NASA MSFC Oral History Interview
Steve Johnson Interviews – Apollo/Saturn Program

Kenny Mitchell
Interviewed by Steve Johnson
Huntsville, Alabama – Unknown, Circa 2012

Steve Johnson: I am talking with Kenny Mitchell. He worked at Marshall Space Flight Center, or rather for NASA [National Aeronautics and Space Administration], from 1960 to 2006, except for seven years off spent working some years for contractors and for about five years as a pastor in the Huntsville [Alabama] area. Kenny, would you talk about your education and what prepared you to be in the space program?

Kenny Mitchell: I needed to go to college. My wife, who was engaged to me in high school, said she was not going to marry me unless I did what my mother wanted, which was go to college. I enrolled at Auburn [University] and I also applied for the co-op program at the Army Ballistic Missile Agency in 1959. I went to school at Auburn from 1959 to 1964, graduated in 1964. At that time, we transferred ABMA [Army Ballistic Missile Agency] and Wernher von Braun and four or five thousand people to NASA, to Marshall Space Flight Center. I did a lot of graduate work back in the late 1980s after I had come back to Marshall, during the short time I had gone away for five years to pastor. I did not get my masters, but I had all the credits. I had some family matters that interfered with that.

Johnson: You are an engineer, correct?

Mitchell: I am a mechanical engineer.

Johnson: With your bachelor's degree.

Mitchell: With my bachelor's degree and some graduate studies.

Johnson: What brought you to the space program?

Mitchell: I remember the night we put the Explorer satellite up. I was on a date with my wife, we were in high school at Butler.

Johnson: That is Butler High School?

Mitchell: That is Butler High School here in Huntsville, the old Roy Stone now that is up for sale. We heard all this racket, fire crackers, and all the horns blowing. My brother came driving into the parking lot of the Huntsville golf course and said we put a satellite into orbit. That was January 31, 1958. We went downtown, it was exciting, and I was very good in math, the sciences. My mother was wanting me to go to school. At that time, everybody was talking about becoming an engineer. Those kinds of memories just sparked me to go to school, be an engineer, and work in the space program.

Johnson: When you got into the space program, am I correct that your first work at Marshall was in thermal control systems?

Mitchell: Right.

Johnson: Explain what that means.

Mitchell: We were designing the heat shields for the engines of the Saturn rockets. The H-1 engines, or the F-1 engines on the first stage, are extremely hot. You had all the electronics and other things on the other side of the heat shields. We had to try to determine what the heat was, radiation, convection, conduction, all the things that might leak through the heat shield and blow up the vehicle. All the cryogenics were on the other side, aerodynamic heating, as the vehicle goes through the air pretty quick, a lot of friction builds up. We had a lot of things, thermal coatings, thermal insulation, that we worked on for Saturn I, Saturn IB, and Saturn V. I worked on that until the Skylab program came along and we had thermal control of Skylab and the Apollo Telescope Mount.

Johnson: You have such a broad career and there is a lot to talk about. Working on the thermal control systems to make sure the Saturn V did not blow up, what were the main challenges to controlling the incredible heat generated by those engines?

Mitchell: We had to try to define what was the heat. Out at the static test firings we had on the Saturn out at Marshall and the kind of concepts people were looking at, liquid rockets versus solid propellant rockets, they each have different kinds of environmental heat loads they could put back in the base. A lot of the Atlas vehicles blew up during that timeframe because of not just structural dynamics but sometimes thermal problems.

Johnson: They got too hot.

Mitchell: That is right. We knew you could not insulate it as much as you wanted because you were also associated with weight and keeping things where you could launch the payload. I was involved in what they call calorimeters that were trying to measure new sensors that had to be developed that could measure radiation like the heat shield would see. When you get into altitudes, the plumes are expanding as you are going up and then they begin to interact with each other and you get the first flow of gases back into the heat shield area where very hot convection is occurring. Of course, the higher you go, the thinner the air is, the less heat you get. It was not a constant situation. We had to try to determine what the total environment was that we had to design for throughout the launch of the vehicle. It was very interesting.

Johnson: Did that require a lot of testing?

Mitchell: Yes, it did.

Johnson: How did you test? Fire static tests and record temperatures?

Mitchell: That is all we could do. We did not even have the luxury of putting a lot of instrumentation on the vehicles we flew before we got into operations because it would disturb the normal design. We had some instrumentation, thermal couples were used that you could correlate back to how much heat was getting to that area to make that temperature rise.

Johnson: When you determined how hot thing got, did you work on ways to keep that heat from doing damage?

Mitchell: Yes, Marshall was developing new insulation that had never flown before and integrated in honeycomb shields. We would try to analyze. You have to remember the analytical capabilities back in the early 1960s, the computers, were very limited. We were using all kinds of state of the art techniques to try to predict things. A lot of testing was used to correlate how well we could predict things.

Johnson: Did you test things to destruction?

Mitchell: No, we were always in a real environment, a ground test. When you run a ground test, you know the environment. Usually you have liftoff within a few seconds after you have ignition, so the environment is the hottest right before liftoff because everything is flushing back. There is no way you do not have a lot of heat looking at your heat shield. We would get the worst kinds of environments and try to analytically predict how much, if you watch the plumes of an actual Saturn flight, they become transparent the higher the altitude you go. They are not the heat that you see at low altitudes. That effects how much radiation is coming from that and it effects, again, the kind of convection as those plumes expand. The higher up you go, the more they expand. It was an exciting time. At first, a lot of our work at the Army was confidential. When [President Dwight D.] Eisenhower formed NASA, he did not want us working on anything classified, so we were able to get access to data from other people. The early space program, it was a real learning curve on thermal control and properties of materials.

Johnson: Were there ever any concerns it would get too hot and we would not be able to control that?

Mitchell: No, we were very conservative. If you go out to the space museum and you look at the Saturn I that is standing there, and the Saturn IB, it had eight engines in the bottom. They had bags that were around the engines because the engines would have to gimbal, be flexible enough. This was a whole new area where you had to design not just for the heat, but you had a lot of convection come back up in there as you went up. We ran a lot of ground tests where we destroyed the curtains. You can see it on video we have of the base region.

Johnson: What were these curtains made of?

Mitchell: Advanced materials that were flexible enough to insulate and strong enough for the severity of the environment.

Johnson: Did you have to develop these materials as you went along?

Mitchell: Our Materials Division, Dr. [William] Lucas, who became center director eventually, Robert Schwinghamer, all those guys worked over in Materials Processing. Jim Kingsbury. They were all the grunts at that time developing materials for von Braun that would help the Saturn survive the severe thermal environment it was going to create.

Johnson: Through all the testing you did, were you confident by the time we got to launching the vehicle with human beings onboard that we had the heat problem licked?

Mitchell: Yes, we were confident that we had a very conservative design and that flights would prove how conservative it was and how cool we kept things on the back side of the heat shield so we could actually save weight in the second generation after we flew the early Saturns. We actually reduced the amount of insulation and thickness of the heat shields and had improved materials everywhere because it was an evolving kind of technology.

Johnson: What is the process of developing a material to insulate from the heat of a rocket engine when you are building rockets that human beings have not built before? What is the process like of developing those materials?

Mitchell: You know what you are looking for as far as physical properties and you want some that will not conduct heat well and resist the flow of heat from one side to the other. You want something that will take tremendous shaking and the environmental conditions that could break it all apart. They came up with these honeycomb schemes. If you think about it, honeycomb is usually metal, so they learned to develop phenolic honeycomb. It is a plastic, very strong, thermally resistant, non-metallic material. That is a composite kind of strength of material.

Johnson: Is it like the composite materials that people are used to?

Mitchell: Not today. They are totally different, carbon kind of stuff.

Johnson: These are early composites. Is there anything you can compare one of these materials to? Do we use phenolic compounds?

Mitchell: Yes, we still do. It is light weight.

Johnson: It is not metal and it is not really plastic?

Mitchell: No, I call it nonmetallic. [Both Laugh]

Johnson: While you were developing these materials, inevitably there was some pressure because we were wanting to fly some things. While I understand the earliest flights were test flights, you said Atlas rockets blew up because they got too hot at a certain point, and the people in charge do not want things to blow up. They want them to make the complete flight so they can test all the equipment. Talk about the pace of work. Yours was sort of a ground floor operation, so to speak.

Mitchell: We worked six days a week. As a co-op, I got a steady dose of real engineering work. I was way ahead in learning things because you were learning with the other engineers. You were helping them learn how to store cryogenics so they do not all boil off before launch. We had insulation inside these tanks that had never been developed before. When I say thermal control, it was every aspect. When I say speeds when you are going through the atmosphere, there is tremendous friction along the sides of the vehicle where the cryogenic tanks are. Heat is trying to get in that way, heat is trying to get in through the base, and you have to design everything so it stays within the limits the people will tell you they will be in trouble if you do not keep the temperatures within these certain limits.

Johnson: Do you remember the limits?

Mitchell: A lot of the time, aluminum begins to lose its strength around 250 degrees Fahrenheit. Almost the entire vehicle was built with aluminum.

Johnson: What kind of temperatures are we talking about around the nozzle?

Mitchell: You are talking about thousands of degrees down there. I am talking about the vehicle structure that is holding the engines in place and holding the whole vehicle together. If you got on the other side of the heat shields, you had aluminum. It was very heavy because the weight of the heat shields. You did not want that to lose its strength. Everything we were doing was making sure we did not even come close to 200 degrees, much less 250. We would try to keep everything on the back side around eighty or ninety degrees. And on the other side, it was 1000 degrees.

Johnson: You had flame, you have friction, you had all these different heat sources that you had to overcome.

Mitchell: Right.

Johnson: What kind of hours did you work?

Mitchell: You have to remember we were developing two or three Saturns at the same time. The Jupiters were just a conglomeration to put together for Saturn, eight of those. Then we were trying to develop an upper stage, an S-IV-B stage with engines that we had never flown before. When we started the Saturn IB, we were in parallel with trying to fly the Saturn I. We changed out the fins, von Braun had a lot of flak because we were venting a lot of gasses overboard that were black. Everybody was always panicking in the press and he said we had to make it to where we do not get that gas where everybody can see it burning.

Johnson: You are saying that one of the things you did was come up with systems so it would not look.

Mitchell: So it would not look like it was on fire when it was not. [Both Laugh]

Johnson: The earliest rickets.

Mitchell: The early Saturn Is had overboard vents of exhaust gases in the turbines.

Johnson: When it was burning, it was black?

Mitchell: Yes, it was real black, like a tire burning. It did not look like it was not on fire.

Johnson: You had to develop systems?

Mitchell: He got questions on that all the time. People thought he was not telling the truth. He finally asked if there was any way. We had these vents, if you go out to see the very early Saturn I design, and we would move those to where we could circulate that gas and burn it up in a way nobody could see it.

Johnson: For cosmetic reasons?

Mitchell: It was purely cosmetic.

Johnson: How much trouble was that?

Mitchell: I do not remember it being any trouble.

Johnson: That is interesting that you had to make it look good.

Mitchell: Absolutely.

Johnson: A lot of hours of work.

Mitchell: We would work weekends all the time. Back in those days, casual is nowhere near what casual is today. You were still dressed up going to work. I remember how hot it was in the buildings. Back in the early 1960s, they were not all air conditioned and it was extremely hot. You would be working and paper would stick to your arms because you were sweating so much, but it did not seem like it mattered.

Johnson: Long hours, papers sticking to your arms because it was so hot. Most people would say that sounds miserable. What was the work environment like?

Mitchell: It was very funny. We maintained a sense of humor. You see *The Office* that is on TV [Television], that is so typical of all these different personalities that are put together into a technical environment. There were not a lot of old people, though there were some. The Germans were the oldest without a doubt. We did not have all the schedule things that you see today and planning. It was let us get to work.

Johnson: Let me stop you there and ask you about that. For all the engineers, would you say that from the way the things are done in the twenty-first century to the way we did it during Saturn V that it was more hands-on engineering?

Mitchell: Much more. We are really good analytically now. We really can do virtual reality. It is just eerie. I learned in all the testing over my career, when some tests looked like they were going to be out of date, like we were wasting our time, why do we not get on it and drop this test, it is taking too long to get it pulled off, I learned something every time we tested that we did not anticipate. One of my old bosses always told me you will always learn something when you test. No matter how compromised you are in the article, you are testing from the real thing, you will learn something that will apply to the real thing. It is the world we live in, but in my opinion, we should do as much testing as possible.

Johnson: Basically you are saying that the hands-on testing during the 1960s, even with computer simulations, we should still be doing more of the hands-on testing?

Mitchell: We did not have much computer simulation. They just made a recent decision on the SLS [Space Launch System]. They were going to fly it for the first time and never had tested it.

Johnson: With just computers.

Mitchell: That is right, just computers. They made a decision early this year.

Johnson: Early 2012.

Mitchell: That we were going to do an all-up test at Stennis [Space Center], Mississippi, the first stage.

Johnson: As a veteran, what do you think about that?

Mitchell: I think it is wonderful. [Laughs]

Johnson: Computer simulations are not enough?

Mitchell: They are wonderful, but it is trust and verify. [Both Laugh] I trust it, but verifying it is important too.

Johnson: During testing and developing thermal controls, was there work to control costs?

Mitchell: I do not remember that. It was not part of the normal engineer value system like it is now. Somebody else was worried about that. It was not like you had a blank check, even though a lot of people think we did. People wanted to solve the problem and move on, moving along let us launch this thing. We knew we were going to learn so much. I worked on a lot of flight evaluation working groups as a young co-op and as a young engineer. Those were some of the most memorable times, all these engineers getting together for a few weeks and evaluating all the data we got back from the flight. What did we learn for the next flight?

Johnson: You are saying you did not know anything about the money part.

Mitchell: No, somebody else worried about that.

Johnson: Were there dead ends? Were there things you tried in the Saturn days that did not work?

Mitchell: We did not do solid rockets. I had gone out to California for Aerojet testing of the solid rocket, big 156 inch diameter solid rockets. It was as big as anything we are thinking of now back then. Solid rockets are hotter. When they go up in the air, they are still hot, they are very hot. You want to make sure you understand that environment. I would take my calorimeters, all the different instruments, and go out to Aerojet. A piece of history here, the Air Force was competing with us and wanted the solid rockets. Von Braun did not like solid rockets.

Johnson: Because you cannot turn them off.

Mitchell: That is right. He just did not think they had the flexibility that you needed. Most of his experience was with liquid propellants. We were out at Aerojet with all our instrumentation. We had these big balloons, blimps, that were measuring the acoustical data because solid rockets really make a lot of racket when they go off. Because we were from Marshall, all we got was ribbing from the Air Force guys about "our solid rocket motors, they go off right on time, every time, nothing like liquids where you have holes." We got ragged the whole week before the firing.

We were up on the mountain looking down into the valley where the solid rocket was going to fire. You hear the countdown over the loud speakers, ten, nine, and they get to one and nothing happens. They do it again and nothing happened. It was really comical. The rocket was pointed with the exhaust going into the air. It was not down like you would normally have. Somebody had kicked the extension cord out of the ignitor. [Both Laugh] They had all these recorders going.

Johnson: How long did it take to discover the extension cord?

Mitchell: It took a long time before somebody wanted to go down there and find out what was going wrong. It took all day for us to recycle and find out. They had to rewind all the tapes.

Johnson: I suppose there was no walking over there to see?

Mitchell: Everybody was a long way off. Nothing had happened and they did not know why. Somebody had accidentally, just like you walking past an extension cord, and kicked that thing. It was unplugged.

Johnson: I would imagine this kind of experience did not.

Mitchell: It is funny when you bring the story back. I have some old newspaper stories that show us. We had brought all our balloons to get acoustical data. The Air Force did not care, but we had flown these big blimps. They were strung down and the solid rocket fired the next day. It was like a concussion. It sucked those big blimps. They had a lot of acoustical data about 200 feet up in the air. They sucked those things down and them shot them right back up into the air. All the string broke and all our balloons and acoustical measurements. My calorimeters were fine. They were down at the base, installed on the structure. They had to call FAA [Federal Aviation Administration] and tell everybody these big blimps were flying over California. That is one of the things you learn.

Johnson: This was the first time this happened, right?

Mitchell: This was the first time this had happened and we brought the information back. We found out our conservatism for building the liquid rockets would have been adequate to cover the solid rockets.

Johnson: I was going to ask if there were surprises.

Mitchell: The surprises were in other disciplines, not mine. My surprise was this was not as bad as I thought it was going to be.

Johnson: A fairly linear progression then from the beginning of the work to develop these thermal controls to verifying they would work and do what they were supposed to do.

Mitchell: Right. We never had a failure in the thermal control systems of Saturn, never.

Johnson: Was von Braun heavily involved in this work? Would he visit you guys?

Mitchell: Von Braun would come down every week and talk with our branch chief, Georg Hopson, at that time, and go over our detailed analysis we had so he was convinced that we knew what we were doing. He would go back and tell the astronomers throughout the world that he was working with his people [and they] were telling him they could keep this canister at the right temperature and that they would be able to do the arcsecond kind of pointing with their instruments at the Sun that they needed to do and there would be no thermal distortions. We had the whole mockup, thermal vacuum testing at Houston's [Texas] huge chamber. We did a lot of testing. This thing was on a cruciform, egg-shaped, had four quadrants, all aluminum. There was a tremendous amount of analysis. It would take two days for our models to run on the computers we had at Marshall. They would take up a whole room up in the Computation Laboratory.

We did not have the tools that we have today that can run in seconds. They would take two days. We would carry a box load of cards, all had to be perfectly arranged and then load them into the computer. We would wait on the results. It was the old way of doing business. It was improving by the year, but it was still nothing like today. The more detailed you made the model, they call it a lot of notes, a lot of individual points, because that is what the astronomers expected, not something superficial that did not really map out the thermal environment of that whole structure inside that canister. Again, it was the state of the art. That is where we did some things that were pretty crude at Marshall in our smaller thermal vacuum chambers where I learned my lesson, you always learn something when you test.

Johnson: Von Braun, of course, he was an astronomer at heart.

Mitchell: Yes, he was.

Johnson: He was really interested in the telescopes and how this would work.

Mitchell: One of our major milestone reviews was all the astronomers were at Marshall, we were on the tenth floor, that von Braun held.

Johnson: Tenth floor of what building?

Mitchell: 4200, tenth floor conference room. Von Braun's office was on the ninth floor. The big conference room was on the tenth floor. He would ask us about new technologies. He asked if we had tried heat pipes. We were doing things that were pretty standard, one of them was a cooling pump. If you know about any kind of pump, it vibrates. You do everything you can to isolate it. That is the last thing astronomers wanted was some pump sitting somewhere inside that canister vibrating. When you are trying to get one arcsecond, you are talking about no vibration. We designed vibration isolation mounts. We could prove nothing was being transmitted into the structure, up into the instruments and all that. He used the word heat pipes on us, which is sort of a common now. Then we did not even know.

Johnson: Heat pipes are actually used on satellites now, is that correct?

Mitchell: They are. Heat pipes have no moving parts. They use capillary action, a wick. It circulates fluid. If heat is coming in down at one end, it will evaporate the liquid you have and it will creep up to the top and move more liquid down. There are no moving parts, so you are keeping things almost, they call it isothermal, which means it a completely same temperature up and down the canister. He wanted to design a heat pipe into the canister wall rather than a pump fluid. Of course, when he brought something up, you had to go find out why a heat pipe would not work. At that time, heat pipes were just in *Mechanix Illustrated*, future popular science and all that. Nobody had ever thought of trying to apply that technology. [Both Laugh] We found out its weak link was gravity. It will work fine in space, but we could never test it on the ground to see if it would really work. The huge size this heat pipe would be, 100 times bigger than these little pieces we were working with. It was way big. We convinced him it was a good idea, but not for now. We have no way to test this to prove it will actually work. We do not even have the analytical tools for testing bigger things.

Johnson: You would have to fly it.

Mitchell: We would have to fly it, and that was way too expensive. We could not risk that. He stuck with our design.

Johnson: After this, the heat pump.

Mitchell: You had a lot of satellites, a lot of smaller things, not as big as what we were building. They worked fine. Goddard Space Flight Center, and JPL [Jet Propulsion Laboratory] to some degree, was the one that used heat pipe designs a lot in their science payloads.

Johnson: After you worked with Skylab, with thermal controls for the telescope mounts and various things like that, you later worked with Spacelab. Was it the same kind of work in thermal controls?

Mitchell: No, it was a great expansion.

Johnson: Spacelab, of course, was the scientific laboratory carried in the bay of the shuttle.

Mitchell: Here is the leap, we went into outer space and you had orbital heating now, not launch heating. You exposed the spacecraft when the payload bay doors of the shuttle opened up and the Spacelab was sitting there. It wanted to look at different orientations, down at the Earth, out to space, towards the Sun. When you pointed that payload bay toward the Sun, it was like a solar collector. The solar arrays would go behind the canister in the payload bay and get trapped. It would reach 300, 350 degrees, get really hot back there. We had to figure out ways to insulate the Spacelab on the outside, have meteoroid debris protection as well, and thermal control that would not let too much heat leak into the Spacelab and overload the air conditioning system inside for habitability. We got a lot of our heat rejection by collecting the heat.

I was much more involved now in active thermal control systems. That means liquid pumps that we used on the ATM [Apollo Telescope Mount] for Skylab to pump that over to the orbiter and let them pick it up and reject it with their radiator doors. Then inside, we had carbon dioxide we had to remove, we had oxygen we had to provide to the crew because the environmental control systems had those things as well as the space shuttle orbiter. When the crew moved from one location to another, they had all the life support they needed.

Johnson: In developing these things, would you, once again, have to go to large thermal chambers and test that way when you tested these systems?

Mitchell: We did not do the Spacelab in a thermal vacuum system. Our analytical tools had gotten pretty sophisticated, nowhere near like today, but back in the 1970s, it was pretty good. A lot of people did not believe our analysis when we were telling them how hot it would get if you turned that payload bay of the shuttle toward the Sun. The Houston people did not believe us, so they put some tests in their chamber down there and used some of their solar simulators and they saw some of their solar insulation melting. It was that hot. It is aluminized multi insulation, super insulation, they call it, which will protect you from minus 460 degrees Fahrenheit to plus 460 degrees.

Johnson: These things that would get so hot turned toward the Sun would get very, very cold when the shuttle would be turned away from the Sun.

Mitchell: You could have tremendous temperature gradients from what is totally out looking at space versus what is laying up against the module. That is why they call it super insulation. It could protect you from the extreme environments of space.

Johnson: This had to be developed, obviously.

Mitchell: We would do testing of those in vacuum chambers where we would take those layers. You mentioned a friend of mine that never did an interview with you, Eric Hyde [Spelling?], that was his baby. Super insulation was something he worked on a long, long time at Marshall.

Johnson: What kind of material was that?

Mitchell: It was the aluminized Mylar with Kapton spacing, maybe fifty layers. We would start off with these real thick things. It would be used for cryogenics as well as for orbital heating. You had an application of super insulation, multiple layer insulation, we would call it a lot of times, to very cold environments and to very warm environments. That was a new technology, a lot of testing going on all over the United States, trying to apply it in different ways. The way you actually attached it to something, you could short circuit the entire design just by the way you attached it. The heat would leak through because of the very extreme environments and our heat would leak out If you were losing heat inside a module, you would get condensation at those points or you would get ice forming because it would get so cold behind the racks. The Russians had that a lot in the Mir. They did not design it well enough to isolate it.

Johnson: Their thermal control systems were?

Mitchell: They had a lot of condensation in the Mir. It would get cold enough outside that they would leak heat inside out and the crew would have to go around every morning with a towel and mop up a lot of places where water would coalesce in a microgravity environment. It would not just drip, it would turn into a big water glob and they would have to go get it.

Johnson: That was one of your jobs, to make sure there were no water globs in the space craft?

Mitchell: Absolutely, no condensation was a requirement that was laid on the designers, we shall not have any condensation where we do not want it.

Johnson: How did that work, or did that work, to translate to working on the International Space Station?

Mitchell: It was all evolutionary. The environmental control systems got more complicated because you were not going up for a week to two weeks, you were going up for months to years. We had to develop regenerative life support systems.

Johnson: The Spacelab missions, did you use those missions to test thermal control systems that might be used on the International Space Station?

Mitchell: The thought was never on your mind that this might work on the Space Station because Space Station was not going to be any more that a lot of Spacelabs all hooked together, a lot of modules. It had a natural progression of application.

Johnson: In your mind, is that how it is?

Mitchell: It did, but you also had a worse meteoroid environment because the shuttle was not protesting you as much anymore. You had to integrate your thermal control systems with your structural systems that were going to try to keep meteoroids, meteorites, from piercing and blowing up the modules. Trying to integrate that all together and make sure everybody was getting what they wanted out of one design was a challenge. Again, you could do small pieces for testing. They actually found out in the meteoroid protection that our multi-layer insulation, when it was stuck between the meteoroid shield and the hull of the module, reduced the chances of penetrating that module ten-fold just by having that real thin aluminum insulation between you and that meteoroid shield. You expended some energy coming through the meteoroid shield, and then a lot of particles would begin flying everywhere. The next layer, the insulation, would pretty well absorb all of that. That would damage the performance of our insulation if we had a lot of that destruction, but that did not happen in space. If you had a penetration, it only happened in a few places.

Johnson: What we used on Spacelab essentially evolved. You worked on something called the 25 kW [kilowatt] Space Platform. This was pre Space Station.

Mitchell: Early 1980s.

Johnson: The early 1980s. Tell me about that.

Mitchell: Marshall was interested in things beyond Spacelab. Dr. Lucas had always wanted to keep a lot of irons in the fire, what is something else we could be doing. One of the things that plagued NASA was the fuel cells on the orbiter did not have any time past two weeks.

Johnson: Let me drop back and say there was about a two week limit on a shuttle mission with a Spacelab in the cargo bay.

Mitchell: Because there were fuel cells in the consumables. If you try to put a lot of fuel cells on the orbiter, you almost could not carry anything up because it took so much weight. The orbiter was looking at a big solar array on the end of their remote manipulator arm and hold it out and point it toward the Sun. That was called PEP [Power Extension Package], that is an acronym.

Johnson: What does that stand for?

Mitchell: Power Extension, something, I cannot remember what the last "P" was called. It was Power Extension something, they called it PEP. We were competing with them because at that time, we were taking the Skylab solar arrays, the technology we had there, and putting them on a type thing like we had on the Apollo Telescope Mount, and putting it up into orbit and having experiments mounted up there. You could deliver it in the space shuttle. We designed it where you could have that attached to the space shuttle and let the space shuttle come up and attach to it, berth with it. It would keep the orbiter up there as long as you had life support. You did not need it for fuel cells anymore.

That competition went on for two or three years. At that time, I was working with different experiment people who were military who were looking at lasers, high-powered stuff. You wonder why twenty-five kW, but they wanted 100 kW. They did not want twenty-five. They could do a lot of experimentation. A lot of material science people, we were looking at flying on the 25 kW Power System and also supporting the shuttle when it would come up.

Johnson: How did that work out?

Mitchell: You go through phase A, phase B kind of studies, and we stayed in the phase B. NASA and Ronald Reagan wanted to build a space station. They did not want a diversion of funds to anything except this space station. They liked a lot of the things we were doing and they liked that the shuttle could deliver elements of a conceptual space station. The whole work started again in a phase B of let us work out what we can do to build a space station on orbit. That took several years of study before you came up with something. By 1988, they pretty well had assignments of different centers of who would do what on the Space Station, and we were given a certain role. You will be Package 2, Houston will be Package 1, Glenn Research Center will Package 3. It was diversity, keep everybody employed. It became a jobs program more than it ever should have, which is a sad part of the Station. You knew you were doing a lot of things that were not necessary to keep everybody employed. Sometimes that would complicate it because too many people had too many says in what was to be done.

Johnson: While you were doing all this development work on Station.

Mitchell: You really need a singleness of mind, singleness of leadership, it was a very diverse leadership.

Johnson: If you compare that to the Saturn Program, it sounds to me like it was not nearly as efficient.

Mitchell: No, everybody had a clear-cut role, Houston did the Apollo capsule, Marshall did the launch vehicle, and the Cape launched it.

Johnson: In your mind, did that make the Station more costly and money harder to come by?

Mitchell: Much more.

Johnson: Did this hurt the Station Program, do you think?

Mitchell: It made it cost a lot more and decision processes were slowed down tremendously. It would take months to get key decisions on things. They would say they were really trying to determine the cost, but it cost more in delaying the decision.

Johnson: You were spending money determining the cost.

Mitchell: Right. It got to be absurd at times. You would find out once it got to the top, you thought to make a final decision, they would make a decision to go back and look at this. You would start all over again, the process.

Johnson: Was that frustrating for somebody who had worked in the?

Mitchell: Very frustrating. I used to try to tell some of my younger employees from the time Skylab was written down on a paper napkin to the time it was over and you looked at what we built, five years from a concept, a figment of von Braun's imagination, to we have flown it. We extended the life, we did a lot of things to Skylab. We had three basic missions all accomplished within one year after it was up there. You wondered what happened to those days. It took forever to build the shuttle, it was very complex, of course, but in parallel, we were building the Spacelab. The Europeans were getting their feet wet on human spaceflight. They wanted to get into the arena, so we gave them our Spacelab concepts. They learned working with the shuttle was worse than pulling teeth. It was trying to integrate those two together, who does what to whom. You had to fly together.

Johnson: Did you ever say to anybody it is too bad von Braun is not around so we can get this thing more organized?

Mitchell: I have all kinds of von Braun memorabilia. He was everything you have read about, he really was so charismatic and so smart and so nice. It is too bad a lot of people did not know him more. The Germans idolized him. If he would have a meeting, they would make sure they were there when the professor was there.

Johnson: Before we finish talking, I want to talk about the fact that you worked for Marshall Space Flight Center for most of your career, but your work at Marshall led you to live in Russia for two years. What was that like?

Mitchell: It was a life-changing experience. I was the person responsible for Environmental Control and Life Support Systems for the International Space Station, and I worked with quite a few internationals. When [William] Bill Clinton became president, he said if you do not redesign it and make it cheaper, I am canceling the Space Station Program. We had not flown anything yet. We went through a major redesign to make it simpler. We were pretty close to having what we call our phase CD hardware development, seventy-five percent completed, and we had to go back and change a lot of things.

One of the things the Headquarters people wanted to know was the Russians had been flying their Mir space station since 1988. This was in 1993 timeframe, and Clinton had been elected in 1992. Dan Goldin had come on as the new NASA Administrator. They sent myself and one of the Boeing managers, John Winch and George Hopson, and my counterpart at Boeing, Harlan Brose, to Russia to talk with the Russian engineers who built the Mir life support systems. You cannot imagine the fear that was in those people's lives of talking to Americans. That used to be treason to talk to anybody in English. You cannot imagine they had not been told what was still country secrets versus I need money badly. Communism had fallen in 1992 timeframe, I think, or 1991. [Boris] Yeltsin was trying to become president.

When we arrived in Russia in July of 1993, we met with some very impressive engineers from one of the companies who had built the hardware for the Mir. They were very cautious. We asked a lot of questions they could not answer. We knew what kind of problems we had.

Johnson: Questions they could not answer because of policy?

Mitchell: Fear. They were country secrets.

Johnson: Yet you were supposed to be learning about what they were doing.

Mitchell: We were supposed to be exchanging information to buy their hardware.

Johnson: You say country secrets, but essentially they are all secrets about living in space.

Mitchell: They considered everything a secret. The paradox was there was a proverb in Russia, "There are no secrets in Russia." They could not answer basic questions that we would have that we were experiencing difficulties in developing with our own hardware.

Johnson: Were these questions that if they had asked you, you could have answered them?

Mitchell: We did answer them.

Johnson: Did that ever change over your two years?

Mitchell: Yes, it did. It had to. When I got back in July of 1993, I was told that Clinton wanted the Russians to be part of the Space Station. We had redesigned it, presented it to him, got the reports, then he throws another curveball.

Johnson: Did you have to redesign after that?

Mitchell: We had to.

Johnson: Why did you have to redesign it?

Mitchell: Because we had to integrate the Russian hardware. A lot of the Mir stuff and new elements that we never had on the old space station, we had to figure out how to get them all attached together, and who flew first. Did they fly? They had hardware way ahead of us and they ended up having some hardware we had never heard of that was used in the military that became the first element of the International Space Station. It was U.S. owned, Russian built, Russian launched. George [H.W.] Bush the first had promised we were going to cooperate with the Russians when he was president before Bill Clinton. He said why do we not fly an astronaut up your Mir space station and you fly an astronaut on our space shuttle? That never happened.

Some of our Congressional people were giving Clinton all kinds of hell because he had not done anything about the Russian thing. We had no boots on the ground, we had no plan. Clinton brought the Russians over and we spent about three weeks up in Washington, D.C. [District of Columbia] huddled with forty Russians and about forty Americans and came up with a design that we thought could work, told Goldin he could take it to the president, and we were ready to go work this out. We could learn a lot if we did more with shuttle and the Mir, how to work together before all these other pieces had to come together for an International Space Station.

It was at that time that I was asked to come down to Houston and would I be interested in going to Russia. I had indicated a little bit of interest when I was in Washington. Is anybody here interested in going to live in Russia for a couple of years? My wife had been in Washington with me. I said, "Do you mind if I ask what they have in mind?" She said, "As long as you do not commit to anything." I said, "I am not committing." I asked what they had in mind. There is a long story about how they snookered me into going over there and living for two years, taking a staff and supporting shuttle-Mir and International Space Station.

Johnson: You went and lived and worked with the Russian space program. Were their methods, their ways of doing things, radically different from the way you experienced things at NASA?

Mitchell: Yes. They had the same people doing the same job for thirty, forty years. Our people career changed, going up some kind of career ladder. These guys, they became so good. They could do more with nothing and it would be such an exquisite level of craftsmanship. They only had one schedule on a canvas board, looked like Moses' scroll or something, only one person kept it, walked around with it. They did not have schedules for everybody. Everybody knew the milestones. They had one set of drawings and they were in a repository like Fort Knox that you had to have all kinds of security access to get to. You might generate a piece, but it went into that vault. There were people, a very few people, who knew the whole thing.

Johnson: Even when they were working on a program that is an International Space Station, it was still sort of a secret?

Mitchell: It was very secret. They would not explain to us. We had our fire on Apollo. We knew through different technology information kinds of things whether it was spying, loose lips, or whatever that they had had fires on the Mir.

Johnson: They actually had a fire once with an American.

Mitchell: They had a fire when we were up there with Jerry Linenger. We were trying to find out what caused the fire, how did you put it out in microgravity, and how did you deal with all the toxins that a fire normally generates. You can put a gas mask on, but you cannot keep it on all the time. How did you clean it up? They did not want to tell us. They did not even want to admit they had a fire.

Johnson: Even though you are working together and our problems were pretty much public knowledge.

Mitchell: They were documented everywhere. NASA got Tom Stafford, who the Russians adored, he went on Gemini, he was Apollo 10, just before it went down, then he was commander for Apollo-Soyuz. The Russians just adored him. Goldin asked Stafford, to get over there and tell them we will never sell to our politicians a way of doing business until we know what they are doing is safe according to our standards, not just their standards. There was a feeling human life was not as important to them, they would take a much greater risk than we would. Stafford worked with an appointed equal. While I was there for two years, he and his NASA team, they were all grey beard guys, they were not active NASA, and some astronauts, some not, and they had the hardcore discussions on safety. They would go to a lot of the manufacturing sites on Russian maps in Moscow. You do not even see those factories on the maps.

Johnson: These are secret factories.

Mitchell: They were not on public information. We were some of the first Americans to ever go into these facilities and talk with them and have technical meetings.

Johnson: You found them to be paranoid, it was hard to share information, they had a different way.

Mitchell: They were in a selling mode too. They wanted money. They were in deep, deep trouble financially, economically, and they were never going to give anything away for free.

Johnson: Did you learn anything they did that you brought back and said we could learn something?

Mitchell: Yes, but our culture, keep some of these skilled people at the same job, just pay them more so they do not have to go up some kind of career ladder to get more money. Give them skilled craftsman salaries because they are good at what they are doing. We promoted them to the Peter principle. You know what that is, the Peter principle book where you promote somebody to a level of incompetence because they are so good.

Johnson: They get past where they were.

Mitchell: They get well past where they were good.

Johnson: Does that disappoint you as something we could have learned from them that we did not learn?

Mitchell: I think you learn it to a degree. It maybe is not as widespread in your culture, but you cannot help but admire. These people were making $150 a month. They were not making the kind of money I was making.

Johnson: And still doing great work.

Mitchell: I had a maid that came to our apartment, she was a chemical engineer, and she did not have a job. She worked doing maid work.

Johnson: You had a maid who was a chemical engineer?

Michell: A lot of the technical people in Russia did not have a job anymore during the 1990s. The government did not have any money.

Johnson: In your career, what was the most exciting thing you did? You worked on the Saturn V, Spacelab, Skylab.

Mitchell: I did not even tell you about Tektite. If you are familiar with that, I have a notebook in the other room, an undersea program.

Johnson: You worked with the undersea program? What is the part of this career?

Mitchell: The highlight?

Johnson: Yes, the highlight.

Mitchell: I think the highlight was the diversity. The last two years of my experience at NASA were some of the most exciting because for the first time almost in my career, I was not working on human exploration. I was working on solar system exploration. We were in charge of products that collided with a comet, collected comet dust, and brought it back to the Earth. It is going to Pluto, it is going to Jupiter, it is going to asteroids that Dawn went to with ion propulsion systems. The last two years, I was working on things that we were flying lickety-split. From conception to flight to finish, some of the missions were five to ten years long.

Johnson: These are satellite missions?

Mitchell: These are all unmanned satellite missions when Marshall was awarded the Discovery New Frontiers Program. It was so refreshing because we were accomplishing things so quickly like we did back in the early Saturn days, they were happening, one right after the other. They were being done in parallel. We were managing with JPL, Goddard, Johns Hopkins [University], and all these people who were making these exotic systems. We were managing the money and we were managing the schedules. We were using radio isotopes to get to Pluto because you get so far away from the Sun you cannot use solar rays. Going through the regulatory process of flying something that might blow up when you launch. [Laughs] Atlas V, carrying nuclear isotopes, you had to prove to god and everybody else that nobody was going to die if it blew up.

Johnson: This was done with computer simulations?

Mitchell: You had that plus all kinds of history of how protective things were, where it was located. That was sort of full-circle to me because I was experiencing, once again, something that did not take eight to ten years to get done. I was seeing eight or nine things get done in two years.

Johnson: For people in an industry like space, is that hard when it is like going fishing and never catching a fish?

Mitchell: It is because I would ask my employees, I felt like they would not hang in there with me and stick through something, they would jump at any career opportunity because it had a grade promotion, about loyalty. I got challenged several times by some of the guys that I really respected. Why are you leaving me? They said they were tired of working on things that never came to fruition. Why were people demanding loyalty of them when they gave their heart and soul to different projects and they got canceled or postponed. If you look back at the past twenty years, the space plane we were trying to develop, all the things that people soaked day and night in trying to make it happen and in three years they would kill it due to funding. That so discouraged so many young engineers. They were not doing anything but run analysis and shuffling papers, they were not off in a test program like we had been when I was a young engineer. That tends to keep you away from that "cannot get anything done."

Johnson: There was no hands-on.

Mitchell: There was not enough. That was not true in the ECLSS, the Environmental Control and Life Support [System]. We had in-house testing going on all the time. Our guys were real motivated. This was for the International Space Station. We worked years on it. Martin Burke, a lot of guys that used to work for *The Huntsville Times*, came through and never believed we could pull off what we were trying to do, recycle urine and condensate, remove carbon dioxide, crack it, and get the oxygen back out of it. All the things that are now flying on Space Station. It is up there humming away.

Johnson: Your career, the best part to you was when things were happening, when you were accomplishing things, not when you were just thinking about them?

Mitchell: The best thing is we did not have a lot of failures. I think if I had to reminisce over what if, what if, that I would not be as satisfied. This sort of summarizes space exploration. What a journey. The whole thing is a journey. Every phase was new in some aspects and not as exciting in other aspects, but it never ceased not to excite me. My work was as enjoyable as a hobby. I have a few hobbies, so I know how much fun you can have in your hobby. I was wondering when I retired if I would automatically get up and head down to Gate 9 and go on in. It was surprisingly a clean, total break.

Then nine months after I retired, I started receiving calls if I would do some consulting work. It has been very nice to have kept my finger in the space programs. I have done it for JPL, Headquarters, Marshall. They would be short-term jobs that I could do some at home, some travelling, some on the spot out at Marshall. It kept the juices going. You never lost the appetite for helping the young guys make it happen. I am doing that right now with Space Launch System. It is pretty exciting to work with some of them and not act like an old conjure who wants you to do it the old way, but try to give them the benefit of some experiences.

Johnson: Your career, programs that have made space history, did you ever consider, or do you consider now, that you were in on helping make history?

Mitchell: Absolutely. I have written down one-pagers that people have never done what I have done, and then I listed about twelve things I have done. It is not that I have done something that nobody else has done except stay married to my same wife for fifty-one years, nobody else has done that. There are so many things I have done that others cannot say they have done. I went to Kazakhstan. I saw the first American launched on a Russian rocket. I went to Star City many times. I sat in [Yuri] Gagarin's office. The Russian experiences are innumerable.

To have been a part of so much history, to actually have worked for von Braun and looked at him like I am looking at you. To have him talk to you and have him asking questions was humbling. You were in awe. This man would show up at your place unannounced. He would not say I will be over there tomorrow. He would come into your office, it would be like a shock to your system. He would want you to gather your colleagues together and talk with him. He could get the truth quick then. It did not have all the cuing and prompting so you would say the right things to the chief. He really knew how to get the right information. Those experiences are memorable. I have three kids and twelve grandkids, and nobody else has gone into anything engineering or space.

Johnson: If you had it to do over again, would you do it?

Mitchell: Absolutely. I have a library upstairs that I could start a museum with. I am a space cadet that collected stuff. I started to work with the Army the day I was eighteen, my birthday, September 4, 1959. They could not let me start work until I was eighteen. From there, I went to NASA when they transferred. It is a journey. It has really been wonderful.