# NASA JOHNSON SPACE CENTER ORAL HISTORY PROJECT
# EDITED ORAL HISTORY TRANSCRIPT

JAMES MIDDLETON
INTERVIEWED BY JENNIFER ROSS-NAZZAL
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ROSS-NAZZAL: Today is August 11, 2014. This interview with Jim Middleton is being conducted for the JSC Oral History Project. The interviewer is Jennifer Ross-Nazzal, assisted by Sandra Johnson. Thanks again for agreeing to sit down with me and share your recollections of some of the first female astronauts. Sure appreciate it. I wondered if you would give me an overview of your career with SPAR Aerospace.

MIDDLETON: I worked with RCA [Radio Corporation of America] in Montreal, and RCA was acquired by SPAR in 1978. At the time of the acquisition, I moved from Montreal to Toronto and I took on the role of, originally, a systems manager for the SRMS [Shuttle Remote Manipulator System] program, and then really I became chief engineer, troubleshooter, and the interface with NASA JSC, working with the PDRS [Payload Deployment and Retrieval Systems] Office and with the crew, who came up and were part of the program, particularly in terms of evaluation of the capabilities of the RMS.

ROSS-NAZZAL: When did you first get a chance to meet some of the astronauts who were going to be working on the RMS?

MIDDLETON: The RMS astronauts originally had started back in, I guess it was 1975. I wasn't involved in it, but Gerry [Gerald P.] Carr was the first astronaut who was involved in the RMS

program, in terms of the design interface. I got involved when Bill [William B.] Lenoir took over, and he took over in the 1977 timeframe. He became the RMS astronaut as part of the design team from JSC evaluating performance and so on. He then brought Sally [K.] Ride on board to, if you want, learn the ropes of the RMS. We worked together with Lenoir and Sally. In 1978, he left the program, I guess it was after the CDR [Critical Design Review], and Sally was in charge of the astronaut program, particularly for doing evaluation of RMS performance.

She was very much involved in the simulations that we were running, testing the capabilities to do a grapple of payloads in the cargo bay, grapple of free fliers. The other thing that she was very much involved in was the evaluation of failure modes and effects of the arm. During the evaluation runs, we would introduce failures into the RMS and then evaluate the various crewmembers, of which she was basically in charge. We'd run Cooper-Harper ratings on the performance. She'd come up and spend three, four, five days at a time doing simulations, and as I say, [evaluating] the various performance characteristics of the arm, as well as the various failure modes and effects.

ROSS-NAZZAL: Had you ever worked with professional women before you worked with Sally?

MIDDLETON: No. We hadn't had a lot of experience. I've been an engineer since 1963, and I had never been involved with women in the past. She was the first real professional I worked with. There were other engineers at SPAR who were female as well, but they were more junior people. Sally was a very senior and very experienced person. You could really operate at a professional level with her.

ROSS-NAZZAL: Were there any other women on the RMS team, though, that were junior?

MIDDLETON: No. I'll talk to you about Judy [Judith A.] Resnik. Judy Resnik took over from Sally in, I guess it was 1980 or so, and what JSC wanted to do—George [W.S.] Abbey wished to do—was cycle their astronauts through various aspects of the Shuttle program. Lenoir was there, then Sally took over. She worked about two years, through 1980, and then Judy Resnik took over in 1980 from Sally and worked the RMS from then on.

ROSS-NAZZAL: She worked until her first flight, [STS]-41D?

MIDDLETON: Yes. I knew both of them pretty well.

ROSS-NAZZAL: How would you characterize those two?

MIDDLETON: They were different personalities. Don't get me wrong, Sally would have a beer or three without any problems; we'd go out and have a drink after we'd run the simulations and so on—but she was very much a straight-shooting person. You worked with her very much on a professional level. You didn't have really serious jokes with her. She was very down, straight and narrow. Judy was a different kind of personality. She was more, how could I describe her? I shouldn't say a fun kind of person, but she had a lot more personality to her in terms of interaction.

For example, American astronauts really liked Canadian beer, because it had more of a microbrewery kind of taste to it. On STS-2, we had a failure on the backup system of the arm during flight. It never got [to be] a serious problem, because they had a fuel cell failure on the

Orbiter and that meant they had to come back early. Judy bet me a case of beer that the fault was in the RMS, it wasn't in the Orbiter. That was the kind of person that she was. She had a lot of personal interaction, and we could discuss a lot of things technically, but she was a more fun person, if you know what I mean.

ROSS-NAZZAL: I understand that she really liked nicknames. Did she give you a nickname?

MIDDLETON: I can't remember. Yes, she did, but I can't remember it.

ROSS-NAZZAL: Somebody told me that, and I thought, "That's interesting," because so many people around here have nicknames.

MIDDLETON: I think you'd find, by speaking to other people, the different characteristics of the people. Those were the two that I worked with directly. I knew Anna [L.] Fisher, but just in passing. I couldn't really comment on her.

ROSS-NAZZAL: She told me that she recalled right around the time they were making decisions for those first flights, that she was asked to go up to Canada and do a little training, but I wasn't sure if you had done much work with her at all.

MIDDLETON: Not a lot of work. She came up. See, what they used to do, they'd send up a bunch of astronauts to do evaluation of performance, and then we'd send the Cooper-Harper rating. Are you familiar with Cooper-Harper ratings?

ROSS-NAZZAL: No.

MIDDLETON: What it does is basically evaluate the performance of a person flying something. Cooper-Harper performance characteristics came out of aircraft and how well the pilot interacted with the aircraft and the performance of the aircraft. We took that characteristic for evaluating RMS performance. We'd do various tasks, and then the astronaut would give a rating of how well they performed it. They'd give a number for the Cooper-Harper rating, and we'd give a number for our evaluation of the performance. Then the form would be sent back down to MOD [Mission Operations Directorate]. There were various characteristics. I can say, though, that without a doubt, Sally was one of the greatest performers in terms of RMS that we ever saw. She was just right by the numbers. She could do things beautifully in control of the RMS. We got to see that on STS-7, where she ran the arm, because we did evaluation performance on how she did on the flight as well.

ROSS-NAZZAL: You think that she came in and she was able to hold her own pretty well, even though she was a physics major and not an engineer or a pilot?

MIDDLETON: Yes, there was no question she was one fine person in terms of the performance. When she took something on, she took it on very seriously, and she did the tests on the arm until she was satisfied. If it meant that we had to stay until nine, ten, eleven o'clock at night doing evaluation, then she would be there nine, ten, eleven o'clock. She was that determined to get things right and do the evaluations really professionally.

ROSS-NAZZAL: Would you walk me through one of those tests? How did those work up in Toronto?

MIDDLETON: Very similar to what you would do down on the SMS [Shuttle Mission Simulator], the big simulator down in Houston. We'd do what was called task training and task evaluation. We had a simulator up here called SIMFAC [Simulation Facility], and it was a very accurate representation of how the arm would perform in space, from a dynamics perspective. For example, we would want to do an evaluation of un-berthing a payload, so we would start at the time that the arm was in front of the grapple fixture until the payload was lifted out of the cargo bay. We would take a look at the characteristics of the hand controllers and see what kind of inputs were being done. We had chart recordings looking at how the inputs of the crew were done. We would evaluate that on how long it took to lift a payload out of the cargo bay, and how smooth the responses were, the inputs on the hand controllers from the crew, like from Sally or whoever was doing the evaluation.

Then we would look at grappling payload, for example, that was moving relative to the Orbiter and using the arm, see how well they would track the grapple fixture on the payload, and the inputs that were given. Then we would speed up the payload faster and faster and see how the crew responded to that. We got a chance to see that work on Solar Max [STS-41C]—the one that Pinky [George D.] Nelson was on. It was my last flight where I was in the MER [Mission Evaluation Room], and they had a problem with the MMU [Manned Maneuvering Unit] when it was going to hook up, and the payload started to spin. I wish I could remember who was crew—I worked with him, as well.

ROSS-NAZZAL: Terry [J.] Hart, is that who you're thinking of?

MIDDLETON: Yes, Terry Hart. The payload started to spin and rotate and translate relative to the arm and the Orbiter, and he was trying to go in with the arm and grab on to the grapple fixture as it rotated around. That was the kind of thing that we were evaluating. Turned out he couldn't do it, and then we had to put it off till the next day. The satellite spacecraft was dying, because we were running out of fuel on the Orbiter trying to get close to the satellite. Those were the kinds of tests that we did. We didn't have the Orbiter DAP [Digital Auto Pilot] available to us up in Toronto. That was just on the big SMS down in Houston, but we were able to do a very accurate simulation of the arm and the payload. We'd do part tasks, put the payload in, lift it out, things like that.

ROSS-NAZZAL: You mentioned you were examining failure modes and effects on the RMS. What does that mean?

MIDDLETON: Failure modes and effects, one of the biggest concerns we had—well, JSC had with the arm and we had with the arm—was something that is called un-commanded motion. It could be a failure somewhere in the electronics that would cause the arm not to respond in a manner based on the inputs on the hand controllers, that it would do something different than what you were inputting. Under normal conditions, that wouldn't be a problem, but if you had a very large payload on the end of the arm and a large mass—15-20,000 kilograms or so, one of which we did have, that we were going to work with—and that it started to move in a direction that was different

than what you were inputting on the hand controllers, it could build up this motion, slowly, slowly, slowly. If you couldn't recognize what was happening, it could get out of control.

The big concern was that one of these large payloads could bang into the radiators or whatever on the Orbiter and cause Crit [Criticality]-1 damage. One of the tasks that I was particularly responsible for was coming up with a software solution to detect this un-commanded motion. This was a very significant problem for us. I'd keep calling Sally, "Come up, take a look at this simulation." We'd introduce a different set of software in, which was called a consistency check, looking at the overall performance of the arm, comparing it to the hand controller inputs. She'd dutifully come up, and she'd go and experiment with it and do various things, and the test would fail. Then she'd storm back down to Houston because I'd wasted her time coming up.

Finally, I came up with a solution that I thought was going to work. Ultimately, it became the solution that flies on the Orbiter and the one that we have on the Space Station as well. Came up with a special software test. Brought her up, she was mumbling again, was I going to waste her time coming up. She got in the simulator and tested for two or three days, and it worked perfectly. She was very pleased with that. With that software test, we would introduce various failures into the system and see how well it responded when she put inputs. Also, she would jerk the hand controllers around to try and see if she could make the consistency check fail. She couldn't so that test worked very well in the end, and it allowed the arm to fly on STS-2, STS-3, and so on and so forth.

ROSS-NAZZAL: I understand for a time, the RMS simulator up in Toronto was the only one. There wasn't one in Houston?

MIDDLETON: There was a simulator in Houston, but the problem in Houston was that they couldn't get the dynamics of the system to replicate what our software said it would do. We had a set of programs that were designed in the University of Toronto for dynamics. The arm is a flexible body, effectively, and it oscillates up and down when you put commands into it, especially when you've got large payloads on the end of it. There was a problem in Houston. They couldn't get the control systems to duplicate what we said the simulation should look like. In the end, we provided them with the software solution for their simulator, so that it could replicate what we were doing.

One of the things that was very important to us on STS-2, STS-3, STS-7, and so on, was that we would go off and do a set of testing in space, getting the crew to put in commands into the system. We have development flight instrumentation, or DFI, on the arm, and then we would bring the data back, and we'd compare it against the simulators to make sure that the simulators accurately represented the performance of the arm, very similar to what was done on the Orbiter. Tests were put in, to see how it performed, and then compared the simulations on the ground in the SMS.

ROSS-NAZZAL: I understand from John [M.] Fabian that Sally wrote the procedures for STS-2?

MIDDLETON: I believe that's true. We worked together on it, but yes.

ROSS-NAZZAL: Would you tell me about those procedures and what that entailed for that first mission?

MIDDLETON: The basic thing that we wanted to do on the first mission was to do some of the dynamic testing. We wanted to demonstrate how we could lift the arm out of the cradle, the procedures for how you would lift the arm out of the cargo bay, then we would command each of the joints individually to verify that the joint would move up and down based on the commands that we would input. Then we tested the arm as a whole. Dick [Richard H.] Truly would put a command in to a certain level, and we would get input responses from the arm which would be recorded in the DFI and brought back. We would bring that back down to the arm. We worked on the procedures that would say, "Here's the kind of commands that we'd like to put into the arm," each joint, command the shoulder, pitch, and yaw, and pitch, yaw, and roll on the wrist. Check that it functioned well, and make sure that it responded in the direction we wanted it to go, then put a command in, check how it moved up and down, and the dynamics of the system. When we went to backup drive, we were going to test backup to validate each of the joints were performing in backup because you just had one controller, and it switched from joint to joint.

We found that when we went to the elbow joint, we couldn't command the elbow joint in backup. That was a very significant problem for us because we wanted to be able to get the arm back down in its latch position in the guides. As soon as that happened, we immediately directed Truly to go back into prime mode and put the arm back into the latches because we absolutely didn't want to have that fail and be unable to bring the arm back down. Basically, she had worked out all the procedures that you would go through in commanding the various joints on the arm to allow us to measure its performance.

ROSS-NAZZAL: Do you recall how long it took the two of you to come up with these procedures and then test them as well, before you took it to orbit?

MIDDLETON: It took us quite a while. We tested the procedures in Toronto. I remember she came up with Dick Truly in September of '81, and with [Robert L.] Crippen as well, and we went through the simulator there with Truly. I would say that it probably took us, I don't know, six to eight months to do it? It's pretty significant. Like when we were doing STS-[4], it was very significant because we had the IECM [Induced Environmental Contamination Monitor]. There were a lot of procedures we had to work on that. That one, I worked with Judy Resnik on, on the procedures for doing that, the IECM.

ROSS-NAZZAL: Can you talk about that?

MIDDLETON: We had a lot of concern about the IECM because it was a little box-type payload with little, little guides on it. We weren't certain about the viewing with the cameras, how well we could see the various guides to make sure that we were able to put it back in its guide system. We spent a lot of time, Judy Resnik and I, in Toronto and also down in Houston, running simulations entering in these small guides and developing a procedure. It took a long time for us to convince ourselves that we'd be able to fly this on that mission, on STS-[4]. Finally, we convinced ourselves. She and I were on the phone a lot to each other, talking about what we were going to do and how we could prove that this was going to work, and if it didn't, we'd throw the payload away. We had the same thing we had on STS-[3]. If I remember right, it was the plasma diagnostics package. IECM was on STS-[4], and it was meant to measure the environment around the Shuttle. What we were going to do is put it on the end of the arm and sweep it around the cargo bay; it was a contamination monitor. We could see what was going on once the doors were

opened, and what the environment was like in the cargo bay. The plasma diagnostics package on STS-[3] was quite similar.

ROSS-NAZZAL: You brought up something that I did want to ask you, you and Judy were on the phone quite a bit. In a day and age before email and cell phones, how did you keep in touch with Sally and then Judy? Were you also, I don't know, Fed Ex-ing packages? Was Fed Ex even around at that point? I'm not sure.

MIDDLETON: Yes, yes. We sent stuff back and forth. There was no email or stuff like that, so we'd have to fax it down. Reminds me, back when we were in the MOCR [Mission Operations Control Room], in Mission Control, we used to send stuff down the tubes, back and forth between the MER and Mission Control. That's how we used to communicate with paperwork, going back and forth on the tubes between Building 45 and Building 30, which was an interesting way of communicating. We did a lot of stuff on the phone, and we would fax stuff back and forth. The fax machine was a very busy device, both in Houston and in Toronto. The other thing was I spent a lot of time in Houston, when Canadians were allowed to go in and out without too much problem, and they both spent a lot of time up in Toronto. John Fabian spent a lot of time in Toronto, too. Jerry [L.] Ross and John Fabian and a lot of the other male astronauts spent a lot of time in Toronto as well.

ROSS-NAZZAL: Did you notice any difference between the male astronauts and female astronauts? Or astronauts are pretty much all a similar kind of breed?

MIDDLETON: No, there were a lot of different breeds. The jet jockeys, like Bob Crippen and Bill Lenoir, not so much John Fabian, he was pretty straightforward, but Bob Crippen, he was a really cool character. The jet guys who came out of post-Apollo days, they were pretty cool guys. For example, one of the jobs that we had, when Bill Lenoir was in Toronto—there's a special kind of beer that we had in Montreal that he discovered. It was called Brador, and it was extra-strong beer. It was around 8 percent alcohol content. He would want us to make sure that his jet had some cases of Brador to take back down to the States with him.

ROSS-NAZZAL: Where did they park their T-38s, and how did they get over to SPAR?

MIDDLETON: The T-38s were parked out at the airport, out at Pearson Airport here in Toronto. There's a special place for private jets, so they'd bring their T-38s and fly them in there and leave them on the tarmac there. If Crippen was coming up or somebody who flew the jets, Sally would fly in the back and Judy would fly in the back as well. If there was nobody coming up and they didn't want to bring a jet up, then they'd just fly commercial.

ROSS-NAZZAL: They'd just rent a car to go around Toronto or would you guys pick them up?

MIDDLETON: No, they'd normally rent a car or we'd drive them around, whatever. All of them would like to celebrate.

ROSS-NAZZAL: Would they? Would you talk about that?

MIDDLETON: They'd like to go out and have a beer. After we'd run simulations, we'd go out and have a beer together. It was a very convivial interface between us all at that time. Sally liked a beer or two. Judy loved her beer and good food, as well. They liked coming up here; it was a fun thing to do. They just enjoyed coming up. It was getting away, travel; you could have some fun up here, away from the bureaucracy at JSC.

ROSS-NAZZAL: How was the culture different up at SPAR compared to, say, Houston?

MIDDLETON: You're talking the difference between Americans and Canadians, now.

ROSS-NAZZAL: You have to tell me.

MIDDLETON: I'd worked in the States for a long time, so I'd become Americanized pretty well. My observation was that Americans, particularly down in Texas, tended to be more—you could get to know them, [be] friends, easier than with Canadians. Canadians would tend to be more standoffish I would say, until you got to know them quite well. Americans tended to be, they'd want to interact quite quickly with you on a personal level. That's one thing that I observed. From an engineering perspective, we all had the same mentality pretty well. We all interacted well from an engineering professional perspective. There was never any particular problems between us from personalities.

ROSS-NAZZAL: What do you think was the strength of having Judy or Sally on your team?

MIDDLETON: We never distinguished them any different than anyone else. They were part of a team. Whether they were male or female was immaterial to us. We could joke the same way with them. Like I say, Judy was very friendly. She had a really interesting personality, a lot of fun person, but I really wouldn't say that there was a difference that you could detect that they were female versus male. We interacted personally, one way or the other. I'm thinking of a Jerry Ross or John Fabian, who I worked a lot with. From a professional perspective, we interacted the same with them as we did with Judy or Sally. The only thing I could say is in the case of Sally, she was really driven professionally. I think she really wanted to be the first woman to fly.

ROSS-NAZZAL: That's interesting.

MIDDLETON: A good one to interview, if he'll talk—I had a lot of close contact with George Abbey, and he really liked Sally a lot. She played on his baseball team, and she was a great sportsperson, as you know. She was great at tennis and all that, but she was great at baseball as well, and George had this baseball team. I don't know if they still have them down there. There was quite a lot of intense rivalry between the various teams. Sally was a really good baseball player. We always joked that that was what decided her for being the first American woman in space.

ROSS-NAZZAL: That's interesting that you say that.

MIDDLETON: That's more a joke.

ROSS-NAZZAL: I'll have to ask him. I'm supposed to talk to him at some point. Any interesting anecdotes that you can share about training or simulations, any jokes, perhaps, or pranks?

MIDDLETON: I don't think we really did anything like that. We didn't do much like that. There may have been more that was done down in Houston for fun, but because time was of the essence for us, there was a limited amount of time. I think if we did something with Sally, she wouldn't have been too happy. She took everything, every minute, very, very seriously. No, when we sat down, we went through things, we went through procedures, what was going to happen, and it was a very, very professional way of doing things. That's the thing I recall about her.

ROSS-NAZZAL: Were you in Houston for STS-2? Were you in the MER?

MIDDLETON: Yes, I was in the MER for all RMS missions up till Solar Max. Solar Max was when I was finished in the MER, with John Peck. John Peck and I were in the MER together. We were on the team when the arm was operating.

ROSS-NAZZAL: Sally was the CapCom [Capsule Communicator] for that mission. Do you have any recollections of her in that position?

MIDDLETON: No.

ROSS-NAZZAL: You were there for STS-7, you were in the MER?

MIDDLETON: Yes, I was.

ROSS-NAZZAL: Did you know that she was going to take the arm?

MIDDLETON: No, I didn't. I didn't know that she and Fabian had planned to make it the seven.

ROSS-NAZZAL: Would you talk about that, and what was going on at the time in the MER?

MIDDLETON: It was impressive. One of the things in the MER was that we were, at that time, the only one who had video capability from the Orbiter. So, everybody else in the MER were just looking at data screens. When they did the seven, when they released the SPAS [Shuttle Pallet Satellite] and let it fly away and then put the thing in the figure-seven, I'm trying to remember, Al Louviere, I remember was MER manager at that point in time. He was pretty strict about what people did, if I remember right. People wanted to come over and take a look at the picture. It was all black and white. We only had black and white screens at the time; we didn't have color or anything in the MER. Everybody came over to take a look at the picture when the seven was created and when they put the arm in the seven position. I recall that quite well.

ROSS-NAZZAL: Any other recollections from the mission about the arm or Sally's performance?

MIDDLETON: No, it was by the book. When you're running procedures, you follow what's going on. We had the procedure book, we had the data that was coming down to us, to take a look at, and you're sitting very intently looking at the data, to make sure everything's okay and all the

commands and responses are the way you expect it. Everything was by the book, everything was great, as I recall. Now you're going back a long way.

ROSS-NAZZAL: Sure, yes, that was over 30 years ago.

MIDDLETON: That's right. I've aged a bit since then.

ROSS-NAZZAL: Did you take part in any of the technical crew debriefs after a mission?

MIDDLETON: Absolutely. I was involved in all that had to do with the RMS.

ROSS-NAZZAL: Did John Fabian or Sally Ride have any inputs or suggestions for future missions?

MIDDLETON: Generally, the response from the crew that we got was, "It performed better than in simulation," and that it was very close to what the response was they expected. I remember Truly saying that, when he ran it, and he said it was exactly what we saw in simulation. I remember that's what Sally and John Fabian said as well. "It's exactly what we saw in simulation." Felt the same way, did the same thing, was very easy to control, and they loved running it. Using the arm is one of the great joys that they had because it's like a video game, running the thing, and doing captures and releases. Besides doing EVA [Extravehicular Activity], it was one of the great things that you could do inside as opposed to any other stuff, and they loved doing running the arm. It was a joy for them.

ROSS-NAZZAL: Did the crew of STS-7 come up to SPAR as part of their post-flight PRs [Public Relations]?

MIDDLETON: Yes.

ROSS-NAZZAL: Would you talk about that?

MIDDLETON: Rick [Frederick H.] Hauck was on it, Crippen, Sally, Fabian, who else? I can't remember who else.

ROSS-NAZZAL: Norm [E.] Thagard.

MIDDLETON: Norm Thagard—we spent a lot of time with Norm as well. He was one of the astronauts that came in to do a lot of simulation work on the RMS. Him, Fabian, Jerry Ross, were some of the male astronauts who did a lot of work on the RMS.

ROSS-NAZZAL: What do you recall about that post-flight PR? Anything stand out?

MIDDLETON: We had a hell of a party up at the Gilruth Center afterwards, I'll tell you that. When the crew came in to one of our parties after that, it was pretty significant. STS-2 and 3, the parties were funded to a great extent by the Canadian government, so we trucked in a lot of Canadian beer to those parties, which was really appreciated at that time. I can recall that several of us, after STS-7, brought a lot of cases of Canadian beer down to celebrate as well. I can't recall all the

details. I remember Sally being there and a lot of cheering going on because I think it was recognized, the significance of the flight.

ROSS-NAZZAL: I was just curious if there was any media interest or anything when they came up to Canada.

MIDDLETON: I can't recall, but I'm sure there was a lot of media interest in the fact that Sally was pretty popular, and of course, she was good at selling space.

ROSS-NAZZAL: You weren't in the MER anymore after [STS]-41C—what was your involvement with Judy's flight, [STS]-41D?

MIDDLETON: Was that the 25-kilowatt array?

ROSS-NAZZAL: I can't remember. I know they had the ice-busters on there.

MIDDLETON: Yes, I remember knocking the urine thing off. I was involved in using the arm to come around and knock the ice off. We did a lot of simulation to make sure because we had to reach over around it. We wouldn't be able to see. One of the things that we always wanted to do in the flights was actually be able to see the end effect, see the arm itself, in its full. On that flight, we were going to go over the side and knock the big ice thing off. We were very concerned about reaching around there and being able to see what we were doing—that we wouldn't bang into anything on the side of the orbiter. I remember coming down. I recall there was concern about

how hard we were going to hit it, and were we going to damage tiles by knocking it off? I recall that, and how we were going to come down. The flight plan—there was a procedure that had to be worked out that was interesting, on how you would come down with the arm to knock the ice off. This big, long tube of ice that stuck out from the side of the Orbiter.

ROSS-NAZZAL: Did you work with Sally on that, or was there another astronaut involved?

MIDDLETON: You're going back a long way on that one. The answer is probably not.

ROSS-NAZZAL: Did you work in the sim then, yourself?

MIDDLETON: I was working the sim, yes, and procedures.

ROSS-NAZZAL: How did you end up coming up with that procedure? How did that evolve?

MIDDLETON: The procedure was basically developed by JSC with the procedures office, and we basically were in the review mode, taking a look if we agreed. Things like arm angles, joint angles, were they good, all that kind of thing. The signoff of the procedure was done by JSC.

ROSS-NAZZAL: Do you have any more comments or anecdotes about Judy or Sally?

MIDDLETON: I remember Judy was pretty irritated when she came out of the Orbiter when the engine shut down. I'd gone down to watch her fly. She invited me down to watch her fly, and

then the engines shut down, what, with 3 or 4 seconds before the solids were going to ignite. When they came out, the water was flowing everywhere and she got soaked. I remember she was kind of irritated about that. She invited me to come down for the *Challenger* flight [STS-51L]. She invited me down to come and watch her fly on that one because I missed her flying on the earlier one. I still have her invitation, as a matter of fact, and I wasn't able to go because I had some business to deal with. I watched the launch on TV. That was, needless to say, very sad.

ROSS-NAZZAL: That must have been heartbreaking, knowing someone so well.

MIDDLETON: Yes, it was. I knew many of the crew on it. I knew Ellison [S.] Onizuka reasonably well because he had done a lot of sims with us. I knew him fairly well from simulation. It was very sad for us, after having worked with her for so long.

ROSS-NAZZAL: I understand she was a pretty private person.

MIDDLETON: Yes. I knew her, I knew her sister. I'd met her sister, I met her mother. They were down for the first launch as well, the aborted one with Hank [Henry W.] Hartsfield, STS-14, if I remember right, was it?

ROSS-NAZZAL: I know it was [STS]-41D. I have a hard time which ones equate.

MIDDLETON: I have a hard time translating back and forth between when we were using the STS numbers and when we were using where it was going from.

ROSS-NAZZAL: I think you're right because I think [STS]-41C was STS-13, so I think you're correct in that. People use those interchangeably—I always stick with the crazy scheme, the 41D.

MIDDLETON: It was going to be 2 when it was going to launch from Vandenberg [Air Force Base, California].

ROSS-NAZZAL: Correct, yes. Luckily, we don't have to deal with those. That would be more complicated. You talked about some of the contributions that Sally made to the RMS, but what do you think overall were Judy's main contributions?

MIDDLETON: Judy had a lot to do with procedures. She had a lot to do with procedures when we were taking stuff in and out of the cargo bay, how to go into the guides and how to come out of the guides. I remember doing a lot of work with her on that, particularly in relation to the SPAS, SPAS-1. She had a lot to do with that. She had a lot to do with the IECM and a lot to do with the PDP. After that, I was less involved in those kind of procedures. I think the last one in dealing with procedures was probably the flight with [Daniel C.] Brandenstein, I think it was [STS-8], where we had the big dummy payload, heavier weight that we were practicing on. I think it was [STS-8.] I had been working the procedures pretty well with that, and I think that was the last one that I worked in detail. You'll have to recall what is on [STS-8]. It was a test payload that we'd built, fairly significant size, mainly for doing evaluation of the performance of the arm under more mass.

ROSS-NAZZAL: When you say "taking payloads out of the guides," could you explain what that means?

MIDDLETON: There were sides on the port and the starboard, they're specially designed guides. One of the things that we were always concerned about was when you contacted the side of the guides and pushed on it, because we didn't have force moment sensing on the arm, we couldn't measure the force that was being exerted by the arm. When you pushed on it, what could happen is that the payload would start to rotate on us as it was coming down the guide. Biggest concern for us was when you were putting something into the guides because you couldn't tell how hard you were pushing against the guides.

We did a lot of evaluation in trying to get the arm to come down in the guides very, very straight and very, very slowly. There are a set of lines that were drawn on the guide. We're talking back in the earlier flights, where our worries about how the payload and the arm would perform, as you were sliding down the sides of these guides. There were various types of guides. There was a type called V-guides, which were fairly easy to slide down, and then there were something that were called Y-guides, and these were the ones that were on the little payloads, including SPAS-01. There was a pallet that was in the cargo bay and it would be attached into the big guides on the side of the cargo bay, and then on the pallets themselves, there'd be these little Y-guides. It would look exactly like a Y. It would come together, and then there'd be a slot down towards the bottom.

Our concern was as you slid down the side of these guides, when you got to the bottom, that the thing would just hang up on you and you wouldn't be able to get it down into the guide. We spent a lot of time doing evaluation with camera angles, using the various cameras on the arm,

on the elbow camera, and the cameras in the cargo bay, to get an evaluation of how the payload would perform as it was sliding down these guides. What the friction level was in the guides and would it jam. We did a lot of simulation on that.

We also had simulation down at JSC. There was a large simulator with a mechanical arm in it, in Building 9, where we could look out and you had the physical arm. It didn't have the dynamics of the system—it wouldn't move up and down—but we were able to do a lot of evaluation physically as you went into the guides there, and using the cameras that they had there, to see how well it would perform. We had a very detailed procedure that was put together, as you went down in these Y-guides. Over time, as the crew did it over and over again, of course, their performance got better and better. I remember that's where Judy was very much involved in evaluating these Y-guides.

ROSS-NAZZAL: Did the crews, who were coming up to Canada, work at all on coming up with a course for training the other astronauts on the RMS? Was that something that they were working on?

MIDDLETON: They supported us. We sent people down to JSC, who worked in MOD, to work on procedures, develop training sessions. The initial training sessions, we were very much involved with crew as well. We worked a lot of the training sessions, prepared the training manuals as the flights evolved over the first few years. We had classroom training which was set up, and we had people involved in that, together with the folks out of MOD in the training group. We were working in there, and crew were part of the class that were being trained.

ROSS-NAZZAL: Since Sally had helped to develop so many of these procedures, did she have to go to the classroom training and then participate as well in training here at Houston?

MIDDLETON: I can't remember that. You'd have to check. I wasn't so much involved in the training side of stuff, so you'd have to check with the folks who still exist who were in there.

ROSS-NAZZAL: At what point did the astronauts stop going to Canada? I'm guessing there was a point where everything got ironed out, and there was a simulator down here that worked effectively and efficiently. Was there a certain date associated with that?

MIDDLETON: The last time I worked with anybody was for Solar Max. I think that's the last time we had crew up here, up in Toronto, was on Solar Max, so whenever that was, probably six months to a year before Solar Max. At that point in time, we had a good simulator in Houston. It had been validated, performed well, there was no need to come up to us anymore. Where we were quite useful, at the final stages when crew didn't come up anymore, was for failure modes and effect valuation on large payloads. I think the last one we were involved in was one for a military payload, where we ran a sim for them. It would look just like a big box—we didn't know the payload—we just saw it as the big box. The reason we did that one was that it was a very large payload. It was a 27-28,000-pound mass payload.

ROSS-NAZZAL: I think I've touched on all my questions, so I wanted to see if you had anything else to add.

MIDDLETON: The Shuttle was a fascinating program to work on. There was always a race to find out who was going to be the long pole in the tent. One of our concerns after STS-1 was the twang when the solid rockets fired. The Orbiter did a large jerk at the firing of the solid rockets, and we were very concerned at the time because of the arm hanging in the vehicle and how it's supported inside the vehicle. Were we going to break the arm? Was the arm going to be significantly damaged on STS-2 with that twang that occurred in the vehicle when the SRBs lit up? We were also very concerned about software. In our area there was a battle that went on, was it the software that was going to go wrong or the engines or the tiles. Which was going to be the long pole in the tent? On STS-1, when they went to switch on the BFS [Backup Flight Software], the software didn't sync. The first launch was aborted on STS-1, until they got the backup flight software fixed. On STS-2, from our perspective, were we going to be able to fly because of this twang in the Orbiter? It took a long time and a lot of work to get flight certification for the RMS on STS-2, because of that twang. Those are the things that really come to mind.

I was involved in a lot of the meetings on engines. I was on the software team, because of course, our software was part of the SM, the systems management computer. I was in a lot of that discussion on how software was performing, which was very interesting. Those are the things that really come to mind. It was great being part of the program down in Houston and being on the change boards and everything.

ROSS-NAZZAL: Was Judy working at all that issue with you guys on the twang of the vehicle? Was that something that you had her working on?

MIDDLETON: Not so much. A lot of it had to do with the mechanical engineering down at Houston, so we were running a lot of mechanical simulations on the impact of the arm with the twang that occurred. More from a keeping the astronauts advised, rather than them being tightly integrated into the analysis. They saw the results of the analysis, as crew always does, but they weren't integrated into the detail of it.

ROSS-NAZZAL: How long have you been retired?

MIDDLETON: I retired back in 2011. I was program manager of Space Station for the Canadian portion of Space Station. That was my job after I left the RMS program, Space Station. I was program manager through the development phases, up till about 1994. Then, I went into the dreaded executive management side and lost a lot of contact with the engineering side.

ROSS-NAZZAL: I've heard that tends to happen to a lot of folks. I want to thank you so much for your time today. I really do appreciate it. Lynn Sherr spoke so highly of you, and I wanted to have a chance to talk with you as well.

MIDDLETON: That's great.

ROSS-NAZZAL: Did you get a chance to read Lynn's book, by the way?

MIDDLETON: Yes, I did. It's very good. I felt she captured things very well, from my memories of things.

ROSS-NAZZAL: I thought it was a great book, so I was glad to see it finally get published.

MIDDLETON: Yes. It's great in memory of Sally. She was a great person.

ROSS-NAZZAL: I thank you so much today for your time, and if you have any other thoughts, like I said, feel free to add them to the transcript or send me an email.

MIDDLETON: That's great, thank you very much.

ROSS-NAZZAL: Thanks, and you have a good afternoon.

[End of interview]