two, I received an officer to go to St. Louis or go to Houston to work in what was then called the Life Systems Division [LSD]. I, of course, chose Houston because that's where we wanted to go. I knew none of the people there, had not met any of them, but I moved to Houston and reported to the Lane Wells Building, one of the satellite facilities that we had in Houston at the time. We'd not built the Center yet. I met Dick [Richard S.] Johnston and Ed [Edward L.] Hayes and Jim [James V.] Correale [Jr.]. Stan [Stanley C.] White was the division chief at the time, Doctor. Dick was his deputy. Ed was running, I guess, all of the environmental control systems work.

They told me I was going to be head of the JSC Environmental Control Section, and my office was down the hall, laboratory on the left, and sent me down there. I still didn't know anybody. Walked in the door, Joe [H. J.] McMann came over and shook my hand and said, "May I help you?" I said, "I'm your new boss." That's how I joined NASA.

BUTLER: That's quite a story.

SMYLIE: And Joe still tells that story. So it was a start. Right away I got involved in the Mercury Program. John Glenn's flight was about two weeks later, I think. I got there—when was John's flight? February the 12th, something like that?

BUTLER: February 20th.

SMYLIE: February 20th. I joined February 12th. So I got to see John's flight and got involved in a controversy among two of my employees about who was going to sit on the control console. I had to decide that. They told me that was my job to make that decision. I hadn't even met one of them.

BUTLER: What a way to start.

SMYLIE: That's the way we ran the agency in those days. They just told you you had to go do it. So that's how I joined and started.

BUTLER: Did you go down to the Cape [Canaveral, Florida] and watch his launch?

SMYLIE: No, I watched it from Houston. Frank [H.] Somonski [Jr.] was our guy on the Control Center, on the console, for the Environmental Control System [ECS] at the Cape. That was before they had formed the Chris [Christopher C.] Kraft [Jr.] Flight Ops [Operations] Directorate, and most of the people on consoles came out of engineering. Shortly after that, they did form the Mission Operations Directorate to become the responsibility for conducting missions, and Frank had to make a choice as to where to go, and he decided to stay in engineering.

BUTLER: So they would pull people from engineering, then, to make up that mission operations team?

SMYLIE: Right. There was a core group under Chris that were missions operations folks, but on the individual consoles it was largely people from engineering. But then they established

that as a separate discipline, flight control, in a separate organization. It worked very well over all these years.

BUTLER: As you came in, in the midst of the Mercury Program and, as you said, Apollo had already been announced, what were your immediate duties in the brief span of time you did work on the Mercury Program?

SMYLIE: I did work on Mercury all the way through all the flight program. That was run by Kenny [Kenneth S.] Kleinknecht, a very simple management format where we had regular meetings and he established action items, and every week we got together and went over our action items and how well they were being accommodated. It was a relatively small program, actually. One man could run it pretty much. Kenny ran that program almost himself.

We had some problems with the ECS that had to be worked. It was a very simple manual open-loop system. There was almost no data available to the crew or to the ground as to how the systems performed, and it was a very manual operation. The suit cooling was on the basis of boiling water in vacuum with a little valve and you just had to guess at where to set that valve. It only took just a fraction of a degree to change the way that it operated. We were measuring the suit duct temperature, which was a very inaccurate way for him to control.

At one of the meetings in St. Louis I suggested we put a thermocouple on the dome of the heat exchanger, which is the same way that your home air-conditioner works, to control what's called super heat. We did that. I've forgotten which mission we first put it on, but that worked very, very well for the rest of the Mercury Program. Frank and I have a patent on that. No, we don't, not on that, a separate thing.

The water separator to collect condensate was a sponge, and every now and then you'd hit a switch to compress the sponge and supposedly push the water off into the tank. The sponge didn't seem to be collecting any water, any condensate. Frank and I developed a—we surmised that the water was bypassing that sponge and it was clinging to the duct wall in zero gravity, so we put a wick in a little device that would pass water but not air, and put that in line. Lo and behold, it collected the condensate and we were able to wick it off into a tank. We have a patent on that. Not that it's worth anything, but we have a patent.

BUTLER: Oh, sure it is.

SMYLIE: So that worked. That was interesting in the way we did business in those days, because we showed that to John [F.] Yardley, who was the McDonnell guy responsible for Mercury, and he said, "Let's try it." We built it in my shop. I put it in my briefcase, took it to the Cape, handed it over to a McDonnell technician. They ran some tests that I supervised, and we put it in. I mean, that was it.

BUTLER: Streamlined process.

SMYLIE: That would take a year to do in the current way that we manage programs. In the first place, putting anything in a system, that's a contractor's responsibility, the contractor would say, "Okay, it's your system now. We're no longer responsible for it." That didn't happen with John.

BUTLER: That's great. Helped get what needed to be done, done.

SMYLIE: For the twenty-four-hour mission, we had to add a lot of expendables. We had to increase the lithium hydroxide [LiOH], we had to add oxygen, had to add water. We finally got a working CO_2 [carbon dioxide] sensor in that mission. I remember that after the hold, that CO_2 absorber was buried out in the spacecraft, to change it, probably a much delayed—Kenny Kleinknecht called me in. I think Kenny and Deke [Donald K.] Slayton and me and maybe Bill [William M.] Bland [Jr.] were in the meeting, and Kenny says, "Do we have enough to make the mission?" And we had run many, many tests on those kind of systems and I said, "Yes, I think we have enough to make the mission." Kenny said, "Okay. Let's go." That was the meeting. And we made it, just barely.

BUTLER: That's the important part, that it was made.

SMYLIE: On the last orbit, the CO_2 level started going up. Our CO_2 sensor worked.

BUTLER: That's good.

SMYLIE: We probably could not have made another revolution with that system, but we made exactly—but a lot of things were running out about then, so it was time to end that mission, and we did make the twenty-four hours. That's probably about it on Mercury. I was not involved in suit development. That was really behind us by the time I arrived, and it was pretty much an offshoot of a Navy pressure suit. Didn't have any real requirements on it other than being able to operate pressurized in a confined environment just like an airplane cockpit, so it was not significantly different, I don't think, but I wasn't involved in it at that time.

BUTLER: Looking back a little bit, actually before you arrived at NASA, Yuri Gagarin had been the first man in space, and Alan [B.] Shepard [Jr.] had gone up into space. When you heard about those events, what were your thoughts at the time?

SMYLIE: Frankly, I don't remember about Gagarin, what I thought. I know I was there and I know it happened, and I was probably excited about it, but I just don't remember.

Alan Shepard I do remember. I was at Douglas. We were all gathered around a drafting board with a small radio, listening to it. I was very, very excited and pleased about it. But that didn't affect anything about what I would do until [President John F.] Kennedy announced going to the moon and the move to Houston was now decided, and Douglas not involved. I decided I had to go somewhere else. I still have a lot of friends at Douglas, by the way.

BUTLER: Oh, good. That's good to hear, that you have those connections. When you did hear Kennedy's announcement or challenge to go to the moon by the end of the decade and return, just after Alan Shepard's flight, little space flight experience and knowing the technology of the time, obviously you were interested in being involved in the program, but what did you think about the possibilities of meeting that goal?

SMYLIE: I was a young engineer and just wanted to be there and help make it happen. I guess I didn't give a lot of thought as to whether we could or couldn't. I just assumed we could, and went down there.

BUTLER: Good assumption. It paid off for you.

SMYLIE: Yes.

BUTLER: Moving into Gemini, I know you said you were only involved very briefly on Gemini. What was your involvement on that?

SMYLIE: Jim [James A.] Chamberlin was running the Gemini Program, and he had a small project office at that interface with McDonnell. Jim didn't feel that he needed or wanted a lot of in-depth engineering support from an engineering organization, and we, frankly, were interested in Apollo, so we really didn't do a whole lot. We got called in occasionally, or sometimes we pushed our way in, in a consulting role, with the person who Jim Chamberlin held responsible for the ECS, but very little involvement with McDonnell.

Of course, the suits were part of Crew Systems' responsibility. We changed the name somewhere along the line. In the sixties, having an acronym LSD wasn't all that great, so we changed it to Crew Systems somewhere along the line.

BUTLER: [Laughter] Good choice.

SMYLIE: Anyway, Jim Correale was primarily the Gemini suit person and kept up with that part of the program. That was GFE [government furnished equipment] from the division, but I wasn't really involved in it. I was not into the suit business yet. That came later in Apollo. Of course, the division was deeply involved in the EVA [extravehicular activity], EVA planning, but again that was Jim Correale and Dick Johnston, not me.

We had divided up the work about that time. Jim was division assistant for Gemini, I was division assistant for Apollo. I worked Apollo exclusively. Jim worked Gemini exclusively, other than when we thought there was some synergism or overlap between our activities. So the things that we learned on Gemini EVA were very important to Apollo and did transfer over in terms of how you do particularly zero-G EVA, not lunar EVA. So we

learned a lot. In fact, the Apollo Program benefited in a lot of ways from the Gemini Program, but mostly in the areas of docking and flight control and things of that sort, not so much in ECS, although a lot in the EVA. But my involvement in Gemini was quite minimum.

BUTLER: Thank you for that, overview of the Gemini, at least. So in Apollo, you first became involved with that just about as you were starting?

SMYLIE: Yes, pretty close. It was sort of transition from Mercury into Apollo. I don't know exactly when and how that all happened. It was just sort of a natural changeover from Mercury to Apollo. I don't know what the percentages were over time, but we had to do both at the same time.

BUTLER: What were your roles and responsibilities during your work on the Apollo Program, or at least initially to start with?

SMYLIE: Well, initially it was environmental control system for the command module [CM] and, a little later, the lunar module [LM], and then very early on involved in what we ended up calling the extravehicular mobility unit, or EMU, which is a combination of the suit and the backpack. We started that program off to build a prototype. I don't think we had any idea how large that program was going to become, because our first contract was just to build a single prototype, was under a million dollars.

We had no specification. The only spec we had was Kennedy saying, "Go to the moon and come back." I remember us trying to evaluate proposals. Me and Dick and Matt [Matthew I.] Radnofsky and Walt [W.] Guy and Jim Correale and Ted Hayes sitting around saying, "What are we supposed to do with this system? Does it get out on the moon, look up

at the Earth and get back in? Does he walk around? Does he have to walk? Does he have to pick up any samples?" Nobody had told us. We didn't have any specification of what to do on the moon, and we were off developing a system. So we made it all up.

BUTLER: Worked pretty well.

SMYLIE: Over time, you know, we began to get experiments, tools, and so forth, so over time the specification developed, but at the start there was nothing. We had to make it up. The proposals we got from that initial procurement, I may not remember all of them, but they were teamed in a way that the best suit proposal and the best portable life [support] system [PLSS] proposal were on different teams. Being, I guess, not all that conversant with procurement policy and how you did things, we picked the best PLSS and the best suit and told them to get together and make a new team. That didn't work very well. We eventually had to split it up. We became the integrating contractor, and we had a suit contractor at ILC [International Latex Corporation] and a PLSS contractor [United Technologies] Hamilton Standard. That's another story that would take another two hours to tell.

BUTLER: Well, hopefully you can break that down.

SMYLIE: But we eventually made it.

BUTLER: What were some of the specifications on the suit? Can you give us little details about what were things that you looked for in selecting these contractors?

SMYLIE: Let me think about that a little bit. Let me go back even a little earlier, the fact that there were no specifications. I think the first RFP [request for proposal] probably was one or

two pages long, so to build us a suit and a backpack that would work for a couple of hours and could walk around in, whatever. I don't know. I don't remember. But what happened over time is that it was clear that we were going to become essentially the third contractor. Crew Systems had become the third contractor in the Apollo system. There was the command module, the lunar module, the EMU.

A man named Joe [Joseph P.] Loftus [Jr.] in the Apollo Program Office suggested that we needed to develop a top-level spec and have a contract with the Program Office on what we were going to do. Joe, coming out of the Air Force, was familiar with an Air Force project management system that we adapted and had G.E. support helping me with some of the configuration management and documentation and so forth. I enlisted Joe Fernandez [phonetic], who was leading that G.E. effort, to help me develop the spec, so we worked with the Project Office and with our people over probably a month or six weeks or maybe longer to develop, in effect, a specification as to what that system would do, and got the Apollo Program Office to sign off on it.

So from then on, we operated in a contract mode with the Project Office. If they wanted us to do something different, they had to process a change to their spec. If we thought we had to do something different, we had to go to them and process a change to that spec. I don't have a copy of that spec. I assume it's around somewhere in the archives.

BUTLER: I'm sure it is.

SMYLIE: But that made it a much more businesslike proposition, even made it easier to work with the astronauts, because they always had things they wanted to have done or changed, which was fine. Most of the time what they wanted to have done was the proper thing to do, but it put the discipline in that if you changed that spec, you had to process the documentation to do that. So you knew what the baseline was all the time.

It was a work in progress all the time, because, as you know, the first foray on the moon with Neil [A. Armstrong] and Buzz [Edwin E. Aldrin, Jr.] was very short. Turns out we had more capability and we were retaining more contingency than we needed, and we were able to continually increase the time on lunar surface and the number of EVAs. We added an extra water tank. I think we added extra lithium hydroxide over time, more oxygen. We increased the contingency capability and were eventually able to do seven hours. We reached the point where it was a workday. You couldn't go any more than that. When you get up to seven or eight hours, that's about as long as anybody can work, especially under those conditions.

BUTLER: Certainly.

SMYLIE: And we eventually got it there. Then we had the interface with the lunar rover, where we were now much, much further away, so we had to increase contingency capability and we developed the buddy system, at George [M.] Low's suggestion, where if we had a system malfunction, you would connect the two astronauts together and they would share the system on the way back to the lunar module. So all of that was developed between the first EVA and the last foray on the moon.

BUTLER: Very versatile that the suit you would be able to just, without making very major changes, be able to help it grow to meet the needs.

SMYLIE: You can rely on it.

BUTLER: That's great. As you were working with the suit, the EMU, you were also involved with the environmental control system, as you said, in the command module.

SMYLIE: Right, and the lunar module.

BUTLER: And the lunar module.

SMYLIE: The lunar module came a little later, but not much later.

BUTLER: What were those systems and the needs, and how did you evolve those?

SMYLIE: A lot of it was heritage, of course, from Apollo—I mean from Mercury and Gemini, although I believe Gemini used molecular sieves for CO_2 removal and we used lithium hydroxide in both the command module and the lunar module, a chemical that reacts with CO_2 to form lithium carbonate and water, is the reaction… There [were]… differences between the command module and lunar module, [the] number of people, amount of time, and the means of heat rejection. The command modules had radiators for which we were responsible in the Crew Systems Division, and the lunar module used water boilers. The water boiler in Mercury, as I mentioned earlier, was sort of marginal in being able to control it and operate it.

We developed, with Hamilton Standard, something called a porous plate heat exchanger, which actually sublimated water rather than boiling it, through a porous plate. It's worked much, much better. So that was a new development. It was strictly experimental. I funded a couple of research activities at Rice University [Houston, Texas] to try to theoretically describe the performance, which we were never able to adequately do, so we based it strictly on experimental results with that system, which made Dr. Gilruth a little nervous. He tried to get me to explain that several times. I never could, to his satisfaction. But it worked.

The radiator was a special problem in the command module ECS, because translunar and transearth, you're out of Earth orbit, and the spacecraft can get quite cold on one side and quite warm on the other. We came up with what we call the barbecue mode, so the spacecraft continually rotated all the way to the moon and back, to try to even out the temperatures. Even so, in low heat rejection loads, the radiator got quite cold. I believe—I'm sure it was Walt Guy that probably came up with the initial idea of what we called a freeze-thaw radiator, that just let it freeze, and it would freeze selectively and, therefore, reduces capability to reject heat. When you got more heat in, it would thaw out and would begin to work again. That was another one that was hard to describe theoretically, but we were finally able to, and made that work. I give Walt a lot of credit, and the people at Ling-Temco-Vought [Inc.] at the time. I guess it was still Ling-Temco-Vought then. That was the radiator contractor, and they kept that business all the way through the Shuttle Program. They still do radiators for the Shuttle, and will probably be doing radiators on Mars some day.

BUTLER: It's their specialty.

SMYLIE: Those were the major differences, I think, in the means of heat rejection. Most other systems and things were common. I tried to make the lithium hydroxide canisters common between the command module and lunar module. We had two separate contractors, AiResearch [Division, Garrett Corporation] and Hamilton Standard, and two separate prime contractors, North American and Grumman [Aircraft Engineering Corporation]. It was just too hard; couldn't make it happen. It was okay, turned out okay. It was a matter of system optimization. Grumman and Ham Standard insisted that their approach to the design of the canister was lighter weight, and weight was a very, very large problem on the lunar module.

I tried to get the suit hoses common so we could take the suit hoses from command module to lunar module when we went over, and not have to put suit hoses in the lunar module. Couldn't make it happen, for probably good reason. Those were some of the things we were trying to do in those days to get commonality and reduce cost and reduce weight. But it all worked out.

The role in ECS development was different from the EMU. The EMU, we were the contractor. The government furnished equipment, we contracted for and we delivered to the Program Office. In the ECS world, we were support to the Project Office. It was a very important role that we signed off on all of the qualification of the system that both North American—I keep wanting to say Rockwell [International Corporation]—North American and Grumman, neither of which exist anymore, it's now Northrup [Grumman Corporation] and Rockwell—Boeing [Company].

BUTLER: Boeing.

SMYLIE: But we had a lot of input, a tremendous amount of support. I spent a lot of time at Downey [North American] and a lot of time at Grumman at [Bethpage] Long Island [New York], interfacing with my peers, who were responsible for developing the system. Generally very much a team relationship. We were not directors [with them] responding to direction; it was more of very much a team relationship in how we got that job done between ourselves and those two contractors. It was a good relationship.

BUTLER: Everybody was just working together?

SMYLIE: I think we made some good contributions to the work. I think that the radiator, as it developed, was primarily due to the work that we had done, that North American

implemented and agreed with eventually. But our role was support for the Project Office and not responsibility for "delivering" the system.

BUTLER: With the command module there were two different—there was the Block I and the Block II. Was there a difference in the environmental control system for those between the two different blocks or was it significant if there was?

SMYLIE: If it was significant, I don't remember what it was. I know there was a Block I and Block II spacecraft, but the only real change I can remember was in the urine collection system which had nothing to do with Block I and Block II, it was just another one of these sponge devices, some that didn't work on Mercury, and I insisted we get rid of it, and finally succeeded in getting rid of it, and put in what we use in airplanes, just dumped it overboard and not try to collect in a sponge. Managed to get rid of that.

I'm sure there were some other changes, and that's the reason I tried to call Frank Somonski, to ask him what they were, but I didn't get hold of him.

BUTLER: Hopefully you can get a hold of him later, and if so, we can add in a few little paragraphs.

You've mentioned a few of the different aspects of the ECS, the urine collection, the lithium hydroxide, and so on. It may be good here to do just a general review, if we could, of all the different aspects of the ECS, what that entailed, each of the steps, if that would work for you. [Laughter] I know that might be asking a lot.

SMYLIE: That's sort of hard to describe in words, without viewgraphs. [Laughter] NASA can't give a briefing without a viewgraph machine.

But in both systems there were essentially two loops in the environmental control system, one for the cabin and one for the suit. In the cabin, it was mostly a heat exchanger and a fan that just absorbed the cabin heat and rejected it either to the radiators or to the sublimators in the lunar module, and circulated air in the cabin. Very simple system.

In the suit loop was where we had the lithium hydroxide to absorb the CO_2 produced by the crew members and a heat exchanger to collect the metabolic heat. This is when the crew is in their suits, hooked up with hoses to this closed loop that absorbs CO_2, condenses out the metabolic moisture produced by the crew, and collects the heat. That's metabolic heat that is produced by the crew member. It also isolates the crew member from the cabin, so if you get a cabin depressurization, you can pressurize that loop and pressurize the suit, and the crew member is protected. So it was a contingency in case of a loss of cabin pressure. But those were the primary functions, was to reject heat, collect CO_2 and reject it, or collect it, and to collect condensate and get rid of it.

The other functions that we were involved in, like biomedical instrumentation, measuring the crew EKG [electrocardio graph] and other factors that the doctors wanted to measure when we developed that hardware, those electronic systems, over time, that we used in both Apollo command module and the lunar module. A lot of crew equipment. The survival gear we were responsible for, life rafts, all the stuff that we had if they landed in the jungle and had to survive for some period of time, or landed in the ocean and had to leave the spacecraft and get in a raft, was all the equipment that we provided directly to the system.

Early on we had the food responsibility. That was later transferred to the medical directorate. Initially, all the medical—when I first joined the agency, when Stan White was division director, division chief, that was all one part, medical and equipment. Later they formed the medical directorate under Chuck [Dr. Charles A.] Berry, and some things like the food were there. It was considered more of a medical thing than it was something for us engineers to worry with.

There were probably a lot of other things, but I don't remember what they were right now.

BUTLER: Well, that's a good overview, and I'm sure there's a record of what specifically—

SMYLIE: Yes, there's a stowage list.

BUTLER: As the Apollo Program was moving along and the initial command module being used was the Block I and was going to be used for Apollo 1 (AS-204) with Ed [Edward H.] White [II], [Virgil I.] Gus Grissom, and Roger [B.] Chafee, were you involved with any of the training for the crew or then, when the accident happened, any of the investigation following?

SMYLIE: Turns out for that year I was not there. I was at MIT [Massachusetts Institute of Technology] in the Sloan Program. I went there in June of '67. The fire was in January of '6[7], I think.

BUTLER: Yes, that's correct.

SMYLIE: I was at MIT. I called Dick and said, "I'll leave here and come back." He wouldn't let me, made me stay at MIT to finish the Sloan Program, so I didn't get back until June, after that fire. So a lot of the recriminations that went on in the congressional testimony and all of that, I was not involved in. So when I came back in June, most of that was behind us, and the work that was going on then was, "Let's get on with the program." So there wasn't a whole lot of recriminations going on at that point as to who was responsible or what happened, and I don't think we ever knew or will know exactly what happened.

I got involved in the redesign. Frank [F.] Borman was running a task force at Rockwell, and they sent me out there for—I guess it was to North American, sent me out there for about six weeks. I really worked with Eberhard Rees, who was the technical person running that redesign effort. Eberhard, I think, at the time was deputy director of Marshall [Space Flight Center, Huntsville, Alabama], and one of the Germans, a wonderful, wonderful man. I think—in fact, I'm sure that he died last year.

BUTLER: Yes.

SMYLIE: So I spent about six weeks out there. We really didn't do a whole lot, I don't think, in environmental control systems, except tighten up specifications, tighten up testing procedures. A lot of materials changes. A lot of what went on was hatch redesign and materials changes and procedure changes, particularly pre-launch procedure changes. That's another thing I tried to call Frank about because I don't remember exactly what we did, but our biggest concern was 100 percent oxygen at 14.7 psi. We had to be at 100 percent at 5 psi when we got to the moon, or else we had a terrible problem of pre-breathing before we could go out on the moon. So I'm pretty sure we launched with a mixed atmosphere, but I don't remember the details. At launch, I think we had a 60-40 atmosphere in the command module to reduce the fire danger, but how we got to 100 percent oxygen, I don't remember.

But anyway, I came back in June, didn't have a job, and Max [Maxime A.] Faget hadn't decided what he wanted me to do. He was all involved in the redesign and was not focused on that, so I got an office next to Dick—and kicked somebody out and took the office next to Dick, and said, "Nobody talks to Dick till they talk to me." What was happening, morale was very bad. I think what was happening is that nobody was taking Dick any solutions; they were just taking him problems. He was getting pretty harried. I don't know whether he admitted that when you talked to him or not, but I could see that it was

really having a hard time, because nobody was giving him the kind of support he needed. So I got in between and said, "We don't go see Dick until we have a recommendation as to what to do and not a problem to be solved." So that ended up being my job, because nobody gave me one.

BUTLER: Well, it seems like it was a good job to move into.

SMYLIE: So the big effort, though, was developing fire-retardant materials. Started off as fireproof, but fire-proof in 100 percent oxygen's impossible. Stainless steel will burn at 100 percent oxygen if you give it enough heat. So we were working on fire-retardant.

If you look at the Block I spacecraft, there was Velcro everywhere. If a fire started anywhere, it would progress everywhere because there were no fire breaks. So a lot of what we did was just be sure that we got discipline in there, that if a fire started, that it ran out of fuel very quickly. So you didn't have concentrations of things that would burn. We developed materials that were quite fire-retardant. Teflon-coated fiberglass that we use, I guess, to this day, throughout the spacecraft was very, very difficult to get it to burn. That was used to cover almost everything, including the life support system. So that was a lot of the work that was going on, was materials work. Matt Radnofsky and his team deserve a lot of credit for being able to bring new materials so quickly into being.

I guess about August of 1968, I began working with the man at North American who was responsible for the arrangement inside the command module, and was—mostly command module. Lunar module was a little simpler, although we did build a lunar module test vehicle and set fires in it to be sure that it wouldn't progress, and the same with the command module.

I can't remember the name of the guy at North American that I worked with, but he and I developed some material to go to a change board, and he and I got up and said, "We

can't make this thing fireproof. We can only make it fire-resistant, and we've got to decide that's what we're going to do and get on with it."

Gilruth agreed with that, and that's when we really began to make progress and began to come together, because up until that time, I think people were still focused on fireproof and not fire-retardant and fire-resistant, and being sure we didn't have concentrations of material that would burn and spread throughout the spacecraft. That's about it, I guess, on Apollo 1.

BUTLER: Sounds like you made some significant changes that worked out in the long run.

SMYLIE: Had a lot of people working on that.

BUTLER: You mentioned that at the time, of course, that morale was pretty low, but it must have been good to see Apollo 7 go up and work so well and be so successful.

SMYLIE: Oh, yes. Yes, we were back on track.

BUTLER: What did you think when you heard the decision to then send Apollo 8 to the moon right at the end of 1968, with only that one Apollo 7 been before?

SMYLIE: The way I heard about that was, Frank Borman came into my office and said, "We've got to change all of the production schedules, because we're changing me," from whatever mission he was on, "to Apollo 8, and I need my suit sooner." So that's how I found out about Apollo 8 going to the moon. You know, I just said, "Okay," and I sat down and wrote a change order. I got Joe Fernandez, I guess, to write it, and I took it over to George Low and got him to sign it, and I sent it up to ILC and we started building suits to a different

schedule. So that's how I heard about it. I thought it was wonderful. That was one of the high points of the program, especially doing it at Christmas.

BUTLER: Do you remember watching and listening as they were going around the moon on Christmas Eve?

SMYLIE: Oh, yes. I was in the Control Center. I was not in flight control, so I was up in the VIP area, watching it. I remember every bit of it.

BUTLER: Quite an accomplishment.

SMYLIE: Yes.

BUTLER: For the missions as they were building up, were you involved at all with training for the astronauts, like suit issues and ECS issues?

SMYLIE: Personally not a whole lot. We had a large support function for training because a lot of the training was done in their suits. So what we instituted was a mission manager concept, and I had a mission manager for each mission. His responsibility was to support the training, particularly the EVA training, not so much the training in the simulators, but the EVA training, which there was a lot of. His job was to be sure that the training suits were ready and the training PLSS's were ready and available for training, to go with the crew wherever they went, and keep that equipment ready and available, to report any problems, to solve any problems we had. So we had a large support function in the training.

The only thing that I initiated, I guess, before Apollo 11 was I did not think that the crew, Neil and Buzz, had ever gone through a complete start-to-finish mission simulation on

the moon, like they were going to be doing on the lunar surface, operating all of the experiments and everything. I suggested to George Low that I would like to see that done, that we go down to the Cape and we set up all the experiments, that we put the crew in their training suits, training PLSS's, and have them go through the whole mission. And we did that. Buzz and Neil went through it from start to finish, and I was there and stayed through that whole thing. Lasted several hours. So that was the only training that I personally was involved in. I think that was a very useful thing to do.

BUTLER: Basically a dress rehearsal for the mission.

SMYLIE: A dress rehearsal of everything they were going to do on the moon. We also went through some contingency things with them, for me to be sure that they understood how to do the contingencies, and they did.

We had one change in the system shortly before Apollo 11. On Apollo 9, which was the only EVA that we did with that system before going to the moon, we had a problem. The liquid cooling garment circulation pump cavitated, and we were not getting circulation. We discovered the reason for that was that in the reduced atmosphere we were getting, oxygen was going through the tubing into the water stream and causing gas to build up, oxygen to build up in the pump, and therefore to quit pumping. So we had to find a way to get rid of that gas, because we knew it was going to be there.

Actually, I think Langley Research Center [Hampton, Virginia] came up with a material that would pass gas but not water, and we built what we called a water-gas separator, that we bring back here by the back. The idea was that when the ground could see that it appeared that that pump was cavitating, in danger of cavitating, that we would get the crew to, in fact, burp this thing. Had to push a little button that would let the gas out. I had to call Neil and Buzz in on a Saturday morning and explain to them that they had a new task

to do on the moon, which was to burp the water separator. If you listen to the—I think if you listen to the transcript of that mission, you hear that every now and then. The capcom [capsule communicator] would tell them to burp the water separator. It worked for every mission. I have one of those, and it's got two little connections on it and makes a very nice pen holder.

BUTLER: Ah, very good. You've talked about EVA and the training for that, and you also mentioned that in Gemini they had had several difficulties with EVA and that helped in Apollo to learn. What were some of the tools and techniques used in the Apollo EVA training? Did you use the pool, the KC-135?

SMYLIE: Used the KC-135. The pool is only useful—in the case of the 135, it was only useful for zero-G, not for lunar surface. So to any degree that that was used, it was for the EVAs that were done out of the command module. I at the moment don't remember whether we did a lot of that kind of training. We did learn about handholds and things of that sort on the command module, for command module EVA. That was primarily to get experiments out of the service module and bring them back to the command module. T.K. [Thomas K. "Ken"] Mattingly [II], I think, did that. I don't remember how many others. Of course, there was the EVA that [Russell L. "Rusty"] Schweickart did on Apollo 9, but that was, I don't think, a very successful EVA. And we did have the problem with the cavitated pump. But it did give us the information we needed.

For the lunar surface training, Langley developed a one-sixth-G simulator that, I think, was a counterweight-type system that was used some to simulate one-sixth-G. We developed in the centrifuge, which doesn't exist anymore, it's now a big swimming pool, but centrifuge had this arm that went around and around, so we developed a way to use a sling to support an astronaut at an angle, and you put an angle in the centrifuge so that in this sling

the normal force on this incline was one-sixth-G. They could walk all the way around the centrifuge, just walk as long as they wanted to, all the way around, essentially walking at one-sixth-G.

BUTLER: Interesting.

SMYLIE: That was to give them a feel for how the system would perform in terms of the amount of traction they had and so forth at one-sixth-G. So that was used quite a bit. Other one-sixth-G training I don't recall. A lot of the training was in places like volcano-type places that might simulate closely the terrain on the moon, but that was only one-G, not one-sixth-G. So the only two, one-sixth-Gs [trainings] I remember was the one at Langley and the one that we did in the centrifuge for training.

BUTLER: You mentioned that you were involved with the dress rehearsal training for Neil Armstrong and Buzz Aldrin for Apollo 11. When they actually went and did the EVA, do you remember where you were and what you were thinking at the time?

SMYLIE: I was still in the VIP viewing room in the Control Center, watching it all, for the mission. George Low was running the program at the time, and he was there. Of course, we landed on the moon and they were actually going to go out, and George turned to me and said, "Are you ready?" I said, "Of course I'm ready." [Laughter]

BUTLER: You'd worked all that time and you were ready to see it.

SMYLIE: Well, when you think about it, is there anything that I would have done, that I haven't done, before these guys do this? And I couldn't think of anything, so I figured we were ready.

BUTLER: That's good.

SMYLIE: Wasn't anything else to do.

BUTLER: Must have been rewarding to see it all come through as well as it did.

SMYLIE: And the system worked.

BUTLER: The system worked and you met Kennedy's goal, his challenge. As the missions went on, Apollo 12 was pretty successful, especially from a standpoint with your division, and then there was Apollo 13 that had quite a few challenges with the explosion in the oxygen tank. What was your involvement with that and bringing the crew back?

SMYLIE: Well, I guess that was our fifteen minutes of fame. I think that was on April 14th or April 13th, I guess, that it happened.

BUTLER: April 13th.

SMYLIE: My recollection, in fact, I actually went back to some notes on this one. About one o'clock on the 14th, 1 AM on the 14th, we had realized that we had to do something about CO_2. My first baseline solution, and I think the one that Mission Control was carrying, was

to continue to operate the command module suit loop thing, had the hoses extended into the lunar module to absorb CO_2.

That probably would have been a power problem in the command module, because we're the ones who shut the command module down. I think me and Jim Correale and probably Dick [Richard E.] Mayo concluded that there was a way we could probably use the command module canisters in the LM, and our first thought was to use the liquid-cooled garment and the tape, liquid-cooled garment bag, plastic bag and the tape, to tape the command module canister on the suit outlet hose in the LM, just blow the air through. That was what we were working towards.

Somebody, I'm not sure who, suggested that it would be better to put it on the suit inlet hose because you get warmer air and moister air, which makes the chemical work better. That was a better solution, They said that would suck the bag down against the canister and block the flow, and that's when we came up with the EVA cue card from the flight plan to form an arch. So that's what we began to work toward.

Early that morning I called both Downey and Kennedy and asked for some canisters to be sent so we could test that. We found them at the Cape, chartered an airplane. Grumman chartered an airplane, I guess, or North American did, and flew them up, and we had them that afternoon. I got Art [H.] Hinners, who ran our test division, to begin to set up a test to test that.

In the meantime, we began to work procedures. I think Correale and I built one. We began to develop procedures, and we got hold of T.K. [Mattingly]. T.K. was busy doing other things, and he assigned Tony [Anthony W.] England to work with us on developing procedures to send up to the crew on how to build this thing.

We got the test going, proved that it would work, and I believe—I've forgotten what day, whether it was the 14th or 15th, that we instituted it in the lunar module. The CO_2 level was about seven and a half millimeters by then, which was getting up to the range that you

could get concerned about, and in thirty minutes it dropped to three-tenths of a millimeter, so it didn't take long to solve the problem.

Our plan was, we were going to need four of those to do the job, and we had two, one on each suit loop, and we were going to have to build two more. Harley [L.] Stutesman suggested that why don't we just tape the other two onto the first two and not try to build more of them, but that will probably work. We tried that in the test and it worked, so that's what they did. So we didn't have to build the other two; we just took the tape and taped the second one onto the first one. It all worked. We had other things to worry about, water and power, oxygen, but the big one was lithium hydroxide.

BUTLER: It must have been quite a challenge to develop procedures that you could just read up to the crew and have them understand what to do.

SMYLIE: It was pretty straightforward, even though we got a lot of publicity for it and [President Richard M.] Nixon even mentioned our names. I always argued that that was because that was one you could understand nobody really understood the hard things they were doing. Everybody could understand a filter. I said a mechanical engineering sophomore in college could have come up with it. It was pretty straightforward. But it was important.

BUTLER: Very.

SMYLIE: And we were pretty proud to have been able to do it. If you read the book and look at the movie, it sounds like I did all of that. I went back and looked at the list of people that I identified were involved, and there was probably sixty people involved in one way or

another. A lot of contractors. There were probably thirty or forty contractors that set up that test to run it. So it takes a lot of people to do something like that.

BUTLER: Absolutely.

SMYLIE: And make it work.

BUTLER: You mentioned that you were working at 1 AM at one point on this. Can you tell us about the atmosphere at the time and how you ran things? Did you just grab sleep on the fly? Were you at the Center the whole time?

SMYLIE: First I heard about it on the radio at home and went out to the Center. Don [Donald D.] Arabian—Don's sort of a wild man, but also very smart and able to generate a lot of activity—had set up a war room, and we all gathered there and were going through what all the things were that we had to worry about, what the problems were, and what had to happen and so forth. Don was sort of running that and was handing out action items. I don't really recall whether we decided the CO_2 was a problem or we just looked at expendables in general at that point, but that's what we did probably from the time I got there around 10:30 until I went back to the division around 1 AM, and began to look at the problem in detail.

My short recollection is that—and Jim Correale was there—is that sometime in the middle of the night, I said, "Jim, you stay here. I'll go home and sleep for two or three hours and I'll be back," so I was back at 6:30—I guess I probably went home at 4:00—and sent Jim home for a little while. So he and I sort of worked back and forth the rest of the time. It had reached a point, by the time we got the test going and so forth, that it was one of just grinding it out.

Maybe a little human interest thing, Fred [W.] Haise lived three doors from me. The press was camped all over his doorstep. We had woods behind our houses. Fred, Jr., and my son were good friends. We took Fred, Jr., over the fence, brought him down to my house, and kept him for three days, and kept my son out of school.

BUTLER: That must have been nice for the family to know that he was being taken care of and not having to worry about the press.

SMYLIE: I took Fred out to the Center and showed him the test we were running, to make him comfortable his dad was going to be okay.

BUTLER: That's good.

SMYLIE: They couldn't leave the front door without facing the press.

BUTLER: You said there were other issues, of course. Were there any specific ones that you'd like to approach?

SMYLIE: I had people in what was called Building 45, which supported the Mission Control, and we were just carefully watching the expendables, use of oxygen, water. Power was somebody else's responsibility, but we were using a lot of the power, so it was a matter of carefully monitoring that. But it turned out that we did have enough, so it was something you had to keep an eye on, but turned out to be okay. I think other things, power in particular, were much more difficult to manage, rather than what we were doing. So our main one was the CO_2.

BUTLER: And all the systems did pull together and everybody made it work and brought the astronauts back safely.

SMYLIE: Yes. I guess the other concern we had was whether the command module would fire up again after it had been cold-soaked for three days, but it did.

BUTLER: Were you involved in any of the tests on that?

SMYLIE: No.

BUTLER: Your division worked closely with the EECOM [Electrical and Environmental Command Officer] in Mission Control, is that correct?

SMYLIE: Yes.

BUTLER: How did that relationship work? Would they call on you for assistance at certain times?

SMYLIE: Yes, they would call on us. They had worked their procedures pretty well. They did more procedures work, actually, than we did. We were engineering support. Primarily I was in the Project Office, a little less so to the EECOM, because by the time I got to the EECOM, it was a developed system. I think the working relationship was generally pretty good. I guess from time to time we got to the point where we figured they had more people working the problems than we did, and we felt we were undermanned and they were overmanned. But actually it all worked out all right. I don't recall any significant incidents or problems between ourselves and them.

BUTLER: As the rest of the missions progressed, Apollo 14, 15, 16, 17, in fact, in later ones, they began to add, as you mentioned before, the longer time and the lunar rover. How did your role evolve, or were there certain incidents for any of the missions that really stand out?

SMYLIE: Well, we go back to even before Apollo 11, there was a lot of concern about whether the suit-PLSS combination really would be able to perform on the moon all the things that we wanted to do. We just didn't know, because you really couldn't determine that on Earth. The scientists and mission planners really wanted to be able to do more than we had planned for Apollo 11, and there was this unknown as to whether we'd be able to with the system that we had, with the amount of mobility and so forth.

So to back up what we were doing, the Project Office agreed to fund two backup suit developers to develop a higher mobility system, and we [contracted one to] AiResearch and one to [a] Division of Litton Industries in Beverly Hills, actually, to develop…prototype suit[s] that would produce better mobility than the suits we were getting from ILC. And they did. The suits really did produce improved mobility. They were heavier, they were bulkier. There was a significant problem in stowing them in the command module. After we had done Apollo 11, we realized that [the ILC] suits would do the job that we needed to do.

Another element of the mobility suit was competition between a more mobile suit with a more capable PLSS versus a lunar rover, so there was competition there between which we would proceed with. At a meeting in Washington [D.C.] somewhere along the line, we made the decision to go with the lunar rover, which I supported, that that was the right thing to do, and so we decided the ILC suit was adequate, combined with the lunar rover, to do everything we needed to do. So we did not proceed with those suits that AiResearch and Litton had developed. That came back again in Skylab as a possibility to use those in Skylab, but we never did.

A thing that people maybe don't realize is the number of constraints that we were working with, with the suit. As you recall, they put on the suit in the suit room before they got in the command module, and so that suit had to operate as a backup in the command module and you had to be able to wear it three across in the command module, you had to stow it in the couches, outside the envelope of where the couches would go on the land landing, and had to interface with the lunar module, the lunar surface. It had so many constraints and interfaces, more interfaces than almost any other thing in the program that we had to design to. It wasn't just lunar surface we were designing for. We were designing for that whole spectrum of things they had to do.

The new suits that we developed at AiResearch and Litton would have been a real problem to stow on the command module, the couches, because if the command module landed on land or even a hard landing on water, those couches would have to compress the stress into the space below the couches, so you couldn't have anything under there that was in that envelope. It was very hard to get those suits into that envelope. That was the main thing against the hard suit. We'd have loved to have a hard suit on the moon. Couldn't get it there.

One change we made between Apollo 7 and Apollo 11—yes, Apollo 11—we had a joint up here in the arm between the elbow and the shoulder which allowed you to move your arm this way [a hammering type motion that allows the elbow, upper arm and shoulder to rotate]. It's hard to describe audibly. Wally Schirra was convinced that he couldn't operate in the command module with three guys side by side with that joint, because it added an inch or so on each side. So we had to take it out. So the baseline going to the moon was without that joint.

When the Apollo 11 crew was announced, I called all my guys in and said, "What's the one thing we can do for this crew to make their job easier?" And Charlie [Charles C.] Lutz said, "Put that joint back in." It was really too late. We had qualified it.

So I went to George Low and to Neil with a proposal that we put the joint in one of their suits. They had two flight suits, a flight suit and a backup suit. Put it in one of them and not in the other one. We proceeded to qualify that joint, and if you qualified it, they would use it. If we didn't, they would use the backup suit. That's what we did, and we qualified it. All the flights from then on, everybody but Wally could operate in the command module with that joint. You know, Wally didn't need it. He wasn't going to go on the moon. He didn't need that joint. So we got it back in.

I've forgotten where we were in this discussion.

SMYLIE: No, that's fine. We're moving right along. As you were looking at the suit issues and for functioning on the moon and working on the moon, you also were involved somewhat in developing the tools, is that correct, that they would use?

SMYLIE: Not a whole lot. Maybe more than I remember. We had a group under [William E.] Feddersen that was involved. He was a psychologist involved in tool design to some extent. We certainly were involved in evaluating tools. I believe the Flight Crew Support Division was more involved in the actual tool development than we were at that time. I think if you look at the Crew Systems today, there's much more involvement in tools than we were at the time. But we were very much involved in evaluating them, being sure that they interfaced.

The glove was always the big problem with the suit, and still is to this day. It was the most difficult design problem because you've got to provide thermal protection. It makes them very bulky. And the fact that they're pressurized makes it difficult to grasp things. So tools had to be developed that could be operated with those bulky, very awkward gloves. Every time I try to do anything in the yard with gloves on, I think about those guys trying to do that on the moon with those gloves.

BUTLER: Quite a challenge.

SMYLIE: Yes.

BUTLER: There were concerns about—in fact, as the Apollo mission was being planned, no one really knew what the lunar surface was going to be like, whether it was going to be firm, whether it was going to be soft and they'd sink into it, the composition or any of that. There were also issues about contamination, whether the astronauts could bring back germs. Were you involved in any of those discussions or in the plans for them to come back and wear the BIGs [biological isolation garments] and the trailer to stay in isolation?

SMYLIE: I guess we did. Come to think of it, I'm not sure. The back contamination suits that they put on in the command module before they came out of the command module and into the van on board the carrier, there was concern about contaminating the moon, that some scientists were quite concerned about, and the fact we were leaking oxygen out of the suit, possibly germs onto the moon, we were going to contaminate the moon.

We had people trying to come up with ways to put the suit in a bubble so that the stuff that leaked out didn't get on the moon. I mean, it got pretty wild. So, a lot of wild things going on that we had to damp down. There was one scientist didn't like the silicon tips we had on the gloves because that was going to contaminate the rocks that they were picking up. That was one place where my spec helped me. George Low sent it to me to resolve, and I send him a note back and I said, "Silicon is about as nonreactive as anything I can come up with. And I said if you want me to do something else, process a change to my spec." He dropped that. [Laughter] He dropped the battle.

But back contamination, back to the Earth, other than the procedures and, I think, the back contamination suit that they had to put on, and keeping the suits in quarantine at least on Apollo 11—I don't know when we quit doing that, exactly.

BUTLER: I think it was after 14.

SMYLIE: We couldn't get to the suits. Well, we had to send people in to get the suits, in between. No, I don't recall a whole lot of effort in that regard.

BUTLER: Were there any other aspects on the lunar Apollo missions that you were involved in or that we haven't touched on at this point?

SMYLIE: Let's see. Which mission was Alan [L.] Bean on? Twelve?

BUTLER: Twelve. Apollo 12.

SMYLIE: I think when Apollo 12—just a small incident in how fast my guys were picking up on things. I believe it was Alan, getting ready to go EVA. Pete [Charles C. Conrad, Jr.] was already on the moon. We had what was called breakthrough in the sublimator, began to get water running out, and he noticed it and said, "We've got water." We were afraid we had a failure in the PLSS. I was in Building 45. No, I was in the MOCR [Mission Operations Control Room], what's called the MOCR, which is in between Building 45 and Mission Control.

Harley Stutesman called from Building 45 and said, "Bean has kicked the door shut on the LM." I said, "How do you know that?" He said, "The pressure's going up in the LM." Of course, the pressure went up and the sublimator began to malfunction. I passed that word

to the guy running the MOCR, and he said, "How do you know?" While I was explaining to him how I knew, Alan Bean said, "Oh, the door's been kicked shut." He opened the door and everything was okay.

Then we had to worry about how much water had we lost. It turns out at Hamilton Standard they had a PLSS in an altitude chamber running the same sequence that Bean was running, so we simulated what we thought had happened and measured the amount of water we'd lost, because we didn't have a well defined indicator, and determined that it was okay. We could complete the mission. We hadn't lost enough water to cause a problem. So that was one on Apollo 12.

[Apollo] 13, we've already talked about. [Apollo] 14, Alan Shepard. Yes, we had a problem with the suit before 14, had nothing to do with his flight suit, but we discovered on some of the suits that the bladder, we were seeing cracking similar to what you used to see on tires in California from ozone. We were getting these hairline cracks, and we didn't know what was causing it. We mounted a big research effort on that. I think we called in DuPont [E.I. du Pont de Nemours and Company] and we had every chemical company in the country helping us worry about that.

We discovered part of the formulation of that bladder was natural rubber. Jim [James W.] McBarron [II] might remember this better than I do. But we thought it might have been copper from some of the vats being used at ILC to mix this stuff. Turns out that wasn't it. It was actually there wasn't any copper there. It was actually copper that was in the rubber that came from Indonesia that was causing the problem, and it was a treatment we could make that would solve the problem.

We also discovered, or examined all the suits for Apollo 14, and they were okay, so they had not reached a point where we had to worry about it. But I went down to the Cape to explain that all to Shepard, that everything was okay. He wasn't particularly interested. He wanted to know if we were going to get his razor ready. He had come up with a wind-up

razor because we couldn't use an electric razor. I don't know where he got it from. We had to qualify it to be able to fly it. We had to run it through outgassing to be sure it was safe. That was his big concern, were we going to get his razor ready. We got his razor.

BUTLER: I guess since you were telling him the suits were okay, then he said, "Well, if they're okay, then fine. Let's have my razor."

SMYLIE: That was quite an effort to figure out what was causing the problem. I may not have it exactly right. If you talk to Jim McBarron, see if he remembers it exactly right. But it was something like that.

BUTLER: We'll ask him about that, because that's a good example of the intricacies of how every system has to—even from back in the rubber in Indonesia, it all has to fall together and meet the specifications to work out.

SMYLIE: Apollo 15 was the first lunar rover, I believe. It was a good mission. I don't remember any particular events on 15. [Apollo] 16, of course, John [W.] Young and there's the back flip. That was exciting. I'd just as soon he hadn't done that. [Apollo] 17 was a good mission. I don't remember anything other than it just being a really good mission. We never had a really significant discrepancy on any of the missions for the suit or the backpack. They always did what they were supposed to do, and we never had anything come up that caused a great deal of anxiety or even any design changes after the mission.

BUTLER: That's good. I think that's probably nice to know that everything had worked so well to build up to it, and then it worked so well on the mission. That shows that everybody was able to pull together and they knew what they were doing to make it all work.

We'll take a brief break here. [Brief Interruption]

As the Apollo missions came to an end, did you have any thoughts on the program ending, or were you looking forward to the next task with Skylab?

SMYLIE: It was very much in parallel with what was going on with the Apollo Program, as I recall. We were involved primarily, again, for the suits and the support to the EVAs on Skylab and a lot of crew equipment and experiments, Skylab experiments. So [unclear], not so much with the ECS, environmental control system or Skylab was closer to the Gemini system, I guess, than to the Apollo system, in that it used molecular sieves.

The manager for that at Marshall was a man named George [D.] Hopson. As far as I know, George is still at Marshall. The last time I talked to him, he was, although it's been close to a year since I did talk to him. We had a pretty good relationship with George, and we did provide technical support to Marshall in the development of the ECS, not unlike, but maybe a little more arm's length than what we did on the command module and the lunar module for the Project Office, because this was a Marshall program, not a JSC [Johnson Space Center, Houston, Texas] program. To some degree, George welcomed our help, and we provided it willingly. And he's a good friend. In fact, I worked with him on one of the programs since Skylab, and most recently under contract with George, actually.

We did support crew training. By then Marshall had a swimming pool to do crew training in. We had the mission manager approach same as we had in Apollo to support the crew training at Marshall. There was so much interaction between JSC and Marshall, that we actually had, I think, a Lockheed Electra that flew back and forth between Marshall and JSC every day, because there was so much traffic. So you could go to Marshall anytime to work with them, and there were a lot of people going back and forth.

When the Skylab was launched and they lost the thermal shield, we were probably at JSC the first to know, because we'd been working with Marshall so closely. My manager, a

guy named Larry [E.] Bell, was my interface with Marshall. He worked for me. He came in my office and said, "I just had a call from Marshall and they've got a big problem," and described what it was. They began to ask about ways to deploy a thermal shield, and we went to the mockup in Building 9 and measured where the airlock was, and began to build a thermal shield almost before anybody else knew when the thing was happening, because we were the ones that had all the capability to build fabric things in the System Division. So we were well on our way as that problem developed.

In my view, other than it was not a condition that put crew in danger, the Skylab recovery was an equally significant event as was Apollo 13, in being able to pull that off in less than two weeks and salvage Skylab.

BUTLER: Quite an accomplishment.

SMYLIE: What we decided in Crew Systems, it turns out wrongly, was that because of the buildup of heat in the workshop, that there would be outgassing to the extent that they would have to depressurize the workshop before deploying a shield. So we began to develop a shield that was like a reverse umbrella, that they would depressurize the workshop, open the airlock, push this thing out through the airlock, let it deploy, close it up, and repressurize it. So we were not designing an umbrella that would fit inside the airlock, but we developed one in a couple of days. I don't remember the exact schedule. This is one I didn't take notes on. In fact, a historian came to me and wanted to interview me in the middle of it all, and I said, "I don't have time. You can follow me around," and that ended that. I probably shouldn't have done that, but that's what happened.

BUTLER: Well, you had to concentrate on the job.

SMYLIE: We built something we thought would work under those conditions. We tested it, and the umbrella we made, or the canopy, we punched holes in because in atmosphere it would not deploy properly unless it didn't have a lot of air resistance. So we had all these holes in it, and we deployed it and it worked.

So I went over to Building 1 and got George Low and [Dr. Robert R.] Gilruth, George [E.] Mueller, [Wernher] von Braun, everybody who was anybody, to come see the solution, and they all marched over to my building, and they deployed it, and it tore itself all to pieces.

BUTLER: Oh, no.

SMYLIE: They all turned around and left. I said, "Wha' happened, guys?" They said, "Well, we thought the deployment spring was not strong enough. We put in a stronger spring."

BUTLER: Oh, no.

SMYLIE: So we kept working for a while, but in the meantime they determined that they would not have to repressurize the workshop and that Max Faget was working on a design, who was my boss, that would fit inside the airlock, and you would deploy it out and it would unfold. It had all these pieces. Max called me over and said, "You've got to stop what you're doing and support this one." I said, "Okay," so I did. We supported that one, that development, because we were the ones that built the canopy to go on it.

One event I recall was we needed some quick disconnects. I forget whether that was the one I was developing or the one that Max was developing, but in any case, in the middle of the night, I think it was Art Hinners came in and said, "We need these quick disconnects." It was a Saturday night. He said, "We can't get anybody to answer at the company."

I said, "Well, go to the library, open the library, go to Standard & Poors [S&P], look up the company, find out who the president is, and call his home."

They did. They called his home, got a babysitter. He was at a black-tie dinner at his country club, and we called him out at the country club, Art did.

BUTLER: You did what had to be done.

SMYLIE: He went and opened his factory in the middle of the night, either built the parts or gathered the parts, I don't know which, but the next day he arrived with a sackful of them.

BUTLER: That's great.

SMYLIE: Turns out we didn't use them. I don't know if we ever paid him for them.

BUTLER: Oh, my goodness.

SMYLIE: But that was happening throughout industry. I think the whole U.S. industry that was able to contribute was ready to contribute. No matter what you asked for, you could get it.

Harley Stutesman, who was working for me, chartered a Learjet on his own authority. He was a branch chief. That Learjet went all over the country. We didn't use it as much as the rest of the program used it to move stuff from one place to another to get that built. But we moved all of the people from ILC who built space suits, all the people, we moved a lot of the sewing machines and a lot of the equipment, set it up in the centrifuge, moved the people down from Delaware, and built the canopy to go on that system. Pete [Conrad] and—I've forgotten who else was on that mission. Joe [Joseph P.] Kerwin?

BUTLER: I believe so.

SMYLIE: Anyway, whoever he was, went up and deployed the canopy and it worked. Later, Marshall deployed a different one in a different way, that was a little bit better solution than the one we developed over a ten-day period. That one saved the mission. I think it's a story in itself.

BUTLER: Absolutely.

SMYLIE: That was one where we probably lost a whole lot less sleep than we did on Apollo 13. A whole lot more sleep. Excuse me. In fact, Charlie Lutz, we thought, was going to collapse, and we rented a hotel room across the street and made him go over and go to bed, wouldn't even let him go home. We weren't sure he was going to make it. He was directing that whole business with the canopy.

BUTLER: A lot of dedicated people.

SMYLIE: So we had a lot of involvement with Skylab, but not so much in the ECS, more in the suits, the EVA, and the recovery from the loss of the thermal shield.

BUTLER: Were you at all involved in looking at a modified command module for a rescue ship and doing any modifications on how that would support so many people?

SMYLIE: No, don't even recall that.

BUTLER: There wasn't a lot done.

SMYLIE: I don't recall that.

BUTLER: You mentioned the suits, that you were involved on the Skylab suits. Was there any significant difference between those and what was used on the Apollo missions?

SMYLIE: They were pretty much the Apollo suits. Again, there was a move to use either the AiResearch or Litton suit in Skylab, but we had a production setup at ILC, we had an experienced crew, we had a qualified suit, and we had everything in place. There was not enough advantage to change suits to go through setting all that infrastructure up at either AiResearch or Litton, and then build a suit. We didn't have a production line, we didn't have inspection, we didn't have all the things, infrastructure, it takes to produce things that we had at ILC, so we just stuck with that. The EVA and Skylab was much, much simpler than what you had to do on the moon, so it was pretty much, as I recall, the Apollo suit. I don't remember changes, if there were any.

BUTLER: I don't believe there were any significant ones. As Skylab was actually in progress, there were discussions that came up about a joint mission between the United States and Soviet Union for Apollo-Soyuz [Test Project, ASTP]. At what stage did you become aware of the program, and how did your role begin and then evolve?

SMYLIE: I guess there was an initial visit to Moscow by a few people. I think I got involved on the second trip, though it might have been the first. I really don't know for sure. But since it was clear there was going to be a significant atmosphere and environmental control

system interaction and interface between the command module and the Soyuz, I got called into it almost from the very beginning.

I made an early trip to Moscow with Chris Kraft and Gilruth, Glynn [S.] Lunney, Caldwell [C.] Johnson, four or five other people, probably. It was a fairly small group. For the initial discussions, even before there was an "approved project." It was exploratory as to whether we thought we could do it or not. So I was involved from the beginning, pretty much, in developing both the designs and the procedures for carrying out crew transfer between the Soyuz, which was a 14.7 Earth atmosphere, and the command module with 5 psi, 100 percent oxygen, and how do you match those two environments, which led to the docking module, which allowed us to make that transfer from one to the other.

The interface with the Soviets, from an engineering and technical point of view, I thought worked very well. I was blessed with working with an individual on the Russian side that was very open, very smart, very candid, and we developed a very professional and friendly relationship over the life of the time that I was involved. I left before it actually took place, which he didn't like. It demoralized him when I left. In fact, I think he left the program. I don't know whether it was because of that or not. He was so independent-minded that I always wondered whether the Soviets wouldn't just tick him off because he was so independent.

There was the atmosphere and there was the nonflammable fire-retardant issue, where they didn't worry about that; they just used what they used because, number one, they had sea-level atmosphere and, second, they just didn't worry about it. When we told them the cosmonaut could not come into the command module without dealing with that problem, we agreed to send them materials that they could evaluate, which we did. But on the next visit, they had their own that they had developed. I guess they just didn't want to admit that they couldn't do it, so they had materials that were okay.

They operated under a system where they were not nearly as free to share information with us as we were free to share information with them, and it really amounted to anything that they gave us had to go through some security apparatus before they could give it to us, so it slowed things down and made it more difficult. I mentioned the independence of the guy I worked with. He would just tell me what it was he couldn't give me and until he got it approved, but then he would tell me what it was going to be. So he and I worked together very well.

In fact, he was the one that told—they had a mission failure where they lost cosmonauts because of depressurized spacecraft, and he told me, on my second visit, took me out and showed me all the mockup, what had happened.

BUTLER: That is very open.

SMYLIE: It was months later before they gave us a report that told us what had happened, and it was the same thing he had told me.

BUTLER: You mentioned that you and he worked together very well. Were there cultural differences that even with others of the team that you really noticed or that made things challenging at times?

SMYLIE: The food wasn't very good. [Laughter] Cultural differences.

BUTLER: Did you work primarily through translators?

SMYLIE: Oh, yes. He spoke no English. I had studied Russian to try to learn some Russian, but I'm not good at languages and it's a very difficult language. So I learned enough to be

able to ride the Metro and recognize a restaurant from a liquor store and things like that, but I couldn't carry on a conversation. So, yes, we had a translator. I had Natalie Latter [phonetic] as my translator—interpreter is the right word. She made sure that I understood that, that she's an interpreter, not a translator. Later I had a different one, Marie—I can't remember her name—who was also very good. Natalie was outstanding. She had interpreted for Khrushchev and Kennedy. That's how good she was.

BUTLER: Must have been nice to know you could really depend on that.

SMYLIE: An example of her being an interpreter was, a Russian gave a long speech one time about—somebody asked him a question and he spoke for maybe two minutes. When he finished, Natalie said, "He said no." [Laughter]

BUTLER: [Laughter] That's great.

SMYLIE: I think then she went back and gave some of what he said.

But cultural differences, of course there were cultural differences, difference in the government. My counterpart was a Communist, but I think he was a Communist by convenience, rather than by any real belief in it. He was a philosopher. He talked a lot about—"philosopher" is not quite the right word. He was very interested in management, wanted to know how we managed, compared to how they managed. He had been a tank commander in World War II and had fought the Germans. Was a very good friend.

BUTLER: Did you have the opportunity to—either while you were in Russia or while he was in the United States, to visit each other's homes?

SMYLIE: I never visited his home. I think his wife was in an asylum. I'm not sure. He never admitted to that. But we did go to the home of one of his employees who worked with us. It was a team. We were invited to their home, their apartment, for dinner one night, which was very nicely done. He was a young engineer, probably three or four years out of college, had a small apartment and a baby, about three or four rooms, but comfortable, in one of those nondescript big apartment buildings that you see in Moscow.

We had the whole team to my home in all one visit, served them a Southern meal—fried chicken, all that kind of stuff. They really appreciated that. But mostly we went to restaurants for meals.

BUTLER: What was their reaction to coming to Houston and America? Was there anything that they were surprised at, that they expressed to you?

SMYLIE: Yes. In those days, when you look at film of Moscow these days, I saw one the other day of the *Gum* Department Store with all of these Western, Gucci and so forth, signs. When I was in *Gum* in 1971, it was miserable. I mean, it was depressing to go in those big department stores. They come to the United States, and their favorite was K-Mart. I mean, look at everything you could get a K-Mart. They spent all of their exchange rubles for dollars on buying stuff at K-Mart to take home. Yes, they were amazed.

Moscow was very dark. Fly out of Moscow at night in those days and look down, and you saw nothing. The streetlights were the old flat pancake type, with a light bulb in the middle which shone down and made a little spot about the size of this desk. That was the light in Moscow. They came here, and all the parking lots and everything is all lit up. My guy was sort of insulted by it all. "You guys are using up all the world's resources." [Laughter]

BUTLER: That's an interesting perspective.

SMYLIE: Yes. He didn't appreciate it at all, and the amount of oil that we were burning to keep all those lights going.

BUTLER: That's interesting. Wow.

SMYLIE: But from a technical side of view, from a technical point of view, we worked well together. I don't know who gained more from it one way or the other. It was a political thing anyway, is what it was all about. They probably learned more from us than we did from them. So I don't know. It was fun. It was a lot of fun.

BUTLER: Was there any anticipation that it might lead to future projects?

SMYLIE: We hoped that it would, but it didn't. I guess we couldn't come up with anything that made a whole lot of sense. Nobody was ready to go back to the moon, nobody was ready to mount a big planetary mission. I guess [the] Afghanistan [conflict] came along. We just never got anything more going. I guess even in the middle of all of that, there was still the bio satellite activity that was going on sort of in the background nobody knew much about, but we were flying experiments on bio satellite, the Russian missions that came out of Ames. So we never quit doing some things together, but the big manned thing, no. That was not in the cards at that time. The political environment wasn't right from the beginning of the program. We were doing Shuttle and weren't doing Space Station. Space Station might have been logical, but we weren't doing Space Station. We were doing Shuttle.

BUTLER: When Deke Slayton had the opportunity to fly on Apollo-Soyuz after he'd been selected as one of the original Mercury astronauts and had been grounded, first, had you had any interaction with him? Then when he did get a chance to fly, what was the general reaction around the Center?

SMYLIE: The reaction was elation that he finally got a chance to fly. I had worked with Deke during the Apollo Program. Deke was running the Astronaut Office since he couldn't fly, and so he was the one I worked with on primarily suit schedules, who was going to be the crew.

Crew selection was quite secret. We had to know who was going to fly long before anybody else needed to know, because we had to build suits. He had to tell me, and we had to assign code names to the suits in development or in production, although they had to go there to get fitted, so there were people at ILC that knew who the crew was going to be. It was one of those things where sometimes we knew before the crew member knew that they were going to be on the mission. So it was a very close relationship where Deke would share with me, and we would have to assign code names and get it through and get production started. So, yes, I had a lot of interaction with Deke, but by the time he was assigned to [Apollo-Soyuz], I was in Washington by then and was on my way. So, yes, we were very happy that he got to fly, thought he deserved it. But I didn't deal with him on that particular mission a whole lot.

BUTLER: Talking about Deke Slayton, and you've talked about some of the other people that you've worked with up to this point. Are there any particular people that just had such outstanding characteristics that made your job easier or that you really depended on or interacted closely with?

SMYLIE: You ask about astronauts. We always had an astronaut assigned for suit development. Astronauts got assigned different areas to worry about, and we always had one that worked with us, interaction with the Astronaut Office on development of the suits and backpacks. Started out to be Mike [Michael] Collins was the first one that I recall.

John Young, T.K. Mattingly. There probably were others, but those are the three that I remember. I don't think Mike stayed with us a real long time. He was very useful, very helpful. John and T.K. worked at it harder than anybody. I mean, they were in the suits, they helped do the qualifications, they contributed to the design. They were very thorough. Two of the hardest working people I ever saw, particularly T.K., although John was equally as hard working. John was a lot of fun because he has a very dry sense of humor, and he would write these memos to us. I wish I'd kept a whole set of them. One about where it took three hands to do the zipper lock on the suit, and on your third hand you do such and such. I wish I still had that memo.

T.K. was through, but very serious. To him it was a very serious job. And always had a lot of good ideas. I worked with T.K. on a lot of things since then. In fact, he worked for me at Grumman for a couple of years on Space Station. So I think both John and T.K. are outstanding individuals.

Others on Apollo-Soyuz, Glynn Lunney. I think Glynn Lunney made Apollo-Soyuz happen. I'm not sure we could have done it without him. He had the right temperament and the right attitude and the right way of dealing with the Russians, knowing when to be, I guess, gentle with them and when to be confrontational. We needed to be confrontational with them a lot. I think he pulled it off. I learned a lot from him.

George Low, of course, made Apollo happen. Without George Low, I don't know that we could have done Apollo. They were the people that everybody recognizes, like Gilruth. I think people like Chris Kraft is another one, Dick Johnston, and people that worked for me. That was an incredible team of people. I said somewhere in the middle of it

all that my job was not to motivate this crew, but to hold them back and be sure that they thought things through before they did it, because they were ready to go.

Walt Guy, Harley Stutesman, Charlie Lutz, Frank Samonski, Dick Mayo. It's a lot longer list than that, that were just all self-starters, you know. They didn't ever come in and say, "What should we do?" They came in and said, "This is what we should be doing." They made it happen.

BUTLER: A good team of people.

SMYLIE: Matt Radnofsky, who's not with us anymore, and, of course, Correale and Hayes. When I got to be division chief, Jim was my deputy and he was outstanding in that he was—to some degree I was the good guy, he was the bad guy, and when somebody came in, he was the guy that just gave them fits about what they were proposing. Sat and listened to all the arguments and here's the point, counterpoint. We made a good team. So, yes, it's an unending list. I wouldn't know where to stop.

BUTLER: That's a good team of people, and everybody worked together to pull it all off.

SMYLIE: Yes.

BUTLER: You mentioned that you were in Apollo-Soyuz for a while, but that you had moved on before Apollo-Soyuz actually flew, and you had moved on to NASA Headquarters [Wasington, D.C.]. What were your roles there and your duties?

SMYLIE: I'm not sure how the idea of me going to Headquarters arose. I think somewhere along the line I talked to Max Faget about doing something different. I wasn't sure I wanted

to be division chief for thirty years. George Low had gone to Headquarters and probably I had worked more with George than Max during the Apollo Program, because George was running the Apollo Program. Max was not terribly interested. He was interested. I don't want to give the wrong impression. Max was the big spacecraft guy, and I was over here doing something different, so he was going to let me do my thing. So I worked with George more than I did with Max.

I guess George may have suggested me to somebody at Headquarters, but, anyway, I had a call to interview for this position at Headquarters, and I went up and talked to Roy Jackson and interviewed, talked to George Low and two or three other people, and came back home.

One Sunday, actually, I think it was either a Saturday or a Sunday, I was out fishing in Galveston Bay with my wife and another couple, and the weather got bad and we came in. I called home to see if the weather was okay at home, and my son said that I had a call from Roy Jackson at Headquarters on Sunday afternoon. I called him back from a pay phone, and he offered me the job as Deputy AA [Associate Administrator] for Space Technology in Headquarters.

So we moved up there. When I arrived and went in to see Roy, he said, "Welcome to Headquarters. I'm going back to Northrup [Corporation] in two weeks." [Laughter]

BUTLER: Oh, my. [Laughter]

SMYLIE: It wasn't something he wanted to do; it was something Northrup demanded, because he was going to lose a lot of benefits if he didn't go back to Northrup. So he left, and a guy named Ed Kilgore, who was his deputy, took over as an acting, and I worked for Ed.

My job was space technology across the board, so it was a whole new world for me, because I had to worry about propulsion and guidance and control, navigation, materials, in

fact, everything but what I was used to, because the responsibility for space suits and environmental control was in a different code. So that I didn't have, which was what my whole background was. So I had to learn very fast about other technologies. In fact, this was in November, and in January I was testifying on the Hill, defending the budget.

BUTLER: Quick on-the-job training.

SMYLIE: So it was a real learning experience, because I didn't know anything about the political world. I was talking about technologies that I was learning about on the fly. I was in the budget world, which I'd never been in before to any great degree, advocating new programs, working with Langley, Ames [Research Center, Moffett Field, California], Lewis [Research Center, Cleveland, Ohio], and Dryden [Flight Research Center, Edwards, California], which were Centers I had not spent a lot of time working with, learning all about them. It was great. I really enjoyed it, did it for a little over three years.

Ed Kilgore went back to Langley, I guess, is what happened to Ed, and we got Bruce Holloway in as acting associate administrator. Bruce was a four-star general who had been assigned to NASA, actually, after he retired. He retired from the Air Force. He was head of SAC, which is one of the really big jobs in DoD [Department of Defense], Strategic Air Command. He had retired, and he came to NASA as actually the interface between NASA and DoD. He ran a small office that sort of took care of any interaction between ourselves and the DoD, particularly in the classified world. They assigned him and asked him to come over and run the office—they didn't think I was ready for it, and they were right—until they could find somebody to take over the job. So he was there for a while, and he was wonderful, a wonderful man. I really enjoyed working with him, particularly because of his background and experience. He was a P-40 pilot in Burma. He was an original Flying Tiger.

So he went from Flying Tigers to head of SAC, [to a] sort of a low-level job, comparatively, in NASA. But a really wonderful guy.

They hired Al [Alan M.] Lovelace to come in as the associate administrator. Al came from the DoD, was head of laboratories, another really interesting, great guy to work with and work for. I worked for Al for the rest of the time I was there, until he was selected as deputy administrator and they made me acting administrator. By then they decided maybe I could carry on. They didn't quite give me the job; they made me acting. So I did it for one budget cycle, I guess. Had both aeronautics and space technology, so now I had to learn all about aeronautics.

I had told Al that three years at Headquarters was about enough, because I felt you began to do the same thing over again after three years, and I would like to go back to the Center. So I was actually at RPI, reviewing some programs they were doing—Rensselaer Polytechnic Institute [Troy, New York].

And I was at the airport, flying home, and had a call over the loudspeaker at the airport that I had a phone call, and I got on the phone and it was Al offering me the job as deputy director at Goddard [Space Flight Center, Greenbelt, Maryland]. So that's when I went out there and went to work for Bob [Robert S.] Cooper. Cooper came from the DoD, actually from Lincoln Labs, was his real background, and they felt they needed somebody in the deputy director job that understood NASA and could help Bob get acclimated to the NASA environment and, I think, to some degree to keep him under control. So I worked out there for about three years with Bob again, in a different environment, because we had everything from launch vehicles to scientific experiments, to spacecraft, engineering, the whole network, another new experience for me. I spent three years there.

Went back to Al after three years and said, "Okay, it's time for me to consider coming back to Headquarters. I've been doing that for three years." So the space tracking and data job came open and he gave it to me, and I went back to Headquarters and sort of took TDRS

[Tracking and Data Relay Satellite] with me, because TDRS was a Goddard program, tracking and data relay satellite program, which turned into a real mess for us, a very challenging program which, like the history of the EMU, is another book you could write on tracking data relay satellite.

After I got back to Headquarters, we had to work out a way to restructure that program to be a NASA program rather than a commercial program, at least effectively a NASA program, which we did, and were able to pull it off and it was a big success. That was probably the major job at NASA Headquarters, was to make success out of TDRS, but also, which I was equally proud of, was to increase the capability of the Deep Space Network [DSN, operated by Jet Propulsion Laboratroy (JPL), Pasadena, California] to support the Voyager mission on the way out to Uranus.

We succeeded in expanding the large antennas from sixty-four meters to seventy meters. We put in new thirty-[four]-meter antennas at all the sites and put in low-temperature receivers, worked out a way to array the Goldstone antenna with the very large array in New Mexico to increase the capability of the DSN and to array the antennas in Australia with Parks, which was an astronomical telescope, to increase the sensitivity and were able to get full advantage of the Voyager mission. I felt that JPL did a very good job on that. My job was to sell Congress on doing it, which we were able to do, and carry out that program.

I had a deal with Jim [James M.] Beggs that after we got the first TDRS up and operating, I could retire. Got delayed because of the problem on the first TDRS when the IUS [Inertial Upper Stage] blew up and it took us a while to get into the correct orbit, but after that was done, I retired. And that was NASA. Although I have not gone entirely; they've still got me on a working group back with Crew Systems Division. I was just down there [in Houston] two weeks ago, reviewing the programs, with still some of the people that I hired. They're now learning the program.

BUTLER: It's good to keep the experience that everyone has and keep applying it to current mission.

SMYLIE: Yes.

BUTLER: As you were at Headquarters, especially the first time you were at Headquarters and you said you were involved in new technologies for you in the propulsion and so forth, this was all for the Space Shuttle, is that correct?

SMYLIE: Space Shuttle was a piece of it, but, no, we were looking out beyond the Space Shuttle. There were very advanced programs, although we did revector a lot of our work toward Space Shuttle in those areas where we thought Space Shuttle really needed help. So it was a mix. It was not entirely Space Shuttle. Some of it was looking out beyond Space Shuttle.

BUTLER: What were some of those systems, if you could tell us in general?

SMYLIE: Well, sticking with the Shuttle for a minute, Max Faget came to me somewhere in the Shuttle development period and suggested that the Shuttle represented a very good test bed for advance technology, and that we should find a way to use the Shuttle not only as an operational vehicle, but as a vehicle to advance technology both for the benefit of technology and also for the benefit of the Shuttle. I thought that was a pretty good idea and started a program called the Shuttle Experiments Program at Headquarters, got JSC to assign a manager.

I set up working groups across the four research centers to come up with experiments that we could run on the Shuttle and do advance technology. That turned into a pretty good program. One was to put an infrared camera in the vertical stabilizer of the Shuttle aimed at the top of the Shuttle so that during reentry you could get a very accurate measure of what the temperature field was like and find out from that, number one, how close did it conform to wind tunnel and other experimental data and theoretical data, to modify our design procedures, and also if we discovered that we could remove some of the insulation, that we could do that. Langley ran that program.

I made a deal with Mike [Michael S.] Malkin, who was running the Shuttle Program at the time, to put wiring into the Shuttle to support that experiment. He paid for it, and we paid for the experiment and we paid for the modifications to the vertical tail to install that camera. That experiment was run long after I left and, I think, was very useful.

Another one which was a little more speculative was to try to measure what's called the windward-side temperatures at the bottom of the Shuttle. That was an Ames experiment. Ames had an aircraft with an infrared telescope in it that they used to do astronomy, and we devised an experiment where the airplane would fly in an area where they could use the telescope to view the Shuttle during entry and, from that, measure the temperature field on the windward side of the Shuttle during entry. I'm not sure how well that one worked, because that was very difficult to get the airplane in the right place and get the measurements. I really don't know. But that was one of the experiments we were trying to do.

Another one was air data. The Shuttle didn't have a very good air data system, and we sponsored an experiment to measure what the actual parameters were of the shock waves and the air that was flowing over the Shuttle during entry. So it was a hypersonic research vehicle and we'd run experiments. So that was one thing that we sponsored.

We sponsored a lot of work—off of the Shuttle now for a moment—and there might have been some other experiments that I don't remember, ion engines. Ion engines are just now being used operationally. There's this deep space [Deep Space 1] something mission flying now that JPL sponsored, using ion engines. We were doing ion-engine research at Lewis Research Center back in the seventies. We had a mission planning activity in the science directorate. They wanted to go to Mars, and an ion engine is perfect for a Mars mission. It's really the very best way to do it. We tried to initiate an ion engine project office to look at ion engines for a Mars mission, and just couldn't get the money to do it. But we did keep the ion-engine work going, which, by the way, is Dan [Daniel S.] Goldin's background. That's what he did in Lewis. That was either before or after my time. I don't remember him at Lewis, but that's what he was doing at Lewis.

We were working very closely with the Air Force on what they called the Space Test Program, where they had a real program to test advance technologies, which we didn't have. We had no good way to, in space, test the technology we were working on. So I got a very close relationship with a colonel named Johnny Brooks in the Air Force laboratory world, and he and I traveled once a quarter to either a NASA facility or a DoD facility to get updated on what they were doing, with the idea being that we would eliminate duplication and develop cooperative programs. Out of that grew a number of things that we were able to do together, and one was to fly an ion engine on the DoD spacecraft. Unfortunately, their program got canceled before we were able to do it.

We had a program at Ames called HMAT, Highly Maneuverable Aircraft Technology, which was an unmanned small aircraft that was to test really advance technologies on high maneuverability for like a fighter aircraft, and we needed an engine. Johnny got me an engine, for nothing, to put on that aircraft. So there was a lot going on, cooperation between ourselves and DoD back then. I hope it's still going on.

We developed a joint composite program. Composites was very important in those days. It was a fairly new technology. We didn't know much about how to test it, didn't know much about how to be sure that when you built a composite part, that it didn't have voids in it. So we were doing a lot of work on composites. That was part of the Shuttle experiments program, was to develop a composite flap with the Shuttle and test it. It could save a lot of weight. We developed a composite program with Boeing, I believe, to build some composite parts and fly it on commercial airplanes, some of the noncritical pieces like some of the flaps they use when they're trying to slow down on landing, which, if it broke, it didn't matter, to get experiments from composites. So there was a very large, both between ourselves and the DoD, composites program.

Even in those days we were working on GPS [Global Positioning System] receivers, because GPS was a program just starting. We had the idea that there ought to be a low-cost GPS receiver for general aviation, so we started a program to do that, which turned out was unnecessary. I mean, it was such a useful thing to have, the industry just did it. They didn't need NASA fiddling around with it, but we didn't know that in 1973. And there was no GPS. It was on the drawing boards.

The only real big project we started back in those days, I guess, was something called LDEF, Long-Duration Exposure Facility. I presented that. That was a Langley project. They were advocating it. I took it on to get it through Congress, the OMB [Office of Management and Budget] and Congress, and did. That program got approved and it eventually flew long after I left.

I mean, most of the things I worked on in '73 through '76 happened five or ten years later. They didn't happen while I was there. And that's the way advanced technology is. In most cases, it's the person in Headquarters who advocates it themselves and won't be around when it happens, because those things have such a long lead time. They stay there a long time, but nobody stays in those Headquarters jobs for a long time, at least not at that level. In

fact, when I was acting administrator, associate administrator, I told—it was Frank Panarada was my administrative guy, and I said, "I need some history on this place. How about putting up in the conference room a picture of all the associate administrators of Aeronautical Space Technology so we'll have this historical perspective?" He came back a week later and said, "Well, we don't have enough wall space to put them all up." [Laughter]

BUTLER: [Laughter] Oh, my.

SMYLIE: Because people had gone through there so fast. In fact, Jim Beggs had that job for a while. So people move through there real fast, and it hasn't slowed down.

Those are the ones I think of off the top of my head that we worked on during that three-year period.

BUTLER: Certainly some significant ones.

SMYLIE: There was a big emphasis, which Lovelace really ran and I just sort of was around helping out when I could, but it was his baby, that was back when we had the big energy crisis and energy savings became the mantra. We even had an energy role in OAST, which eventually grew into an associate administrator of its own for energy and answered to Jack Schmidt. But anyway, aeronautical commercial aircraft energy efficiency became *the* thing to work on, and so there was a very large program on aircraft energy efficiency, both from an aerodynamics point of view, from an engine point of view, and we had joint programs with Boeing and Douglas [Aircraft Company, Inc.], jointly funded by NASA and by those companies to develop—and with G.E., Pratt & Whitney [a United Technologies Corporation Company], on developing energy-efficient engines, energy-efficient aircraft, revisiting

boundary layer control, all kind of things to make aircraft more energy efficient, which paid off in the long run.

The energy efficiency sort of went away as being important in itself, but from an operating point of view, energy efficiency is extremely important to the airlines, so a lot of that work did end up in the engines and in the aircraft, and, along with composites, was a piece of that, because composites makes airplanes lighter, better navigation, just the whole spectrum of aircraft operations. From an energy efficiency point of view, it was important. It was paramount then and is still important, although NASA is now concentrating on safety in the current program is the big thing, safety and air traffic control. Those are the two things, to increase aircraft capacity and to increase safety, which is getting to now, rather than then in our history.

BUTLER: History leads us up to now. What happens now is all based on what happened then. It must be interesting for you to see this variety of projects that you were pursuing here. Like you said, they happened five, ten years later. Must be interesting when they do follow through.

SMYLIE: Yes, it's very satisfying to see them actually happen.

BUTLER: And be successful.

SMYLIE: And be successful. Right.

BUTLER: As deputy director at Goddard, you mentioned that again you went into a job where it all changed for you, where you had to learn new tasks and things. If you could give us an overview of what some of those projects and roles were.

SMYLIE: At Goddard. Well, I arrived the week that the TDRS contract was signed with Space Com, and so right away we got involved in TDRS, which was an experience in itself, because it was an entirely different way of doing business. Theoretically we had contracted for service. We were not on the spacecraft, we were not on the ground station. We would require data that the contractor would provide as a result of building that system. So they were to raise the capital to build the system, and we didn't start paying them until they began to deliver data. So there were no progress payments.

But it got a little bit colored as being a privately funded venture by the fact that we used the Federal Financing Bank to provide the funds, rather than Chase Manhattan or some investment bank. The reason for that was, we got a lower interest rate by going through the Financing Bank and got congressional legislation to do that. This all happened before I arrived, but that was the mechanism by which this system was to be built, was that the contractor, when they needed money, would go to the Federal Financing Bank, draw down money, develop the system, build it, deliver it, begin to deliver data. We would start paying them and then they would pay the Federal Financing Bank back and take their profit.

That was the theory, and that was pretty much the way we were doing it, except we immediately ran into all kinds of problems, that the spacecraft weight grew and we couldn't launch it on the Atlas, it had to go to the Titan or the Shuttle, and Shuttle wasn't available. We didn't know when the Shuttle would be available to launch it, so we carried a Titan back up, and that was costing a lot of money. It's a story in itself. If I tried to tell that whole story, we'd be here till tomorrow, so I've got to stop somewhere.

BUTLER: Hopefully that's a story that some day can be recorded.

SMYLIE: Well, in a way it has been. Bob Aller [phonetic], who succeeded me in Headquarters, did a TDRS lessons learned symposium, and it's documented. A lot of it is documented. If you want to pursue any of that, you can talk to Bob Aller. I've got a copy of that, I think, of that TDRS lessons learned, because I participated in it.

But to make a long story short, we eventually restructured that program so it had a commercial service element in it that was going to be used both for commercial service and to provide data to NASA. We eventually had to get rid of the commercial service, and that was the big deal, was to get rid of that commercial service part of it so it became dedicated to NASA use, for several reason. One is, we now had a classified program on it, which I guess is known, but I can't talk about a whole lot, was using it rather than just NASA. And it was essential to the Shuttle. If TDRS didn't work, Shuttle didn't work. So we decided we have to have more control over it, so we did all that and took it over, in effect, although it was still theoretically a commercial program. Actually, when NASA and OMB began to play games with the Federal Financing Bank financing—how did that work? Well, I won't get into that.

So that was one program, and that spanned both Goddard and Headquarters, because I took that with me when I went back to Headquarters. I didn't take it with me, but I assumed the Headquarters responsibility when I went back to Headquarters.

Delta launch vehicle was ours at Goddard at the time. We were launching a Delta about once a month, about twelve a year. I had to sign the flight readiness review, okay to go launch, on every launch, so I had to review that program fairly regularly, although we had a whole organization to do that and they came in and briefed me in about an hour, did we think it was okay to launch or were there things needed to do. But by the time it got to me, it was okay to launch. I mean, they had worked out all the problems. All they had to do was go through what they had done and we would okay it.

We had one experience that is interesting, which I guess is all right to put in the record. We had a Delta on the pad at the Cape, ready to launch, and we were doing a

countdown demonstration in which you went through the whole countdown, except the pyros [pyrotechnics] were not armed, which are the things that destroy the spacecraft if something goes wrong. Right in the middle of the countdown, we got a command destruct signal came in from somewhere, which, if the pyros had been armed, would have blown it up. So we shut down everything, and [Robert S.] Cooper and I, who was [Goddard Space Flight] Center director, got involved. "Wha' happened?" We couldn't find any source of it.

Actually, we finally doped what happened, although I don't think they ever admitted it, but there was an Air Force tracking ship in port, and that ship had the capability to send that signal. We think that a new commander was being toured on this ship and briefed on what all the ship could do, and normally what they do, if they're testing that signal, is, it goes into what's called a dummy load. It doesn't go anywhere; it just goes into a resistor that's right there on the ship. And then somebody hit that button on the ship, and we think that's what happened.

But we were worried about Soviet submarines off the coast, and all kind of things like that. "Where did this come from?" So a few days later, we felt we understood the problem, had figured it out, and it was okay to launch.

BUTLER: Wow. What a situation.

SMYLIE: And we launched it. But that was an interesting time, figuring out what happened there. That whole story about "Wh' happened?" I don't think was ever formally known or admitted to or actually figured out that that's what happened, it's only we can assume that that's what happened, because it didn't come from us and we don't think it came from a Russian submarine. [Laughter] But we did worry about that.

We lost a couple of Deltas here in my tenure, where a solid rocket booster burned through. In fact, when the *Challenger* [51-L] accident occurred, that was assumed that's

what had happened, but it wasn't exactly what happened, but similar to what happened to the two Deltas. Solid rockets is an art rather than a science. You pour this propellant and if you end up with a void somewhere, when the rocket burns up to that void, it creates like a torch because of that void, and then burning starts going horizontally and burns through the case. That happened on a couple of Deltas where we had to go in and modify the way we built some rockets. It's always a worry. A lot of effort on nondestructive testing to figure out of you've got voids in the propellant.

Science programs, [Hubble] Space Telescope, instrumentation. The instruments were ours. The project was Marshall's. That was one of those experiences of a big program being run by two Centers, all of the problems that go with that, that we had to work through. We submit our budget to Marshall, Marshall submits the budget to Headquarters, we hope the same way we submit it, but not always. Working with them. And we had to do the ground system for Space Telescope at Goddard, and the network.

There's a tendency in all programs, not peculiar to Hubble, where when the flight spacecraft gets into dollar problems, they start stealing money from the ground system to solve the flight system problems. Did it in Space Station, did it in Shuttle, did it in everything. So I don't want to blame Marshall for being different; that's just what they did. They would cut our budget for development of ground system to solve a spacecraft problem or, conversely, they would take a function of what was to be done on the spacecraft, and rather than do it on the spacecraft, push it off to the ground system to solve, which would raise our cost. So we had to go through all of that.

We ended up, I think, with a much less than optimum system for Hubble because of all of that, which I think as Hubble has developed and they've gone through repair missions, they've slowly gotten it back to optimum. I think it's getting very close to being the right system that it should have been from the start, had not we had money problems that we had. It's not peculiar to Hubble. It's the way program solve problems.

Let's see. Hubble. International Ultraviolet Explorer [IUE] was an interesting, good program because of an international program between us and ESA [European Space Agency]. We had two Control Centers, one at Goddard and one in Spain, and the spacecraft was in high elliptical orbit, so for half the orbit we controlled it, and the other half Spain controlled it.

It was the first spacecraft in which we had some elements of what we call today telescience, in that the astronomer could come to Goddard and he took over control of the telescope. He sat in a little Control Center separate from the spacecraft Control Center, and he pointed the telescope, took his observations, not unlike he would do at Palomar [Observatory, California]. So we felt that was sort of a breakthrough in the way you ran scientific missions.

Also a good international program and the biggest in-house project Goddard had ever done, because we built that spacecraft in-house, and it was a big spacecraft, half the size of this room, and was very successful. Still operating, I think. I'm not sure. I think we've turned over complete responsibility to ESA, and I think they're still running it out of Spain. I'm not real sure about that. A very good program.

The Network, Science, Applications, LANDSAT, was going on then. The big thing was development [of the thematic mapper] for LANDSAT [D], with Hughes [Electronics Corporation]. I talked to Hughes once a month in Santa Barbara [California]. That was a nice place to go. We eventually moved a lot of the meetings to Los Angeles. A big instrument, very complicated instrument, very difficult, always behind schedule. G.E. was developing the spacecraft. A lot of time in Valley Forge [Pennsylvania] interacting with G.E. on getting LANDSAT [D] done. That was the big applications program, the big science program, Space Telescope, and I guess IUE. There were a lot of others.

The network was controlling about twenty satellites, so we had a big function in controlling and getting data from around the world because we didn't have TDRS, so we had

ground stations all over, all the way around the world, Ascension Island, Spain, Australia, Guam, Hawaii, California, Alaska. I can't remember where they all were. Bermuda and Chile. I guess that's most of them. I guess that about covers it. We had one in Botswana for a while, mainly for Shuttle, I believe. We had to put one in Dakaar for the landing in Africa if the Shuttle had to abort.

Engineering was, of course, the big effort at Goddard, but it supported a lot of the programs. We were doing some advanced technology for our own missions. Applications, science, engineering, programs, network, launch vehicles. I guess that about covers it.

BUTLER: A little bit of everything.

SMYLIE: A little bit of everything. Well, that was one thing that we used to say, is that we had the scientists, so we could conceive an experiment for the scientists, build the instrument, build the spacecraft or get it built or manage it, launch it, have the network to support it, collect all the data, have the scientists to write the report. So we had it from beginning to end. Still got all of that at Goddard except the Delta launch vehicle. We went somewhere else to get the launch vehicle.

BUTLER: That's a pretty good system.

SMYLIE: Yes. Some great scientists out there. In fact, I just saw in yesterday's paper, they just discovered a solar system around a star in Andromeda, and Steve Marin [phonetic] was talking about that. Steve was a young astronomer at Goddard, and I guess he's now running the American Astronomical Society. I don't know whether he's doing that or whether he's still at Goddard or not. I think he's still at Goddard. AAS is a professional society position.

But maybe not. Maybe he's left and is on there full time. He was one of our young astronomers.

BUTLER: That's pretty neat to see that follow-through.

SMYLIE: Yes. I guess that sort of covers Goddard.

BUTLER: Looking back over your career with NASA, what was your greatest challenge?

SMYLIE: Well, I guess the challenge of making it to the moon in the time period we made it and having to invent things that didn't exist because there had never been a requirement for it within that time frame, and put together both the contractor and the government team to pull that off was the biggest challenge. It was both a technical and a management challenge, and I think we made significant progress in both.

The technical challenge was the most fun to be able to accomplish that and to maintain the discipline to be sure that we did enough to be able to accomplish the mission and not overreach and try to do too much. It was the old cliche that better is the enemy of the good. We had to know when we had it good enough and stick with it and have the discipline to stick with it, and not have somebody talk us into taking the next leap. That was part of the management challenge, and the rest of the management challenge was just the size of that team and the geographic dispersion of it and trying to bring it all together.

I think the leaders that put that together that way did it in a way that ensured its success, because the philosophy they adopted—and I guess it was people like Gilruth and George Low and von Braun, they were able to divide that job up in a way that would minimize interfaces, so that you could do your job and you had the minimum number of external things to worry about, that you had to satisfy between Marshall and JSC, for

instance. I think George Low used to say there were ten wires that went between the command module and the Saturn, and that was the interface, the physical interface. So we took that on as a management strategy that we'd work it out so that you can do your job and not worry about somebody else's job any more than you absolutely have to.

I think that was a management technique that helped make it successful, and I think the lack of that has been one of the problems with Space Station, that the management challenge of Space Station has been immensely more difficult than the technical challenge of Space Station. In many ways, Space Station ought to be easy technically, but management-wise, it is a horrendous problem, with all the nations and the Russians and all the contractors and all the Centers. I worked on it for two years at Reston [Virginia], and the management challenge was the challenge.

BUTLER: Hopefully that challenge can eventually be met.

SMYLIE: I think they're going to get there. I talked to Gretchen yesterday, and even though she's leaving, she thinks they're going to get there. [Laughter]

BUTLER: That's good to hear.

SMYLIE: The other one, I guess, was TDRS.

BUTLER: Certainly.

SMYLIE: That was a challenge.

BUTLER: Certainly. In reflecting on the challenges, what was your greatest accomplishment?

SMYLIE: Same thing. Challenges go with accomplishments. We made it to the moon on time, having that system work without failure, and getting the first TDRS up and working, especially after it went in the wrong orbit. There was another satellite that just happened to, I think on the same launch vehicle.

BUTLER: Yes.

SMYLIE: I don't know how to call anybody to find out whether it was a similar problem.

BUTLER: I believe they're looking into that now, how it will impact the future missions.

SMYLIE: In the wrong orbit. It sounded like it was on the same upper stage, but I don't know.

BUTLER: When you were in college or beginning your career, would you have ever expected where it would lead you?

SMYLIE: No, not at all. I had no idea. When I finished college, I just needed to make some money and get independent. Actually, I was supposed to go in the Air Force because I had an ROTC [Reserve Officer Training Corps] commission and was supposed to go to Wright-Pat [Wright-Patterson Air Force Base, Dayton, Ohio], which I think I would have enjoyed, but earlier I had spent a year in the Navy on a one-year enlistment, and even though they had sent me orders to go to Wright-Pat and I was not seriously looking for a job, all of a sudden I

got a telegram from the DoD, from the Air Force, saying that, "We have noticed that you're a veteran, and therefore you don't have to report." So they canceled my orders.

I had to go find a job right quick. [Laughter] But I'd done some interviews, so I went to the Ethyl Corporation, actually, in Baton Rouge [Louisiana], and worked for them for about eighteen months. Sort of boring. I was in Houston and I went back to college and got a master's degree, and that's how I ended up at Douglas.

But, no, I had no idea, and first began to think about things like that when I was at Douglas because working on a brand-new airplane is about as exciting to a young engineer as anything they could do. So I began to think in those terms. I think if NASA had not gone to Houston, I don't know whether I would have joined NASA or not. I don't know. But Houston was one of the draws, because I'd lived there and liked it. My wife was from Texas. That's where I met her, although we're divorced. But that was where I met her. We moved back to Texas.

BUTLER: Are there any last thoughts that you have for us on this? Anything that you wanted to say any last things about? Or anything we didn't cover?

SMYLIE: I think you've covered about everything. The only thing I might say is that I still have a lot of regard for NASA, still am involved. I have served on about five or six or seven—I don't know what the count is—different working groups and committees, reviewing NASA programs or helping review NASA programs. The first one after I left the agency was for Jim Beggs, on Shuttle management, ran a Shuttle operations management study, which was a lot of fun. And I served on the Federal Lab Review, that happened under Johnny Foster a few years ago. I was on the NASA Council. I resigned from that several years ago, mainly because my dad was living with me, was in ill health, and I just couldn't spend the time. More recently, they asked me to come back to serve on a working group on

advanced life support technology, which I'm doing. So I stay involved with NASA and hope to stay involved as long as I seem to be useful.

BUTLER: I'm sure you'll be able to be useful to NASA for many years to come yet.

SMYLIE: I hope so.

BUTLER: I want to thank you for joining us today.

SMYLIE: Thank you for the opportunity. I'm very pleased to do that. This has been fun also. You really tested my memory. I don't remember what happened thirty, forty years ago. I sometimes wonder if it really was the way you remember it or if you remember it the way you would like it to have been. So I hope I didn't get too much of that in there.

BUTLER: I think you did just fine. I know it is certainly a challenge to try and look back that far and remember details, but I think we've got a good amount of information here today.

[End of Interview]