ORAL HISTORY TRANSCRIPT

THOMAS V. CHAMBERS
INTERVIEWED BY KEVIN M. RUSNAK
HUNTSVILLE, TEXAS – 20 JANUARY 2000

RUSNAK: Today is January 20th, 2000. This interview with Tom Chambers is being conducted in his home in Huntsville, Texas, for the JSC Oral History Project. The interviewer is Kevin Rusnak, assisted by Carol Butler and Sandra Johnson.

I'd like to thank you for joining us today and allowing us into your home to do the interview.

CHAMBERS: My pleasure.

RUSNAK: If we could, I'd like to start with something about your background, growing up, and any interests you might have had that led you into aviation or engineering or the career path that you eventually ended up on.

CHAMBERS: Okay. Well, you're going to stop me if I dribble on too long on any particular subject?

RUSNAK: Okay.

CHAMBERS: I was born in the north of England, July 1920, in a town called Hull, East Yorks. After I left primary school, I was offered an apprenticeship at Blackburn Aircraft Company,

which is a company that is now extinct. But it was about ten miles outside of Hull. We used to catch a train from my home to Brough where this place was. They specialized in naval aviation. They built the Shark, Blackburn Shark, which was an unsuccessful competitor to the Fairey Swordfish, the old stringbag of World War II fame. Then they were just introducing SKUAs and Rocs. The SKUAs were the first all-metal monoplane built for the [Royal] Navy… The Roc was a version of it that had a four-gun turret mounted in the back seat.

The idea of apprenticeship was that you worked in various departments of the company and at the same time went to night school working towards your higher national certificate. This was a Ministry of Education deal whereby it had the equivalence of a bachelor's of science degree, but you could do it at the night school. It was a good deal. They used to let us off early to go to night school, half-past four instead of five o'clock. It doesn't compare well with the co-op programs of today.

Anyhow, I did that for about four years and I started off holding up a dolly for riveting guns, sort of menial tasks, sharpening drills, and then progressed to the tool room, which was a fairly high-class operation, when the war started, talking September '39, and I joined the Royal Navy. When I went to join up, they had not started recruiting for hostilities only, so I had to join for seven years with the fleet and three with the reserve. Subsequently, it turned out that I had to do ten years. I was recalled later for the Korean conflict and a year and a half then, and so I did a total of eleven and a half years with the Royal Navy.

I don't know if it's of any interest, but in the Navy I served in the Mediterranean, Atlantic, and Pacific theaters of war. The ships were the *Ark Royal* in the early years. It gained some fame as being the ship that stopped the *Bismarck* in the Atlantic. One of the Swordfish managed to hit the steering gear and held it up until the fleet could catch up with it.

RUSNAK: Were you on it then?

CHAMBERS: Yes. And it was subsequently sunk in the Mediterranean, [November] of '41. In fact, this last trip to England, last fall, I went to a reunion of the ship's company. Of the 1,300, there's about 80 people there at the reunion, and at least half of those were caregivers who had to help the old guys in. I remember looking around about ten o'clock and all of the caregivers were whooping it up and all the survivors were nodding off over there at their tables. So that's life, I guess.

I was also—this is interesting from the point of view of previous exposure to the United States—I was on a ship called the *Trumpeter*. Actually, we commissioned it in Portland, Oregon, as a lease-lend escort carrier. We did Atlantic convoys on that and mostly involved in ferrying the Eighth Army Air Force across to Britain.

Then I guess later on I was with a MONAB-4, Mobile Overseas Naval Air Base, which was the Royal Naval idea of how to fight the Pacific war. They dressed us up in khaki and gave us guns and we were supposed to capture islands from the Japanese. Fortunately, the one I was assigned to didn't have any Japanese on it, so I was lucky in that respect. But I was there when the war finished and, like I say, my service was extended for another three years, so I was in the Navy for ten years.

When I came out of the Navy, I had been married, and my wife lived in the south of England, so instead of going back to Blackburns, I went to De Havillands and worked with De Havillands on the first Comet, prototype Comet. Probably nobody remembers that now, but it was the first jet airliner, and it was a pretty good job and very successful at first, but it ran into

troubles with metal fatigue in the cabin area and had to be abandoned after a while. It was too expensive to repair and run.

Then I got recalled for the Korea conflict, spent eighteen months, as an instructor on aircraft instruments. When I got out again. De Havillands put me to work on their missile program, which was just starting. The missile was the Bluejay air-to-air missile, eight inches in diameter. It was good fun. It was a good project. I was developing the alternator power supply. There were no transistors in those days, if you can think that far back. All the electronics were magnetic amplifiers, and you had to have a high-frequency supply to keep the weight and volume down. So this alternator was driving by a compressed air bottle, little high-speed turbine, and it generated 2,400 cps power.

It was a good project from the point of view you're in it from start to finish. You did the drawings, you did the prototype, you kind of helped build the stuff in the machine shop, you put it together, you tested it, and then you went to the west coast of Wales and fired it, if you were lucky. It didn't always go. It was that sort of a job.

During that period, I finished my higher national certificate, electrical engineering, was offered a job with another company, Rotax, a big increase in salary. If I remember right, it was almost twice as much, but it turned out to be nowhere near as interesting a job, nowhere near as challenging.

At that point, I guess, I decided to go to Canada. Really I wanted to go to Australia, but my wife thought that was too far. Not much difference it made, but in those days you had to go by ship, so it did make a difference.

RUSNAK: Were you just looking for a new challenge or did you have a job offer?

CHAMBERS: No. Generally dissatisfaction with progress in the U.K. On a kind of a human note, the thing that really made my mind up was I had been running a small car by the skin of my teeth. The situation in Britain then was, you know, gas was very, very expensive, cars were expensive. If you could run a car, you had to maintain it yourself, do everything. [That is,] people on same salary range as I was. I just decided that I could upgrade to a Wolsley. Wolsley was the car the police used, and its main attribute was it had six cylinders instead of four. That same weekend that I set out to buy it, they introduced gas rationing again because of the Suez crisis. It wasn't just that thing, of course, but that added up to a lot more things. Still, shortages from the war and all kinds of problems.

So I decided to move out. I wrote to Canada, all the companies I could think of in Canada. De Havillands was willing to fix me up with a job, they had a company in Toronto, but it was a very small outfit. AVRO Canada didn't respond. I didn't get a letter back from them, and that was my main hope for a good job.

Finally, I decided to go anyhow, and went. Me and another guy started looking around for a job in the Toronto area. Although I knew the States from our previous visits, I'd underestimated the difficulty in North America of looking for a job without a car, and hitchhiked most of the time. We didn't do very well.

Finally, I went to AVRO Canada for the first time—I'd stayed away from them—and they received me with open arms. There apparently had been a foul-up in the personnel office and my letter of employment hadn't got out of there. Unfortunately I'd have had my one-way paid over if I'd got the letter.

But I was given a job there in the simulation lab. They were building the AVRO Arrow, of course, CF-105, magnificent machine. They wanted to mock-up the flight control system in the lab. It was a pretty advanced flight control system, first fly-by-wire system, had an electronic yaw damper, and they needed to make sure this thing would work before they flew the first vehicle, of course. My job was to build a mockup of a vehicle flight control system, using as many parts of the actual vehicle as I could, and then simulating the rest with levers, push rods, analog computers, and so forth.

That, again, was an interesting job. I worked for a guy called Len Packham, who was a Canadian. He joined the Space Task Group later. Unfortunately, he died early. He used to put salt in his beer, which I always thought might have been part of the problem. But I more or less became his deputy on this stuff.

Next door was an analog computer lab, which did the computing for the arrangement, and it was run by a guy called Dick [Richard R.] Carley. You may or may not have heard of him, but he joined the Space Task Group as well. Of course, over the two outfits was Jim [James A.] Chamberlin, who later became [the Gemini] program manager.

I guess that's all about this lab, except that as is true of all systems of that nature, it didn't work, of course, at first, and I got involved then in designing fixes, electronic black boxes which filtered out the oscillations in the systems and so forth. It was all very instructive.

Then I guess we get to Black Friday, as you call it and I guess everybody else calls it.

RUSNAK: That seems to be the case.

CHAMBERS: Yes. Well, it was black, all right, my memories of it. I had not been at AVRO as long as most of the people who came down to join NASA. I'd only been there about a year and three-quarters to two years, so I wasn't as familiar with the Canadian politics as some of the others are. I may be entirely off base, but from my point of view, it was one of the worst decisions that any government's ever made. It was a political football. The opposition party wanted to get in, of course. They based their appeal to the voters on the fact that, "If we cancel this Arrow, very expensive project, we cancel this Arrow, your income tax is going to go down." From what I saw, Canada was getting pretty much a free ride. They were relying on the United States mainly and, to some extent, Britain, for their defense in the North Atlantic. Their income taxes were much, much lower than Britain and the States. So there was no reason to forward that argument that your income tax—it wasn't right.

But anyhow, they, like politician usually do, they sell lower taxes to get in, and this guy got in, canceled the program. That was bad enough, but the thing they did after that, which was destroy the evidence, they bulldozed all the vehicles that had been built, just in case somebody might try and re-ignite the program. I thought that was criminal. I mean that really sickened me.

Anyhow, it started a slump in the Toronto area that lasted for quite a long time. Then, of course, they bought Bomarc missiles from the United States, which didn't help them a bit.

From a personal point of view, it was pretty much a disaster. We'd bought a house in Georgetown near Toronto and just nicely settled in. There were seven houses on the street, and five of them were up for sale at once. So the prospect of getting your money back was practically zero. There was no Social Security for people who earned above a certain amount, so there was nothing coming in there. You couldn't get a job. When I say you couldn't get a job

in the Toronto area, I don't mean you couldn't get a desirable job; you just couldn't get one. One of my friends got a job as a policeman and he used to come back and tell me stories about working as a policeman in Toronto. But I was considered too old for that.

There was plenty of work in the United States, but you couldn't get a visa without going on this waiting list, which apparently was eight to ten months. So we really basically had—the only choice we had was walk away from the house and go back to England, where there was plenty of work [—would not have any trouble there]. Then NASA came along, and from that point of view it was a good deal. They could get a visa, they could get you a visa straight-away, of course. The job offer they gave me was a particularly poor one. It was about 30 percent less than what I was earning in Canada. It turned out later that that was just a peculiar problem.

But anyhow, it sounded like a real interesting deal, and I jumped at the chance, and promptly packed my bags and drove down to Langley Field, Virginia, left my wife with the house and two cats and the furniture, and said, "Do the best you can." [Laughter] She did a damn good job.

I don't know whether this fits in, but when she finally joined me in Virginia, she'd caught an airplane with these two cats. The two cats, she'd had them tranquilized for the journey, and she was supposed to land at Newport News, near where I rented a house, but it was fogged in, so she had to land at Norfolk. By this time, the cats had recovered from the tranquilizer and they were yelling their heads off and pee-ing and whatever. She had to get a bus from Norfolk to Newport through the—the tunnel had just been built, I think, right before. By the time I met her, she wasn't sure she wanted to come to the United States anyhow. She'd seen too many films of robbers and murders and guns and so forth.

But she very rapidly fit in down there, particularly when we rented a house on Wormley Creek, off the York River… It was a very pretty spot and we made friends right away. The welcome we got was quite fantastic. We were invited out to meals all the time. The first time I went on travel, my boss, without saying anything to me, he went around the house, picked up Doreen, took her to his house and stayed there all day and he entertained her. They couldn't do enough for us. I fitted in straight-away from the point of the view of the working atmosphere. So that was great. Socially we were very kind of happy there and everything seemed to be working good.

I should mention that it wasn't just the social activities where the people were helpful. At work I had—I say "at work." I had a problem when my mother and father died suddenly in England, just after I'd gotten down there, and two guys in particular, my immediate boss, Bob [Robert G.] Chilton, and Bob [Robert O.] Piland, went to an enormous amount of trouble to make it easy for me to go back there and try and sort things out.

There was another thing. Chilton and Piland took up this question of my pay. You know, as I said, I hadn't gotten a very good offer. There again, they went to an enormous amount of trouble generating documentation and God knows what else to get me upgraded. Apparently there was some rule that said the way we were pulled into the United States, there couldn't be any great changes at the time or something like that. I forget what it was. But I know that Bob Piland got the administrator himself to sign my upgrade from 11 to 12. I was told that was the first time it's ever been done. But that's the sort of people they were, the sort of trouble they would go to.

Where am I? In Virginia, I guess.

RUSNAK: Let me ask, what was the first job you had when they brought you down? Where did they start you working on there?

CHAMBERS: It was a bit confusing. When I was hired in Canada and I was told I was going to work for Chuck [Charles W.] Mathews and Scott [H.] Simpkinson at the Cape, they were going to have—there wasn't a KSC [Kennedy Space Center], of course, but Space Task Group was going to have a contingent [at] the Cape and I was going to be part of that, the part of the crew down there, on the Mercury stabilization control system. Because there was nothing down there in existence, I was loaned to [Maxime A.] Faget's division, Flight Systems Division. Bob Piland was the assistant chief, and Bob Chilton was one of the branch chiefs. I worked along with them on the attitude control system. Carley was the section head, Dick Carley, the guy who was next door in Canada.

We did the stuff like writing the specifications, negotiating with the contractors, choosing the contractors in some cases. We monitored most of the test activity at the contractor's facilities, not only the subcontractor, Honeywell, but also the checkout of the capsule with the control system. There was no Mission Control Center in those days, so we did that job as well. The Mission Control…was done at the Cape, and we went down there when there was a mission and did the real-time monitoring of the subsystems and wrote the post-flight report afterwards.

It's a long string of activities that, in general, are associated with the subsystem manager's job. There was a kind of a defined job called subsystem manager and you were the NASA guy responsible for a particular subsystem on board and you reported to the program

office how it was going. You went to the program office if there was a problem and tried to get their support in fixing it.

So it was a general mix-up of tasks, and in the meantime doing anything we could to explore alternate solutions to problems. If the contractor was working on a particularly sticky problem, we would mount an in-house effort to try and find a solution, irrespective of whether it was the solution he was working on or not, anything to try and keep the motivation going to get the problem fixed.

RUSNAK: What were some of the key problems at that point? Was this prior to any of the manned launches?

CHAMBERS: Yes, I'm talking about primarily before the manned launches. I think most of the problems we had on the early Mercury were getting to grips with the testing. How did you test it? What did you test? There's all various kinds of testings. There's the performance testing, which is sometimes difficult to do in the lab, rather than the Earth orbit. There's the environmental testing, and that became a big issue, like, do you know the environment well enough to test it and how do you specify it?

A lot of problems in those days with the early electronics, the integrated circuits, or the transistors, as they were in those days. It seems like every few months they'd come up with a batch that would have solder balls inside the little box, and how did you find those out? Could you rattle all the transistors and see if they would short out?

Testing, detail testing. I don't think too many people realize how big an effort it was in the program, specifically on Apollo. I'll talk a bit about Apollo later. A lot of effort going into

defining the testing and then monitoring it and tracking down. If you had a problem, you never kind of just shrugged your shoulders and said, "Got a problem." You had to find an explanation for it, otherwise you never knew when it might bite you.

RUSNAK: Was any of your experience in the aircraft industry really applicable to this, or is this a completely new thing since you're going in space?

CHAMBERS: Some of it is entirely applicable. The kind of electronics growing all the time, but the aircraft had special purpose electronics, like Mercury did. Gyros were completely familiar to me, and the controls and displays somewhat familiar.

The biggest difference, of course, is the type of effectors, instead of pushing elevator and ailerons, you're turning on a thruster. It's a change in philosophy there. There's no friction, of course, on a spacecraft, so control system turns on the least amount of thrust to make the vehicle move and then it has to put in an equal and opposite thrust to stop it from moving. Whereas, of course, that's entirely different from an aircraft-type control system.

But, yes, a lot of it is applicable and the disciplines by which you get there from a test point of view pretty similar, although it's more difficult to create the environment.

RUSNAK: Were the thrusters then part of your responsibility as well?

CHAMBERS: No, they weren't involved. By the time they turned the thruster on, my responsibility finished and it was taken over by Dick [Richard B.] Ferguson, who was my

opposite number in the propulsion division. We had a good relationship. We worked well together.

I think from the point of view of difficulty in the design and the testing, probably the yaw reference system was the big problem. You have, of course, to have a three-axis reference system, to be able to allow the control system to operate, or even to display to the astronaut, if that's what you want to do. The pitch and roll are pretty easy. We had two-axis, two-degree-of-freedom gyros, which were monitor[ed] by horizon scanners. The horizon scanners torque the gyros so they kept a correct local reference to the Earth, local vertical to the Earth.

But yaw, how did you do that? The scheme that was ultimately involved was to use the—if the vehicle deviated in yaw, then a component of the pitch orbital rate would feed into the roll axis of the gyro and you could detect that when the roll gyro started precessing, and that was a measure of the amount the vehicle was off in the yaw axis, so you could use that to operate the thrusters and bring them back. I don't think I've explained that too well. I can probably have done it forty years ago when I was on Mercury. But anyhow, that's the basis of the thing.

Then to test that, how do you know it's going to work? You can do an analog computer simulation, but when you take into consideration all the thresholds and whatever else in the gyros, you're never quite sure it's going to work. So later on when we got to Houston, we devised an [air] bearing simulator that was going to demonstrate this thing. The air bearing simulator is a table that sits on a big steel ball with air flowing—you've seen how you balance ping-pong balls on a jet of water. Something like that. The table has essentially no friction, and if it's well balanced, it provides a fairly realistic simulation of a space vehicle.

The trouble is getting it balanced, which is a damned awful job, because you have the system mounted on the table and thrusters. We didn't use hydrogen peroxide, we used air, but the same thing. We were able to demonstrate to some degree of accuracy that the system did work, but it was an expensive effort and there were some flaws in the table operation, [that] left you with some kind of [doubt]. But as it turned out, in orbit the system worked fine. So sometimes you go to a lot of effort and find it wasn't necessary.

I guess the other thing was, there were two different thruster systems. One was proportional control, operated by levers, [which] opened a proportional valve and [controlled] the propellant. The idea was, the thrust was supposed to be proportional to the displacement of the hand controller. It never did work very well. Proportional valves for propellant, in those days at least, [just] didn't work very well.

The other system was strictly an on-off system. You bang the stick over and it opened the valve fully and that produced full thrust. Then you put the…stick back and it cut off the thrust. That was a pretty clumsy system. So relatively late in the game—and I think this was a Dick Carley input. I should say, Dick Carley was a pretty bright guy, one of the brightest guys we'd come across. But he was probably the worst guy I've ever met from the point of view of human relations. He just was an awkward—whatever.

But anyhow, this rate gyro system, [or] rate control system, [summed] the stick output with the rate gyro output in such a way that the displacement of the stick controlled the vehicle rate. I think in subsequent vehicles we kind of learned that that's not a particularly good mode of operation either. The idea is to produce the absolute minimum impulse, turn the thruster on for the least possible time, otherwise you just waste fuel.

But anyhow, all the systems worked pretty well. There were a few anomalies along the way, some the hardware, some the flight crew. Not always came out that the—some from the flight crew, but that was the way of the world in those days.

RUSNAK: Speaking of the flight crews, I think [Virgil I.] Gus Grissom was the astronaut that had control systems as his technical area.

CHAMBERS: I meant to mention that. One of the good ideas they had in those days was—and I guess Carley had gone on his merry way after falling out with too many people. He'd gone to Gemini. I was in charge of that branch then. Grissom was assigned to the branch, and when I say assigned to the branch, he kind of came over and lived there a great deal in his time, had a desk there, and that was good.

There was always a tendency in the flight control area to be this division between the engineers and the astronauts as to the amount of automatic control and what mode should be implemented from the point of view of the astronaut, and it went through cycles. I mean, there were some times where it definitely went overboard from the point of view of providing too much flexibility for the flight crew. Other times, of course, I think they felt this about Mercury, they felt that there was too much automation in the system and they didn't have enough get up and go.

So there was always that kind of tussle, and I think the idea of assigning an astronaut to—it wasn't just flight control, all the subsystems had astronauts in them, they saw both points of view and I think became less inclined to be a fighter pilot and more inclined to be a flight control system designer. So, yes, he was involved.

RUSNAK: So how much do you think he contributed to the success of the system?

CHAMBERS: Well, I think his contribution to the success was from the point of an astronaut, rather than a control system designer, but certainly he was a big help. We could use all the manpower we could get from the point of view of going out and talking to contractors and just doing that. Anytime you had Gus with you, it gave you an extra kind of bit of prestige. The contractor might be inclined to listen to you a little bit more carefully. So, yes, I was glad to have him and enjoyed his company and thought he was a great guy.

RUSNAK: Was he there just for Mercury?

CHAMBERS: Yes. They didn't do that on Apollo, and that was probably a mistake. It's easy to say it's a mistake. There's all kinds of demands on their time and training and so forth. But if it could have been managed, I think it would have been helpful. We used to get a fair exposure to them from the point of view of design meetings and flight crew inputs. They always had a bunch of operational civil servants who were representing them and so forth. But it's not quite the same thing as having the guy sit in the desk next to you for periods and joining in all the conversations and why is this like this and why is that. So it worked out good.

I think that's all I have to say on Mercury, I guess. Jim Chamberlin was the project manager then, but I was kind of already getting involved in Apollo at that time.

Then, of course, came the move down to Houston. We got a very bad first impression of Houston. We came down on a sightseeing trip just after a hurricane had passed through.

Went down to Galveston, the beaches were heaped high with rotted seaweed and flies, and a lot of the shacks had been blown over. Of course, there weren't some of the pleasant-looking buildings that there are now. Sort of a mess. I mean, we kind of thought, well, maybe the Gulf of Mexico will make up for some of the things that we're going to miss in Virginia. It didn't.

Then I was assigned to a building, Rich Building, Telephone Road, a temporary building. I don't know whether you know Telephone Road or not in Houston, but at that time it seemed to consist mainly of topless bars and places like that. I met my wife for lunch a couple of times down there, and she was not impressed at all. [Laughter]

But, you know, things move on and some things changed, of course. When we got out to the center, it was quite a lot better. We lived in Friendswood, lived there twenty years or so, I guess.

RUSNAK: Was your wife more excited about the move to Houston than the move to Virginia in the first place?

CHAMBERS: I think she was apprehensive about the move to the States in general. When she got to Virginia and made a lot of friends there, she really liked it. I mean, she would go back there like a shot now, I think. Maybe not. But, yes, she liked it there. She liked Williamsburg and she liked Yorktown and the history. Now, mind you, I went back there just a few years ago on a business trip and I got lost. The place had changed entirely. She probably wouldn't like it now. Amazing how things change.

Gemini involvement. I had very little involvement in Gemini. I was head of the control systems development branch then and I'd been assigned a very capable deputy, a guy called

John [F.] Hanaway. He was an ex-Air Force type who'd been working at headquarters and came down to Houston, very capable guy. I was able to say to him, "Handle Gemini." Of course, Gemini was going to be run by Chuck Mathews and Carley was the guidance and control guy.

A measure of how competent Carley was, if it'd only been possible to get along with him, he was doing the job practically unaided. And with Hanaway, another powerhouse, they were able to handle that thing pretty much unaided, compared with the myriads of people we had later on on Apollo. They did an excellent job.

But anyhow, my involvement with Gemini was just to give Hanaway some moral backing now and again, or assign him a guy, maybe, when he was really hard-pressed, writing post-flight reports.

RUSNAK: Then you essentially moved right from Mercury into the Apollo program?

CHAMBERS: Yes, I did. Yes. I guess, in summary on Mercury and Gemini, I thought Mercury was an excellent program. I don't know how big the group was when I joined it, but probably, I don't know, maybe 150, something like that. Very sharply focused, very good leadership, and I'm talking about two or three guys there. Everybody had enough to do so there were no turf battles, no in-fighting, or very little that I could see. I sometimes compared it with being on board ship during wartime where you don't have time to fiddle around and back-bite; you just forge ahead. If you've got a good leader, it's perfectly simple and it works out. That was my impression of Mercury, [Robert R.] Gilruth, of course, being the prime candidate there as a good leader.

Gemini—I'm probably one of the only guys who will say this—but I wasn't sure it was needed. I've read all the stories about why it was, but it seemed to me that the demonstration of the rendezvous and so forth had to be done later on in Apollo anyhow. Gemini took some resources away from Apollo, and it's debatable in my mind whether it was as good a deal as people make it out to be. There's no doubt that it filled a gap between Mercury and Apollo. If it had been that we were able to retain the same prime contractor from Gemini to Apollo, I would have thought it was a good deal then, but as it is, I have my doubts.

RUSNAK: It's interesting that you say that, because your boss, Bob Chilton, told us almost the same thing, that he didn't feel that Gemini was necessarily an important program to have in between Mercury and Apollo.

CHAMBERS: Maybe I picked it up from conversations with him sometime. Most of the stuff I read from some of the powerhouses in the organization seemed to feel it was such an extremely good deal. But it wasn't a big resource robber, it went very smoothly and it didn't take a lot of people. I guess my main problem is that we weren't able to follow through on the prime contractor from Mercury and Gemini to Apollo. Not that I'm trying to—anyhow, let's move on to Apollo.

RUSNAK: Sure. When is it that you first heard of the Apollo program and first had work to do on it?

CHAMBERS: That's a tough one. If you're talking about a date, I couldn't give you that. It's a process of gradually kind of unweaving yourself from Mercury and getting involved in Apollo. I could remember the first time I actually had to do something. Bob Chilton came along and said, "We need to write a specification for the…control system for Apollo."

I just looked at him and said, "Hackle." [Laughter] But we talked about it and we made a rough draft and then we kind of tore it up and started again, I guess. But it was that sort of a deal.

Bob Chilton was, of course, the best I know, mainly responsible for getting MIT [Massachusetts Institute of Technology, Cambridge, Massachusetts] on board. He was an old MIT guy. It become pretty controversial at one bit. I think that it was, all in all, probably the best thing that could have happened on the program. Got an early start. These guys had done the Polaris guidance system. Again, tremendous team. I guess Milt [Milton O.] Trageser and Davey [David G.] Hoag, John Miller, who founded Intermetrics, and Dick [Richard H.] Battin, the software guy, they were all masters. I felt privileged at the time to be working amongst them. But they got accused of schedule indifference at times. I'm not too sure it was indifference, but they certainly got behind schedule a few times and got sometimes accused of technical arrogance. I think there's some justification there.

I wasn't at the meeting, so I can't vouch for this, but it appears to be true that at one meeting where Dick Battin was getting chewed out by NASA for being behind schedule with software, he was asked to get some help from the industrial support contractor, AC-Delco. His answer was, "Well, that's like asking Michelangelo to get some house painters to help him." That sort of remark, of course, didn't endear him to everybody in the world. [Laughter]

But the interesting thing about this setup was—and it carried through on Shuttle—you had a situation where the prime contractor didn't have responsibility over the guidance and control. From where I sat, it had its pros and cons.

There's an immediate kind of division. The prime contractor's miffed about this. He doesn't like it. In many cases he fights it, sometimes underhand, sometimes not. In many cases it showed up that when there was a problem, you know, the interface between the guidance and control and the vehicle, whose problem is it? Most of these problems are complex enough that it's not immediately obvious. So each one of those would sit on his haunches and say, "It's that guy's problem."

So NASA had to resolve the problem and gave rise to the fact that you needed to have a good NASA in-house capability. You had to have people who'd worked on the systems physically. You had to have people with hands-on, smart. And we did that on Apollo. We put together a guidance and control system in house that had that kind of capability, and just touching on the future, started off the process by which eventually SAIL [Shuttle Avionics Integration Laboratory] grew up in the same building.

There was a particularly bad problem on Apollo 7 where we started having EMI [electromagnetic interference] problems, and a particular one made the inertial guidance platform tumble every so often, just pkkkkk. Very difficult one to sort out. Didn't happen all the time, just when we least expected it, which is probably true of most [EMI] problems. But it became a significant program-stopper. Both [North American] Rockwell, of course, with their in-house spacecraft, and MIT with their rig, were working the problem hard, but didn't seem to be making any progress. I think some of it was at least due to the fact that they thought it was the other guy's problem.

So we put to in the lab to try and solve this problem, and we did. I had a particularly bright young lad called Paul [E.] Sollock, who I think he was just out of his co-op training at that time. I think he's now just recently retired from Building 16 as a division chief. But he thought up a scheme whereby the system could be exercised in such a way that it would consistently demonstrate the problem. Of course, once you could demonstrate the problem, you can find a fix for it. It's when you can't look at the problem that you really get into difficulties.

A good example of how the in-house capability was needed, particularly if you don't have a prime contractor who's responsible for everything on board. The other side of that is that if you have an associate contractor who's responsible to NASA, you've got a lot more control over the way things are going, and you find that the prime and the associate will work their tail off to try and put the other guy in a bad light, which isn't all bad, because it unearths a lot of problems that way. You can't afford to have too many people who look at a problem with a different point of view. I think that's why Apollo was a success. There were a lot of people working on it, it cost a lot of money, but it worked.

I guess responsibilities during Apollo were pretty much the same as on Mercury, but more advanced, I guess—building this in-house capability, writing the early specifications. We were, of course, involved in the evaluation teams which got the main contractor on board and the MIT's industrial support on board, onto the technical teams that did that.

At one point in time, I forget the exact timing, but the Apollo program office changed its way of operating significantly. They had started off under a program manager called Charlie [Charles W.] Frick. He didn't last long, but he initiated a program office, which had all its own in-house capability. He did not want to be dependent on line divisions or anything else. So all the subsystem managers were in the program office, and at some point in time they found that

that did not work very well. These guys didn't have the support, they didn't have the exposure, they didn't have the capability of asking for a test to be run. So they assigned them all to the line divisions in the engineering directorate.

So I picked up about six of those people, a subsystem manager for the LM [lunar module], LM control, CSM [command and service module] control, guidance, inertial components and so forth. It worked pretty good. It made a fairly cumbersome branch, but these guys then were able to get a lot of support from individuals who knew the hardware from working on it in the lab.

We ran independent verification tests in the lab with this rig. We did the post-flight reports. A couple of things I personally got involved in were accident investigations on the lunar landing training vehicle, which I guess it was flying to Ellington Field [Houston, Texas] and suddenly kind of [crashed due to a flight control system failure].

RUSNAK: When Neil [A.] Armstrong was flying it.

CHAMBERS: Oh, yes, right. Yes. And it was an interesting problem when we finally figured out what was happening.

And Little Joe, a development booster at White Sands [Test Facility, Las Cruces, New Mexico] , it took off one day and spun up and blew up. We were working for weeks on that, to try and figure out what happened. I'm not sure we ever really did pin it down, but we pinned it down to a narrow range of things.

So that was a pretty busy time, and I didn't enjoy it as much as Mercury. The outfit had grown too big. There had been a sudden hiring surge to build up for Apollo, and it just didn't seem to me that the same quality of leadership had been maintained through that buildup.

RUSNAK: You had mentioned that you were part of the Source Evaluation Board for the contract that eventually went to MIT. I know the private aerospace industry had some problems with that contract being given to them, since they were essentially a nonprofit.

CHAMBERS: Yes.

RUSNAK: Do you recall any of the other bidders who really stood a chance of getting that, given MIT's experience in that?

CHAMBERS: No. In fact, it's not my recollection that the actual agreement with MIT caused such a problem. It may have been and I may have kind of missed it. But the problem with the—and I think the main reason for it was, of course, MIT was not going to do the whole job; they were going to get industrial support contractor on board to do the actual job, hardware and so forth. And that became a very, very difficult process.

I was on the technical team with John Miller, from the point of view of the industrial guidance platform, and we had all these bidders; I forget the number. We picked AC, of course, Delco. But there was another guy on the East Coast, Bosch [phonetic] or something like that. I can't remember the name now, but they protested it, and we had to go through the whole damn process again. That gets very, very irritating. So that's what I remember, the industrial support

contractor being the problem, not the actual award to MIT, although I'm sure there were some. I mean, the prior contractor himself would have liked to have had that responsibility.

RUSNAK: Of course, this was still pretty—go ahead.

CHAMBERS: I was going to talk about the issues and problems as I saw it during the Apollo development. Performance itself, although it's a very demanding job to go to the moon and back, guidance and all, was never as big an issue as reliability, in my mind, anyhow. It was asking much more than had been asked of any airborne system before to operate like that. In fact, a digital computer on an airborne vehicle had never been in the flight critical path before. Gemini had a digital computer on board, but it was bypassable; you didn't have to have it to get back.

So an inertial guidance platform and the computer that would operate reliably for that length of time was the real requirement. We—I say "we"—MIT, the industrial support contractor, everybody had to go to extreme measures to try and do this. The digital computer itself was almost entirely made of one chip, duplicated. The memory was limited, 16K probably, and it was a wire-rope memory. I've got one of the sticks upstairs. It's a bunch of little ferrous cores which have the wire wrapped and woven into these little cores.

In fact, the machine at MIT was an adaptation of a weaving machine. I was amazed, the first time I saw that. But that was for the utmost reliability, a hard-wired memory that couldn't be kind of sunk by EMI or lightning or whatever. It worked very well, but, of course, the extreme power and weight limitations on the system meant you couldn't have a bunch of them;

you could only have one, and even then you were kind of struggling to keep the weight down and so forth.

So just in case this system did go by the wayside, you had a get-you-home system, which was done by the prime contractor and Honeywell with strap-down gyros. In theory, it would allow the flight crew, give them a chance to get back home if the primary system failed.

But the reliability measures taken on the system were something that you couldn't tolerate cost-wise today. Every component was tracked from the time it was made to the time it was in the vehicle. If it was dropped on the floor, it was scrapped. Every slightest malfunction was traced with a big sheaf of paperwork, tremendously expensive and yet it worked. The system did turn out to be reliable enough to do the job, but it also kind of demonstrated, I think, that it wasn't the way to go on future systems; it just cost too much.

One of the smart things that was done was make the CSM system and the LM system almost identical, so big saving there and a tremendous advantage from the point of view of training and simulation and whatever.

I need to stop for a moment.

RUSNAK: Okay. [Tape recorder turned off.]

CHAMBERS: A big hiccup in the Apollo guidance and control was at the time of the Apollo fire, not that that affected us directly, but it gave the opportunity to do something that had been talked about, ([but] schedule and whatever else [had] not allowed,) and that was to digitize the flight control. The existing system, the guidance system fed steering signals to the Honeywell control system, which was special-purpose electronics. Honeywell control system turned on the

thrusters or the main engine or whatever. There's not a good reason for doing it that way, except at the time the system was first specified, it was the way things had usually been done. But if you have to have a digital computer in the loop, and you did, then you might as well have the digital computer do the control calculations as well.

Joe [Joseph F.] Shea, who was the program manager at that time, made the decision to redesign and go with a digital flight control. I have to say that I was very dubious about this at the time, not that I didn't think it would work, but it looked like a tremendous upheaval schedule-wise, contractor-wise, because you more or less took a job away Honeywell and gave it to MIT and AC. But they did it and it turned out good. I was wrong. It was a good decision, but it was a big change in the procedure of how the systems operated. And, of course, it all had to be verified and tested again that way.

RUSNAK: Do you remember if there were significant differences between the Block I and the Block II spacecraft from the guidance control?

CHAMBERS: No, that was it. Well, that's the one that sticks in my memory, because it was a sizeable change and it did change contractual setups as well as technical.

Comments on the missions themselves. For me, Apollo 8 was the one. [Laughter] I'm not quite sure why I say that. I guess it was all the agonizing over EMI problems. Those EMI problems we had on Apollo 7 and 8 were a cause of great concern. Jim Chamberlin at that time had been shifted as a—that was his sole job for the program office: monitoring, chasing up and making sure EMI problems got fixed. So I was in that lab. I was descended upon from all sides, program office, my own E&D [Engineering and Development Directorate] management,

and Jim Chamberlin used to call me every morning and, in his own unique way, berate me for taking too much notice of my own management. [Laughter] which was one of Jim's favorites.

But emotionally, I guess, Apollo 8 was a kind of culmination of all that work and I just thought it was real neat.

RUSNAK: Do you remember where you were when they made the Genesis reading?

CHAMBERS: I was home in Friendswood, but, no, I don't. I don't remember what I was actually doing, no.

Eleven, of course, was a fantastic success, and I believe everything that everybody else says about it, but just to me Apollo 8 was a good deal.

RUSNAK: You're not alone in that sentiment. We've had a lot of people express exactly the same thing.

CHAMBERS: Yes. I don't quite understand it myself, but that's the way I feel. I wasn't involved much after 11. I'd already been transferred to the Information Systems Division [ISD]. The problem there was they wanted to get started working on—and strangely enough, it wasn't the Space Shuttle at that time, it was advanced work on Space Station. There were a lot of pertinent system issues that were going to have to be resolved in the avionics world. In other words, did you have an avionic system or did you have a GNC [guidance, navigation, and control] system, an instrumentation system, and so forth, or was it all going to be integrated into one mess of

avionics? Did you have a centralized system? Was it one big computer doing it all, or did you have distributed computers? Did you use data buses?

I guess Max [Faget] had three different organizations working on these types of problems. He had a group in Ralph [S.] Sawyer's division, Communications, he had a group in Chilton's division, he had a group in [Paul H.] Vavra's division. In fact, he had two groups in Vavra's division, the Checkout Systems Branch under [W. Cliff] Bradford and another outfit that had grown up in his own organization. I guess the E&D management wanted to get some cohesion together here and start getting organized, planning an attack on these issues, and so I was sent over there to integrate these three or four different entities.

I think we got pretty knowledgeable. We put together some in-house systems. The Checkout Systems Branch, the outfit that started off doing the [ACE (Automatic Checkout Equipment)] system [at KSC] many years ago, stayed in Houston. They'd already got a pretty viable test going on an onboard checkout system. So we had all the elements there, and the way I tackled the problem was to start putting together an in-house system that incorporated onboard checkout and instrumentation, data management, and the capability for GN&C, if so be, and that was the way to go.

We became, I think, fairly expert at that time in data-bus systems. We were asked to join a team that was evaluating the B-1 bomber at that time. It had three different data-bus systems. People were getting apprehensive about whether these things would work or not. So I went on a sojourn on the West Coast for several weeks doing this, and the results appeared to be evaluated very well by the Air Force. Both the Air Force and the prime contractor sent us letters of congratulation. It's not often that that happens where one agency is looking at another agency's work and another prime contractor. So I think we were doing a job that needed doing

there, particularly the question of centralize-versus-distributed computing. That's still being kind of debated on the Space Station, I guess, but a big problem. So I was doing that for the rest of the Apollo program and had no involvement to speak of in Apollo until the end of its time.

RUSNAK: Was that a move that you were eager to make? Were you looking for something different?

CHAMBERS: Yes, I guess I've always been in that process that when one program is starting to get routine, I've moved on to the next one. I prefer it that way. In the same way, I got very little involved in Skylab. When I say very little involved, there were always exercises that you could get picked on for. I mean, I got charged by Bob [Robert F.] Thompson, or requested by Bob Thompson, to be on a technical panel that evaluated the suits for Skylab, the maneuvering unit.

RUSNAK: The Manned Maneuvering Unit?

CHAMBERS: Yes, right.

RUSNAK: Astronaut Maneuvering Unit, I guess.

CHAMBERS: Yes, things like that, so there would always be the possibility of some involvement, but as in the main you were employed on something else as a main track.

RUSNAK: So was it the same then for the Apollo-Soyuz Test Project?

CHAMBERS: Yes, right.

RUSNAK: Of course, with Space Station that kind of went away in favor of Space Shuttle first.

CHAMBERS: That's right. It didn't change the direction [we were going] very much. Obviously, on a Space Shuttle you would do less of the types of on-board systems monitoring and maintenance and checkout onboard and so forth. But still in the early days of Shuttle it was considered to be a valued concept that you would do some of that stuff, even if you wouldn't do it to the extent you do it on Space Station.

So the work in ISD that I was concerned with was mainly on that nature, most of it in-house, doing conceptual studies, putting together the breadboard in the lab, trying it out, getting knowledgeable about the problems with distributed systems and centralized systems. That kept me happy for quite a while.

The question about the differences between the Shuttle and the earlier vehicles. I think it was Dick Carley, who had since moved up to headquarters, I think he was the first one that I heard discussing multiple identical redundancy to the extent of eight parallel systems. Well, I think he was way overboard there. I don't see any way you could do that. But maybe he was exaggerating for effect. But in principle, the idea—it wasn't just Carley; there were other people proposing the same thing—was you couldn't provide the vehicle with computer systems like Apollo had with that kind of reliability and have several of them to provide necessary redundancy. Remember, in those days the Space Shuttle was being talked about like an airliner,

had to kind of land and takeoff just like an airliner [with] just a little bit of maintenance, and if one of the systems was out, you might still go with it being out…

The multiple identical redundancy sounds great and it is great, but sooner or later you have to vote. You have to decide which of these computers is right, and do something about that. In other words, there's always one point in the system where there's a potential single-point failure. When I say there's always one point, if you're really smart enough about how you implement the redundancy, you can get around that, but it's not easy and it takes a lot of figuring out and it takes a lot of testing to make sure it works.

The Shuttle was also different from the point of view of time-critical failures. There are points in the Shuttle mission where the astronaut can't possibly cope with the question of switching—during the ascent phase and so forth, so you have to have something that will make those kind of decisions. It's only true of very limited phases in the missions where the astronaut can't kind of contribute, but it's there, and if it's there, then you have to kind of cope with it with the automatic mode. So all those problems needed to be worked, and we had no contractor actively working on those, you know, at that stage in the program.

I think from that point in time I got involved in the Shuttle Avionics Integration Lab. The Shuttle avionics eventually evolved into mostly a centralized system with multiple identical redundancy. It wasn't completely centralized in the sense that the main engine had its own computer and there were several other minor computers scattered around, but it was mostly a centralized system. And it also evolved in the same [way] as Apollo, in that the prime contractor didn't have the responsibility for the onboard software. He had responsibility for the hardware, but the software was GFE [government furnished equipment], by the government, but with IBM as the government's contractor, a decision Chris [Christopher C.] Kraft made, and

made it basically on the fact that later on in the program, operationally that becomes a tremendous advantage.

The other thing about the Shuttle is that for the first time we have significant interfaces with non-avionics systems. I mean, the propulsion system, the reaction control system, the life support systems previously had been entirely divorced from the avionics, except for a little bit of instrumentation that was passed on.

Now we have the central computer involved in monitoring, switching, doing things to these [systems] which hadn't been done before. The whole concept makes for a mess of problems unless you're able to demonstrate that the central computers and the software can manage all this stuff. And there are significant interfaces with the so-called mated elements, which were the Marshall Space Flight Center's [Huntsville, Alabama] contributions to the Shuttle, the main engine, the external tank and solid rocket boosters and so forth.

So it became pretty obvious that some integration facility was needed, and enormous debates raged about who would do it, where would it be done and so forth. It became pretty obvious that Building 16, the guidance and control building, had most of the elements in place already. It had a very significant hybrid computer lab, which had been involved in simulations of the Shuttle systems and environment. It had a big annex that was capable of housing a mockup of the Shuttle. It had a lot of smart in-house [from] the point of view of putting systems together and demonstrating them.

So it was finally chosen that Building 16 should house this Shuttle avionics integration lab. It turned out to be a nightmare [of] a management and funding problem. This isn't a criticism of anybody; it's just the way the program was. For instance, if you wanted to demonstrate that the onboard hardware/software worked, just worked itself, then you had to put

together that mockup. If you wanted to demonstrate that it didn't have EMI problems—and we had been bitten by that several times—you had to have a flight harness. If you had to have a flight harness, you had to have a total Shuttle mockup.

If you needed to demonstrate the interface between the Orbiter system and the main engine and the solid rocket booster, you had to have parts of their systems incorporated. You had to get the Marshall Space Flight Center involved. They were responsible for that. They had to bring their own contractor in to provide and maintain those pieces.

If you wanted to demonstrate the interface between the Orbiter and the checkout system at the Cape—and you did—then you had to bring that stuff in. So we had a launch processing system in Building 16, too. That meant that the Kennedy Spacecraft Center got involved and they had to bring their own guys to maintain their equipment and so forth.

There were six contractors involved. There were three NASA Centers, six contractors, and the six contractors were Rockwell, IBM, the two main antagonists, McDonnell Douglas, Intermetrics, who did the HAL language, Intergraph, who [did] the [mated] elements for Marshall, and the launch processing system. I don't know who their contractor was.

Then we—when I say "we," the poor little civil servants in the middle, we had Lockheed. Lockheed were the lab contractors and they ran the hybrid simulation lab and did most of the work in maintaining the labs and supporting the civil servants in essence there.

So those six contractors, of course, all believed that their part of the job was the most important, and to them it was. They were also charged by their responsible organizations to defend their system. When you start a test in a complex operation like that and something goes wrong, sometimes it's immediately obvious what goes wrong and you can write a discrepancy

report and move on. Sometimes it's a minor problem, and you write it up as a discrepancy report, you don't understand it, but you leave it for a troubleshooting period later on.

A lot of the times you haven't the foggiest idea what the problem is, and Rockwell, of course, will say, "It's the onboard software that the government provides." IBM would say, "It can't be us. Our software has already been checked out in the software development lab."

So a big problem from the point of view of keeping control of all these elements, we finally had to maintain a system where we had a Change Control Board that had a representative from all organizations on it, just like the big boys did in the program office, and nobody was allowed to change anything without this board approving it. We had a discrepancy report meeting whereby each discrepancy that arose was talked about there and an action assigned to some individual on my best judgment or my guy's best judgment, who it might be, start working it.

Then we had an eight o'clock meeting in the morning, every morning. That turned out to be a real circus. Not too long after I took over, I was real disgusted with what I'd seen the day before. The operation was not going well. People were kind of floundering around and throwing their arms up and so forth. I marched in there, and I'm usually a very mild-mannered guy. And I chewed them out, all this bunch of guys, civil servants and contractors and said, "You're running around like a bunch of little girls in black stockings." That sort of remark would have gotten me fired, I guess, nowadays, as being sexist or something. But it's a remark that's used a lot in England, or it was in my days. English schoolgirls wore little short gym skirts and then long legs with black stockings on, and it used to be a common thing for guys to say, "You're running around like a lot of girls in black stockings."

Of course, this entirely befuddled the meeting, but it quieted them down and they listened. But a couple of people came up to me, "What's this about girls in black stockings?" In fact, I got a plaque upstairs given by Rockwell when I retired, and they discussed these various things about SAIL and so forth, it said about "this weird guy who talks about girls in red and blue stockings." Now, I don't know where the red and blue stockings came from, but they were just pulling my leg, I guess, but interesting. Before you leave, go up and have a look at the plaque.

But things went on. The funding. The funding was another tremendous problem. SAIL was a hog, a resource hog. It used up to 500 people, over 500 people, I think, if you count the people at Rockwell that supported it. That's a tremendous amount of funding and somebody has to pay for it all. Because I worked for E&D and a lot of the resources came from E&D, Lockheed, civil servants and so forth, E&D were not very happy about SAIL. I mean…the [other] division chiefs, as far as they could see, it was getting all the attention, it was getting the people, it was getting the funding. Aleck Bond, in particular, although good friends, Aleck Bond and I, and I'm hoping to see him next week, I guess, but he was charged [by] Max, you know, with running those divisions, and as far as he was concerned, SAIL was a program office-type job and should be funded by the program office and they should pay for it.

So I was constantly—I would say every two weeks—up in the program office or in Chris Kraft's office trying to defend SAIL's budget. The budget was made up of so many small pieces that you had a devil of a job keeping track.

RUSNAK: If we can pause for a minute, we need to change out our tape, if you don't mind.

CHAMBERS: Oh, fine.

RUSNAK: As far as SAIL went, you'd talked about support from the program office. If you could say a little bit about Bob Thompson.

CHAMBERS: Yes. Bob Thompson was one of the guys who was wholeheartedly behind SAIL, and not everybody was, by a long shot. I mean, we had to fight off some significant criticisms of the whole operation. First of all, we had to get a flight harness from Rockwell. Without that, we were no good. And they dragged their feet quite a lot. I think it was Bob Thompson who finally made it happen. Of course, Rockwell were bitterly against it. They thought they should have it at Downey [California] under a guy called Cy Rubenstein, another one of these individuals who has all the smart in the world, but a hard-nosed beggar to get along with. He was the chief in the avionics world, and a lot of tussles with him about how SAIL should be managed, how his Rockwell manager in SAIL was—he didn't say this directly, but the implication is he's more important than all the other contractors. And to some extent that's true, but, you know, how much?

Bob Thompson and Owen [G.] Morris were two guys in the program office that I really relied on for—see, what would happen, if any of these contractors got their nose bent out of joint too much, they would feed up back through their management and eventually it would come back to [Aaron] Cohen or Thompson, "Keep that guy Chambers in his place," you know, not as crudely as that, but words to that effect. Most of the time I got a lot of backing from Bob Thompson or Morris, and got a lot of respect [for them]. Just wish I could beat him [Thompson] at golf.

When I was talking about the 500 personnel, that sounds a big number, but what I forgot to say was that SAIL operated seven days a week, twenty-four hours a day, on three shifts. So that, to some degree, explained it. It wasn't going full bore twenty-four hours, but the maintenance and investigation of problems and so forth would go on during the night hours.

We also had the astronauts in there. Good friend, George Abbey, sent for me one day and said that he needed the astronauts in SAIL. It made a lot of sense. I didn't like the way it was put to me, but the idea was that during the process of checking out the system there is a cockpit technician, usually a Rockwell guy, who, in response to test conductor's inputs, switches, a switch here, or waggles the stick, whatever. And the idea was that if the astronauts were used in that position, they would become familiar with the controls and displays, they'd get an indoctrination of how the systems operated. The training simulators were going full bore. This was just an additional capability and it worked out pretty good. They didn't cause me too many problems. They signed my plaque when I left, so it must have worked out all right. But they were an added confusion factor from the point of view of number of organizations you had to deal with.

I was an assigned SAIL manager in 1975, and I was there until I finally quit in 1981. I should say that I retired at the end of 1980, along with some distinguished company: Chris Kraft, Max Faget, and Kenny [Kenneth S.] Kleinknecht. There was a quirk in the retirement rules that made it very advantageous to retire at that time rather than the next year or the year after. Of course, we were all rehired. I was rehired to complete the STS-1 verification and we did that. So a year later I retired again. This rehired wasn't all that good a deal, of course, because the government regulations don't allow you to draw your salary and your pension as well. Your salary is cut down by the amount of your pension, so you just got the same money.

RUSNAK: Had you had any involvement with the approach and landing tests?

CHAMBERS: Yes, that's what I was basically talking about, and I've got a little flag that flew on the STS-1, as well. Did you catch that before, that the little flag I had that went to the moon was advertised on the Internet at $12,000—not mine, but one like it, $12,900. So I immediately went and looked through all my memorabilia to see if there was anything else like that. I've got scads of different medals and so forth, but probably that's the most expensive piece I have.

So retired a year later, '81. Any questions you might have about the NASA period before I move on?

RUSNAK: Well, sure. Let's go back and there's just a couple things I wanted to ask you about, I guess some certain events from NASA. When you were at AVRO, do you remember when the space race began, with Sputnik, being someone from England and in Canada, and seeing this go on between the United States and the Soviet Union, what your perspective on that was?

CHAMBERS: It doesn't come through very clearly. If I'd been doing any reading on U.S. space activities, it seemed to me it was mostly concerned with the effort on the West Coast, dropping the vehicles from high-flying aircraft and boosting into space that way. I can distinctly remember being interviewed at AVRO by, I think it was Chuck Mathews, and asking about that, were they connected with that. I think he was a little bit taken aback, he said, "No." He said, "We're going to put a capsule on top of an Atlas booster."

I kind of grinned and said, "Sounds like a good idea." [Laughter]

I should say my first trip after I joined NASA was down the Cape to see an Atlas launch. It blew up about 100 feet off the pad, and I kind of thought it was going to be a long hard road before we'd stick a man on top of one of those things.

RUSNAK: Well, that certainly wasn't a rare sight at that time.

CHAMBERS: Yes. It was very frequent.

RUSNAK: Right.

CHAMBERS: Yes. But, no, I don't remember much about concerning—as I say, I remember seeing the Sputnik and wondering what the United States' response would be. I guess I'd read about the efforts by the Navy to launch a satellite, failed efforts. But, no, I was too involved in trying to make a way in Canada.

RUSNAK: Later on when you were part of the space program, and shortly after Al [Alan B.] Shepard's[Jr.] flight, President [John F.] Kennedy made his famous "get to the moon by the end of the decade" speech. Do you remember that?

CHAMBERS: Yes, very well. Very well. In spite of what came out about the guy later, which I didn't know about at the time, he's still, to me, a bit of a hero. I guess I'm big on guys who can lead. There are so few people who can kind of make you want to get up and march with them to the end of the earth, if necessary. He had some of that element in him.

Strange enough, I was thinking about that the other day when somebody asked me if I'd heard [Winston] Churchill's speech, where he took over as Prime Minister of Britain during the war, and there was some of the same element there. I mean, I was, I guess, a twenty-year-old, didn't quite know what was going on, and then I listened to Churchill on the radio and I felt good about what I was doing and I wanted to do it, and I wanted to give it 100 percent. And that's what Kennedy's speech did for me, I think. A sharp focus and a good leader and somebody who will go to extremes himself to make something happen, that's all you really need in a project or any endeavor in life, I guess. But without that if that—yes, let's talk about the—well, we'll do that later, talk about the Space Station. I can talk now about jobs after NASA?

RUSNAK: Yes.

CHAMBERS: After I finally quit, it took me about three weeks to find out I wasn't suited at that time in my life, for idleness. Intergraph offered me a job. They were the contractor who helped out in SAIL on Marshall, mated flight elements. But they were also a big deal in the computer-aided design area, and still are, for that matter. They were an offspring from IBM at Huntsville, Alabama.

They wanted me to get involved in computer-aided design in the chemical industry in the Houston area. It sounded good and they had some beautiful equipment. Even in those days, they had monitors bigger than that pouf there, and I was given the opportunity to play around with this stuff. So it was a good job.

Then I found out that the manager, who eventually became a millionaire and used to ride around Clear Lake City in a Rolls Royce, he wanted me really to work personnel problems for

him. I guess I'd attained the reputation of being able to calm people down and make them happy together. I didn't want that. I mean, that's why I left SAIL, take a rest from that sort of stuff. So I quit after six months.

In the same building on Gemini, I guess Owen Morris and Hugh [Hubert P.] Davis had started up Eagle Engineering, and every time I met them in the washroom they kind of said, "Why don't you quit there and join us." So I did, as vice president for electronics, avionics, or something. I enjoyed working with them, to a large degree anyhow. I got promoted to CEO and chairman of the board eventually, not because I was the smartest guy there, but, again, able to keep the peace between warring factions.

RUSNAK: What kind of work were you doing?

CHAMBERS: Well, our main bread-and-butter income was from support of major contractors who were bidding on NASA contractors or who else got into a bind from the point of view of a schedule. We would go down to the Cape and help—I forget what contractor won the support contract down there now, but we supported him through the proposal-writing, evaluation and so forth. That was our steadiest income, I guess, but we got involved in some fascinating things besides that. We supported Deke [Donald K.] Slayton and his outfit on the Space Services, Incorporated. I don't know whether you remember, but he fired a kind of vehicle from Matagorma. Is that right? It's an island south of Houston, southwest of Houston.

RUSNAK: Matagorda?

CHAMBERS: Matagorda. That was a lot of fun, and he was a great guy to work with. Then, of course, Max Faget, who was on the Eagle board for a while. He started up Space Industries, which was a cheap and nasty space station. We did most of the initial work on those concepts. That was good, too.

I remember Max coming up to me. One of the things working for Eagle was you often worked two hours and only got paid one, but if you were having fun, that was okay. Then you had an annuity. But Max came up one day and he said, "Give me five dollars. Give me a check for five dollars."

So I said, "What for?"

He said, "Going to make you rich."

So I gave him a check for five dollars and he gave me a little certificate for—it wasn't exactly a stock certificate in SSI, but it was part of a partnership. It didn't make me rich, but I did get a few dollars back, a few hundred, sometime later when they sold out.

There were some other kind of feasibility studies we did. I remember [for] Texas A&M [University, College Station, Texas] that I was the leader on for a nuclear-powered dirigible, lighter-than-air. [Laughter] Apparently there was a lot of politics involved in it and some guy with a lot of power over Texas A&M had taken the idea up and thought that they should study it, so rather than study it themselves, they hired Eagle to study it, so they'd be rid of it. We made a credible pass and finally concluded that it wasn't really feasible.

RUSNAK: Was it filled with hydrogen, too? [Laughter]

CHAMBERS: Probably. [Laughter] I don't remember. But strangely enough, when we gave our final report at Texas A&M, there was a mysterious individual, who none of us were allowed to meet, in the group. I often wonder who he was and why he had the power to torque Texas A&M around like that. But anyhow, there's that.

There was another project whereby the guy invented the Weed-eater. He'd bought a couple of hotels at West Chase, west Houston, and some guys had been killed in a fire, so he wanted Eagle to invent a warning system for the hotel in case of a fire. Somebody would push a button in the lobby and all the rooms would immediately know what was happening. Well, this guy hadn't the foggiest idea how wireless worked and or any other thing. We talked to him about—I mean, he made millions from the Weed-eater and apparently he had a little motor and you put a coffee can on it and wrapped some string around it and just played around, and eventually he got a patent for it and made a pile of money.

These hotels, we made a couple of recommendations to him. It was just interesting to meet these kind of people, these people who have made millions of dollars and you find out that it's more or less an accident. [Laughter]

We had another project whereby we supported Italia, the Italian company, space company, in some satellite work. We went to Italy for three weeks, Turin—snowed all the time. Our per diem wouldn't cover us so we had to go hungry and couldn't drink. But it was all good fun, I guess.

The other thing that we did to a significant extent was support the NASA Space Station through McDonnell Douglas, as one of their subcontractors. Of course, that finished some years ago. I'm not current now on the Space Station, but to my way of thinking at that time, it was a disgrace. There was apparently no one in charge that could make decisions. If they made a

decision, it was immediately overturned by someone else. I'm talking a few years ago. It might be fine now.

But just an example, the question of whether the Space Station needed a SAIL, as it was usually phrased, was debated endlessly. I was involved in at least four presentations on my thoughts on the subject. Basically the answer is, of course, it doesn't need a SAIL, it's a different vehicle, but it sure as the devil needs something if you're not going to spend a lot of time in orbit piddling around.

So I was very unimpressed with the way that NASA was running things at that time. The impetus seemed to have been lost. The powerhouses that ran the early NASA programs appeared to have gone and not been replaced. I was very disenchanted with the whole operation.

RUSNAK: Was that with the latest version of the Space Station?

CHAMBERS: No, I'm saying that's a few years old and it may be entirely different now. It's just that I couldn't believe my ears sometimes when I listened to guys at various meetings where they were supposed to solve problems and they were attacking the same old problems and not solving them.

But to get back to Eagle, I guess it was going along good. We'd been expanding. We had a tech services organization, you know, an outfit like SIGNAL [Corporation]. Got involved in a lot more things. Then we had the misfortune to win a contract directly with NASA. Most of our contracts, of course, had been with McDonnell Douglas, Rockwell, Lockheed. This one we won direct with NASA, and it was the worse thing [we] ever did. The contractor sued us

for—I don't know what they called it, alienation of affections, the old boys' club, or something, most of us were retired NASA and therefore the NASA group had given us the contract and so forth. It sent Eagle into a tailspin. Obviously, NASA, [or] the prime contractors weren't going to use us while that sort of litigation was going on.

Then a fairly incredible string of events, the judge that was given—I should say that the outfit that we won it from was a minority group, of course. I can't remember their name, probably Jackson or Johnson, something like that. The judge that got the case didn't seem to ever want to move on the thing, and it turned out later—and you may have read it in the paper, I can't remember his name either—but he was impeached for various offenses. And apparently they don't just hand the case over to another judge; it just kind of dribbles on until the guy's actually out of the job. Then incredibly enough, our own attorney we'd hired was charged with embezzlement. So that kind of fouled things up [and cost us more money].

I'm talking now about a five-year process. I don't think I'm exaggerating when I say five years. And all this time, of course, we're having to expend money to defend ourselves and so forth. It finally got to trial, must be, I don't know, maybe a year ago, and we were absolved of all charges. It's just that you can't get your money back. I mean, the attorney that represented the other side was a fairly famous guy, a black guy who's on the—I think he's on the Houston City Council, and took the job on—what do you call it? Took the job—

BUTLER: Pro bono?

CHAMBERS: I don't know whether that's what you call it or not, but he would get paid if he was able to get some significant payment, and, of course, the other side didn't have anything to lose

on that basis. We had to defend ourselves and we had to pay attorneys. So we all became innocent and broke.

Tuesday I'm going down to Clear Lake City to the final shareholders' meeting. Another part of the problem is that when you dissolve a company like that, you have 401(k) plans to dissolve, and they have strict regulations on how you do that. You have to find all the people who were in the 401(k) plan to pay them off and all sort of thing. So I go down next Tuesday to the shareholders' meeting in the Holiday Inn, we're going to dissolve the company and then we're going to Owen Morris' house for a party, and that will be the end of Eagle.

It was real good while it lasted, a lot of fun and good people, and I think it did quite a lot of good for the program in various ways. I don't know whether you know Owen Morris or not, but he's something special.

RUSNAK: We have talked to him.

CHAMBERS: You have talked to him? Yes.

One of the questions you seemed interested in was significant people. There's no doubt in my mind that the early Space Task Group management was something special. Gilruth I've already talked about, and I think everybody acknowledges that if they had anything to do with him, they couldn't help but come away with the utmost respect for all his capabilities.

Faget and Chris Kraft, of course, were two other giants, I guess, in their different ways. They both had quite different personalities, but all three of them—and, later on, George [M.] Low. George Low was a guy I didn't get to know as well as the other three, but when I did interface with him, I was impressed with an enormous intellect. I don't know how to explain

that better, but you just felt you were in the presence of somebody who was always three steps ahead of you, whereas the other guys might only be two steps. So those four all had outstanding leadership qualities.

I don't quite know what it is, but I think it's a question of being able to listen to several varying differing inputs from competing sources and then be able to say at a point [in] time, "I've got enough. If I listen anymore, it's only going to kind of dilute the thing 2 percent—I'm going to make a decision, going to make a difficult decision," and then you make it happen. And it doesn't matter whether that difficult decision you've made was the 100 percent answer, as long as it was a good one and it was a way to go and you could get the other people going along that same track. And these guys had the capability to do that.

At another level, the people I worked with in SAIL were something special, too. The three I'm thinking of, although there was a lot of them, but the three I'm thinking of was Pat [M.] Kurten, my deputy. Pat Kurten's dead now. He was much younger than I was. Irv [Irvin J.] Burtzlaff, who just recently retired, I think. Teresa [R.] Sullivan, the girl who did the embroidery there that you noticed. They were all outstanding people, extremely loyal and worked their tail off. It doesn't matter what you asked them to do, they would not only do it, but do it willingly and cheerfully. I couldn't have done the job without them, and I still don't quite understand how I was lucky enough to get them. I inherited them and it just worked out that way. But that's people.

RUSNAK: It sounds like you had the opportunity to work with a great deal of very talented people from the beginning through.

CHAMBERS: I'd worked with some good people before, both in England and Canada, but certainly my impressions of the Space Task Group people when I first went there, I was really impressed. My first few years with NASA I consider the happiest part of my life. It was ideal. Interesting job, very few politics, guys that I liked, and to some degree exploring the U.S.A., which I didn't know much about, so it all came together.

RUSNAK: Are you still keeping up with the space program and what's going on nowadays?

CHAMBERS: Not for the last year or two. I have a friend who's working for the successor to Eagle, Muniz Engineering [Inc.], and we correspond by e-mail and he lets me know sometimes what the latest Space Station disasters are. I check out the NASA Watch. Is it NASA Watch site, the rebel station or whatever it is? I get a lot of information from that, never know whether to believe it or not, but I check it out. [Laughter] But, no, not a lot the last couple of years. Before that, I used to keep in touch quite regularly, especially going to Eagle meetings and listening to what was going on there.

RUSNAK: I was just thinking, the recent flight with Eileen Collins, where they had the computer failures—

CHAMBERS: No, I don't know anything about that. I read about it, just what was in the newspapers.

RUSNAK: Looking back on your career as a whole, what do you think the biggest challenge was for you?

CHAMBERS: Oh, I'd have to say STS-1 verification, the last job I did. It's certainly the one that gave me the most gray hairs, I guess. It's the only one I got a peacetime medal for, so it must be considered to be the one, yes.

RUSNAK: What do you feel is the most significant accomplishment you made in the space program?

CHAMBERS: Oh, the same thing, yes. I don't think anybody knew who I was until I got that job.

RUSNAK: Is there anything else you'd like to talk about before—

CHAMBERS: I don't think so. We've talked about the current space program, and, like I say, I'm not really current enough to be able to make comments which are of much value. However, I suspect that if I was current, I would not be impressed.

RUSNAK: I'd like to ask my colleagues if they have any questions for you. Carol?

BUTLER: None here.

RUSNAK: All right then, I'd like to thank you for participating in the program today, and I guess we'll call it a wrap.

[End of interview]