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

Alex McCool
Interviewed by Steve Johnson
Huntsville, Alabama – Unknown, Circa 2012

Steve Johnson: I am talking with Alex McCool. Alex, talk about your service with the agency. How long were you with NASA [National Aeronautics and Space Administration] and Marshall Space Flight Center?

Alex McCool: We started with the Army in the early years. NASA was formed in 1958 and we went to Marshall Space Flight Center in 1960. I retired in 2004, which is something like fifty years of service time.

Johnson: Talk about your education and how it prepared you for this. Give me a little bit about your educational experience.

McCool: I studied mechanical engineering, got a B.S. [Bachelor of Science] in mechanical engineering. I got a master's at Louisiana State University and studied mechanical engineering. I transferred here in 1954. I was working for the Corps of Engineers. It was hydraulic dam design and more civil engineering, but I wanted to

work in mechanical engineering. I heard about rockets and came to Huntsville [Alabama] in 1954 and started with the [Wernher] von Braun team working on the Redstone missile. I went from dams to rockets.

Johnson: What brought you to the space program? Was it an interest in space or did it just kind of evolve from working with missiles to working with rockets?

McCool: It was a little bit of that, but I had a friend I grew up with in Florida and he had some up here in 1953. He was always in touch with me and said there were a lot of interesting things going on. We are going into space and are working on rockets. I want you to come up here and look into it. I came up in 1954 and was offered a job. It was future stuff, it was space. There was a German team and it looked like it was going to be a good future. We decided to pick up and move. We came here with a six month old son. We had not been married but about a year and a half, I guess. The interest was get into rockets.

Johnson: How would you describe the field you were in during your time with NASA?

McCool: I think it is a challenge and a lot like the team. Whatever an organization is, it starts with the leadership. For sure, we had excellent leadership. Dr. von Braun was our

leader. He would come around and we would talk to him. We were given a job and they treated us as equals. We would express our concerns. He would always want to know. The other leadership he had, his team of directors, we worked for them.

Johnson: At Marshall, what area were you involved in?

McCool: In the early days, I started in propulsion. You get involved in fluid mechanics and fluid flow, pumps, a lot of that, handling propellants. I use an analogy like your car uses gasoline or diesel fuel, we were using liquid oxygen and alcohol, seventy-five percent alcohol. A lot of my experience and my master's was in fluid mechanics and fluid dynamics. I was interested in that and doing a lot of analysis and analytical work. It was interesting to me, the challenge and work we had to size lines, we had to size tanks to carry the propellants. I use that instead of gasoline or some of the other fuels that you might use. It was challenging and very interesting. They would give us tasks and we would work very close with the team. We would work with the people who do all the flight dynamics, ballistics, and all that.

We had intimate relationships with those guys because the rocket engine, the propulsion, is key to the rocket. I was fortunate to begin my career there. There was a lot of fun stuff, long hours, you just got caught up in it. It was new stuff. Of course, we

learned a lot from the German team because they had been down that road on a V-2 rocket. We were working on the Redstone, which was a ballistic missile. Then we had to modify the Redstone. Von Braun had a lot of ideas about putting somebody into space and we were going to modify the Redstone, make the tanks larger to carry more propellants, maybe uprate the engine to get a little more thrust. Eventually, that is what we did with Mercury and Alan Shepard flew that way in 1961.

I kind of worked in that world of sizing the tanks, making them larger, fluid flow and all that stuff. We had to predict what the propulsion performance would be during flight. We worked very closely with contractors. I went down to the Cape [Canaveral, Florida] in the early days and did a lot of the work down there with those guys during the Redstone flights. It was, to me, very interesting and challenging, a whole new world when you see that rocket fly. I was down there for Alan Shepard's flight to be a part of that. That was our first opportunity.

In the meantime, of course, the Russian's had beat us with Sputnik. The whole world got interested in that. Von Braun and us, we had already worked and had a satellite, which was to be called Explorer. It was put in a warehouse. We were ready to fly. That was the International Geophysical Year and the Navy was selected to put up the first satellite, which was the Vanguard. Here came Sputnik. Then the Vanguard tried a

couple of time. Caput. They had modified a rocket and did not have the reliability we had on the Redstone. The Russians were first, so von Braun and the team, we said we could put ours up. It was still coming in after the Sputnik had gotten attention. I was heavily involved in propulsion, rocket engines, the pumps, fluid flow, thermodynamics, fluid mechanics, you name it.

Johnson: Talk about the main technical challenges in your field during the Saturn Program.

McCool: The main technical challenges in the rocket engine development, in those days, we did not build the rocket. We had contractors doing that. We took the Redstone engine, an outgrowth of the V-2 engine, used the same propellants, alcohol, liquid oxygen. We selected Rocketdyne Division of North American Aviation and we worked very closely with them, day by day by day, on the design, the pump's design, the fluid flow, performance of the turbine, all of that. We worked very close. In the early days, a lot of problems were developing components like the valves. We had fluid flow to deal with. We were doing a lot of component testing and then subsystem testing and then we would do the engine testing. We did a lot of that at our contractor site and we did a lot of testing here at Redstone in the early days on the Redstone engine.

Working with them, with our contractor, in developing the rocket engine, we had to certify that the engine was certified for the performance requirements we had. In other words, how long it was supposed to burn, what thrust it was supposed to give it. We had instrumentation. Every time we did a static firing, we had a lot of instrumentation. We would look at that data and evaluate the data, thrust, chamber pressure, temperatures, fluid flow, all of that. We had to deal with that and look at the performance. We had to do enough tests to certify the engine would be okay.

In the early days before we flew Shepard, we were doing it for the Army because we wanted to deploy the Redstone missile, which we eventually did to Europe. It had to have certain characteristics to deliver a 1,500 pound nuclear warhead in Europe, which is over 200 nautical miles. Developing the engine and getting it qualified was the critical thing. That would be the same thing later on getting up the Saturn/Apollo because we went from 78,000 pounds of thrust up to a million and half pounds of thrust for the F-1 engine, which was one of the five engines on the first stage of Saturn. We had to develop all of those.

As we got into other areas, we started looking at other propellants, started then with liquid hydrogen. Liquid oxygen is an oxidizer. It is minus 300 degrees Fahrenheit. Liquid hydrogen is minus 400 degrees. Both of them are cryogenics. We knew what to

do with liquid oxygen because the Germans had pioneered that. Liquid hydrogen was a whole new ballgame. Our friends at Lewis Research Center [now Glenn Research Center] and Pratt & Whitney down at West Palm Beach [Florida] developed an injector using liquid hydrogen as the fuel. They say why use liquid hydrogen. It is for performance. It is miles per gallon, in the case of your car. You get about forty percent increase in performance because of the molecular weight. Molecular weight of hydrogen is two, so it gives a much higher performance. The downside is you have to deal with a cryogenic that is minus 400. The only thing colder than that would be liquid helium. We learned how to solve those problems.

We had to design an injector to get the combustion process going, had to use the hydrogen to cool the system. In the chamber, we have five thousand degrees. What we want to do is convert that temperature to velocity, which gives us thrust. The thrust comes from the high pressure in the combustion chamber. You had to deal with combustion dynamics. That is a big issue. The bigger the engine, you get into what we call combustion instability. Let me use the analogy in your car, sometimes you turn the switch off and it does duh, duh, duh and stops. I call that combustion instability because you have residual gas in the combustion chamber in your car. In a rocket engine, it is very similar. The bigger the engine, the more pronounced that problem can

be. It has high frequency vibration, both tangential and circumferential, and it can destroy itself in milliseconds.

We had to deal with that problem in the early days on the F-1 engine. One and half million pounds of thrust, we were blowing up engines trying to figure out what to do and how to do it. This was in the early days. We did not have a lot of analytical tools. We were still using slide rule in those days and mechanical calculators. We tried to bring in the best team that we could. One of the guys that worked for me, Jerry Thomson, I set him up for an ad hoc team from the government side with our contractor. His key was at Rocketdyne, a guy named Paul Castenholz. Jerry on his team, Dr. Luigi Crocco from Princeton University were probably the world-leading authority, another doctor from Lewis Research Center, a Richard Priem, they were experts in terms of analysis and these things. We spent over thirty million dollars in something like a year trying to solve that problem.

We learned if we could just put compartments in the combustion chamber and have to deal with that, then we could break up these high frequency vibrations. It was smaller compartments, in other words. We had to keep a lot of flow coming in from the propellants to keep it cool . We were able to design with our contractor and ended up with a system we call the kitchen sink injector. Why? Because we tried everything in the

kitchen, thinking about the recipe and what you might do. We still use that as a colloquialism, if you will. If you look some time at the [U.S.] Space and Rocket Center, you can see the injector, the design. How did we know that would work? We took a bomb and insulated it and set it. We would set it to a specific time to see if it could set off vibration oscillations. Sure enough, it would dampen or attenuate the vibration. That is how we solved the problem. That was probably the biggest problem we had in the early days on the F-1 engine.

The other big problem was development of a high pressure oxidizer pump, liquid oxygen. The fuel was not too bad, but we were blowing up pumps. Liquid oxygen is very dangerous if you get around sparks. You cannot have sparks. You have to be very careful about what you have in there. You cannot have rubbing in a pump because it will go critical in a millisecond. We blew up a lot of pumps. We did a lot of these tests here at Marshall. We did a lot of the tests at Edwards Air Force Base. We had a facility out there in California. We had people on the road. We had to analyze the data, always had a lot of data, instrumentation, had a lot of high-speed, and we spent a lot of time looking at records. Back in those days, we had to do a lot of data reduction and analyze that, look at the parameters, chamber pressure, temperatures, vibrations. We had a lot of accelerometers to look at vibrations.

The biggest problem we had in the early days was the liquid oxygen pump on the F-1 engine. Likewise, the combustion instability, which we were able to solve through trial and error, because we did not have the analytical tools. There were some other issues because we had big valves. We had to develop valves, components. We had a lot of big components on the engine and we had to deal with the propulsion system. You had to go form the engine up to the vehicle, the tanks, to get the propellants out of the tanks into the engine. We had valves there we had to deal with. We had to design those valves. We went to other contractors for those. We had redundant contracts, the same thing with a lot of the flex lines.

Another thing you get involved in when you start clustering the engines, you had to be concerned about interfaces. You had to be concerned about the cross-talk in terms of fluid flow, fluid dynamics. You had to be concerned about base heating because the gas coming out from one engine effects the others. In addition, we had to work on what we call thrust vector control system. When the whole bird flies, there are four outboard engines that actually steer the bird as it goes up hill. We do that with hydraulic actuators and it gets the intelligence from the brain, which is in the Instrument Unit. It is all preprogrammed up there, and you had the gyroscopes and instrumentation, telemetry, and all that. It goes with the whole vehicle. It is all preprogrammed, nobody is pushing buttons or anything. We were just saying our prayers, watching it, and

looking at parameters as it flies. We tested all this on the ground because we did full-up static firing of all five engines, we did the cluster, single engine first then do the five engines.

Johnson: Did you have to develop any new tools or come up with new materials while you were in the middle of this process?

McCool: [There were] a lot of new materials. You had to deal with several things. With kerosene, you get into what you call coking, and that can cause problems. You had to get some new high nickel alloys to deal with it in the combustion chamber. You had to be concerned, like I said, with the liquid oxygen pump where you had to use materials that you did not get any sparks. Another concern was when you get into the tanks where the propellants were. You had to be concerned about the corrosion problems. A particular thing where you have stress corrosion, that is where you have unlike materials and it can set up by itself stress and stresses that you cannot predict what is going to happen to them. You had a lot of things to do in terms of that. The big thing is during the component test, we were doing valves or testing the engine in a test stand to see how it is going to perform, and then we would inspect it. We would look at all the records and everything, like I was saying earlier, once you start clustering. That is the first stage engine. The second stage engine was different.

Johnson: Were there different challenges with those engines?

McCool: You had different challenges. Why? Because you were using liquid hydrogen. Liquid hydrogen is minus 400 degrees. You had to provide insulation, and the second stage had insulation on the outside of the tank, very similar to what we have today on the hydrogen tank for the space shuttle. It had insulation on the outside. Why is that? Because you have ambient temperature. You have 400 degrees inside and you do not want that stuff boiling off. The third stage had the insulation on the inside of the tank. We had different contractors helping us with that. We had to deal with that. We had to deal with getting the propellants out of the tank into the engine so they get back to the valving and so forth.

We did not have the combustion instability problems like we had in the first stage engine in the second and third. We ended up putting baffles on the Space Shuttle Main Engine, but we never did put baffles on the second or third stage engine. We did not have the problem. I think what it is when you are dealing with hydrocarbon, you get coking and you get other problems. You do not get 100 percent burning and you get a lot of smoke when you look at the exhaust plume. It gives you problems. In hydrogen, you end up with steam. When it burns with liquid oxygen, you just get steam, so you do not have the problem of the hydrocarbons. In other words, the coking buildup and a

lot of the smoke. What it does is residual stuff and can lead to this combustion instability that we were talking about. That was a big issue.

Developing all the components, working with our contractors, was a big issue. Not the contractor, per se. They had a problem. Let me get into that one. This is 1967 and Douglas [Aircraft Company] was our third stage contractor up in Sacramento, California. We thought the engine and everything had blown up. Nobody was there, nobody got hurt. A bunch of us went out there, von Braun was with us, and we went to Van Nuys, California to meet with our contractor, Rocketdyne. We thought the engine blew up. When it blows up, it wrecks everything. One engine has 200,000 pounds of thrust. We went up to Sacramento and talked to Rocketdyne in California and flew up to Sacramento to the test stand. What a mess. It tore up the test stand, parts everywhere.

It turns out it was not an engine problem. It was a high pressure sphere made out of titanium and contained high pressure helium, 4,000 psi. They had used the wrong well wire. When you get a high pressure gas like that blow up, it is very dangerous, like a bomb. I did not have to head up that group, but I went out to that, von Braun and a bunch of us.

As a side note, let me mention a humorous story to that. We were coming back on a Jet Star, a Lockheed plane, that his friend, Kurt Debus, who was director at Kennedy [Space Center], had leased with Lockheed. He had him bring the plane up here, and von Braun and six or eight of us flew out. Being a propulsion guy, I am looking out the window, I had never been on a jet, there are two pods on either side and they had a Lockheed crew. I asked the attendant what the thrust of those engines was and he started telling me. He went off and did not come back until fifteen, twenty minutes. I gave up on him.

Next thing, I look up where the cockpit is and there is von Braun standing there and he is looking at me with a big grin on his face. He did not say anything and this guy handed be a brochure. On the last page in there is a certificate that said my name, Alex McCool, did fly to Sacramento, California, air speed so and so, altitude so and so, Redstone, and signed by Wernher von Braun. The pilot, he had been sitting up there, and he had not been qualified to fly as a pilot. I thought that was funny. That is why he gave me the thing. Anyway, that was a sideline story, but it reminded me we did have that problem.

You go to the second stage, we had a problem trying to get it built. This is during the Apollo 1 days when we lost the crew on Apollo 1, which is 1966, 1967. We lost the three

astronauts on the pad. We had nothing to do with that. That was a problem in the capsule, a short, and they were in a pure oxygen environment. They got killed in the capsule. I had been going out to Downey [California] for months working on the second stage. Let us call it S-II-T, being T-bird. We wanted to get it built and ship it to the Mississippi Test Facility [now Stennis Space Center] and put five of those J-2 engines. This was a big milestone for Washington [Distract of Columbia]. They were really tracking us. I had a team of guys out at Downey and spent months out there. It was at the same time and this was the same contractor, by the way, North American, building the second stage that had the explosion.

Dr. [Eberhard] Rees, von Braun's deputy, he was involved in the investigation on the accident. He would come out from time to time and I would see them. I had nothing to do with that investigation. My job was working the S-II and getting the hardware built. To make a long story short, we were finally able to ship the thing from Seal Beach [California] all the way through the Panama Canal to the Mississippi Test Facility, come up the Pearl River from the gulf to our test site down there. Then I went down there and spent a bunch of time there getting it set up. We had what we call travel work. They did not get it all built, there were still a lot of valves, a lot of components. We had some real tough problems to deal with then.

We got a few full duration tests of the five engines for the second stage, but this was important because we wanted to know how they operated with four other engines. Then what happened when they were doing an ambient test down there, they failed the tank. What had happened, when you have hydrogen, then you have cryogenics, the metal get stronger at the lower temperature. This is ambient, so the whole stage ruptured and blew up.

I was sent down there with another. I had to go back down there. I was not there when it blew up. I had to go back down with a team to investigate the problem. They had some well repairs where the fill and drain hydrogen tank came to the tank. They used what is called a come along to get it stretched up there to where the bellows are and everything. It put some loads. We were able to go back and look at that weld and sure enough, it was not a good weld and that is what failed the vehicle. In building the tank and everything, I guess as I moved up in seniority, I ended up getting a lot of these jobs, heading this up, heading that up. I got a team and we would all go and spend months working the thing. That was on the second stage, the vehicle itself. It did not have anything to do.

We got ready to fly all three stages, I am changing subject, on the whole Saturn V, this was Apollo 6, I believe. It was not manned, but it was a full stage. It was going to go all-

up. Everything would burn, but nobody on it. What happened with the first stage when we flew is the center engine shut down, but as it was getting ready to shut down, we saw some longitudinal oscillations in the first stage, which we call pogo. The concern was the crew. They were not on there, but when you get moving, it gets worse, especially when you fly into space. In here, you are worried about it. We had to deal with that, what we call pogo, in the first stage. Let me come back to that in just a second. We had to find out what the problem was and fix the problem, certify it.

Second stage, we had a similar kind of problem as oscillation. It was in the hydrogen line that came into the J-2 engine. Inadvertently, one of the engines shut down. We had temperature measurement and all, but we saw a real low temperature, which meant we had a hydrogen leak. It inadvertently, because the wires were crossed, shut an adjacent engine down. We did not meant to do that, but it shut it down. The vehicle burned longer as it was going up because it had to carry the third stage to orbit.

The third stage ignited, same engine, and worked well and they shut it down over Australia. Then they reignited the engine. It would not reignite. Sure enough, it was exactly the same problem. To make a long story short on that, we were able to test that in a vacuum chamber. The line is a little bit bigger than my finger. There were bellows in there and you were getting oscillations. The analogy would be like a chimney, you

get vortices coming off that when the wind blows on it, or a bridge. I could show you a picture of the Tacoma Narrows where you have a force in frequency and it resonates with natural frequency. That is what happened with the bellows. How did we know that? We ended up taking that same line and putting it in a vacuum chamber here at Marshall. Inside there is no air liquification to get around the line, which is what we were getting on the ground. Why? Because the air and hydrogen inside, the ice attenuated the oscillation and it could not vibrate on a test stand. We put it in a vacuum chamber and it failed. We got rid of that thing and put in a braided line. That is how we fixed that. We did tests and everything in the vacuum chamber and it was all good.

The first stage, how did we get rid of pogo? We had seventeen inch prevalves upstream in the engine and there was a cavity in there. We found out we could pre-charge, put some helium gas in there, and all that did was attenuate the fluid flow. That is how we fixed it. Come a little later, this is getting ready for Apollo 8, we had a big meeting out here and I was heavily involved in all the propulsion stuff to show what we had done, how we verified it. They brought a guy called Donald Douglas, he was the president of Douglas Heating and Air years ago, von Braun, all the Washington crowd, everybody was out here at Marshall. "What do we do on the next mission? Can we fly," number one, "with people?" We agreed yes, let us go do it.

In the meantime, George Low had suggested looking at what the Russians were doing and looking where the Lunar Module is schedule-wise. He said, "Let us go around the Moon." This gets back to that story I told you about von Braun recommending to LBJ [Lyndon B. Johnson], Vice President Johnson, that we could beat them to the Moon. They decided on Apollo 8 to go around the Moon, but it was predicated on showing how we solved the problem and did we really know that we had fixed it. The first time we go manned, to send them all the way to the Moon, three days out, three days back, 300,000 miles away from Earth, escape velocity going 25,000 miles an hour. I was involved in all of those problems, solving those problems, and then convincing our leaders, our management, why and how we could prove, by test, by analysis, that we are okay to go fly. We flew all those Saturns and had no problems like in the case of the shuttle where we lost two shuttles.

Johnson: You have done so much work and so much testing, which you have been describing. How fast did these things have to be accomplished? Was there a time constraint? Were you always thinking about how long things were taking?

McCool: Congress was tracking us. They had milestones we had to meet at certain times. Like I was telling you about the second stage of the Saturn V, that T-bird, we had to get it shipped down there and start getting ready to test. In fact, when von Braun

came down there, Jack Balch was center director there, and he had a highway patrol that landed to escort them up to the test site, highway patrol from Mississippi, Louisiana coming up there. It was a big joke. Once they got there, they had to wait on the countdown. We were busy, busy, busy, with milestones we had to meet.

Johnson: You were being thorough, but you were hurrying?

McCool: We had to hurry, yes, we had milestones to meet. The other part is the many days and days and days being away from home on the road. I think I made thirty something trips in one year.

Johnson: Did you work long days?

McCool: Oh, yes, long days. Everybody was so caught up in it. It was so interesting, the team and everything, that you did not even look at the clock. You did not think about taking leave or doing some things and you really neglected your family. I think back on it, 1972, my son graduates from Grissom [High School] and I am at JSC [Johnson Space Center] on a Source Evaluation Board with Houston [Texas], helping them down there. I did not come home for his graduation. It does not bother him, but I think about things we did back them to put the job first, long hours, lots of travel, a lot of time on the road.

In fact, I think some of the worst places, particularly, were at Kennedy Space Center, the mortality on marriages and everything, long hours. I would see that when we would go down there and work with them, the long hours they would do.

Johnson: Talk about the work environment. You worked these long hours and it put pressure on families, but when you were at work, what was the environment like?

McCool: It was interesting, you were always trying to solve problems, you were trying to see results from the testing and everything in terms of design or trying to solve the problem. You were caught up in that, the team. It was just like the guys over in Iraq and Afghanistan, working with your buddy, looking out for him and he is looking out for you. It was the same thing with us because we had teams having to depend on each other. You did not want to hold them up, they needed some analysis or numbers from you, performance and so forth. You were always working and caught up in that, team spirit. Really, von Braun is the one that encouraged that. He was the orchestrator.

Johnson: I realize this was a time when NASA was flush with money, but did you have to do things to control cost? How did you control cost?

McCool: No. To tell you the truth, I never did get involved in those days with costs. For example, a lot of components, to be sure, are critical combos we had to have, we had two contractors doing that. We had a dual source, so we had plenty of money to have two valve contracts for the big, seventeen inch valve. Nobody had ever built components like this before. We had to do component testing, had to design, had our people going back and forth to different contractors. We had sufficient money to do that. Like I told you about the problem on the F-1, we spent, back then, $30,000,000. You back in the 1960s and extrapolate that today, do the math, probably a billion dollars just solving the combustion instability problem. We had plenty of money.

Johnson: How about dead ends in the work? Did you have dead ends where you would start down a path and it would not work out? How did you recover from that?

McCool: We did a lot of that in the case of the instability in the F-1 engine. You would try this, try that, you would get kind of discouraged sometimes, have an idea and try that now. This is what it was, cut and miss. In other words, you would try something and you could predict. I am not even sure today you could have an analytical tool, we are better off today with high-speed computers, computation fluid dynamics, and all that. We were still using slide rule and Mershon mechanical calculators in those days, same thing as our contractor. We did not have a lot of the tools we have today, the high-

speed. We ended up getting a Univac and some of the IBMs [International Business Machine] later on, but we did not have the analysis techniques to do that. It was work, work, work, try this, try that, trial and error a lot. Of course, we learned a lot from the Germans in what they did in terms of design, how they solved a lot of the problems.

Johnson: Were there surprises? Were there things that happened that surprised you?

McCool: I think so. I think we had a lot of disappointments and failures. Components would fail that you did not predict, like I was describing the little bellows a minute ago, and a line. You did not think it would do it, but that is nature. You are dealing with nature because we tested on a stand, it was minus 400 degrees, and this air goes to ice. The air just liquified and that would attenuate, would not let the thing move. That was a surprise to us. In the case of the line a little bit bigger than my finger, there was ice, it would oscillate, and broke and spewed out hydrogen. That could be bad because you have flame and could wreck the engine in a hurry, wreck the vehicle.

Johnson: Would you say the testing was to find out what the surprises were?

McCool: That is right, absolutely. There is only so much testing you do and can hope to do, but you still have to fly. When you start flying, there are some things you cannot

simulate on the ground. You try to anticipate all these things, and in addition, you put a forty percent, 1.4, safety factor on top of the unknowns. On the well-defined things, you try to do the best you can, try to test for it. If you look at the tall structure out there, the tallest one, used to be, in the state of Alabama, that is where we did the ground mated vibration tests. We did those tests to try to understand the vehicle. We would shake the vehicle in simulators, on mechanical shakers, a lot of instrumentation, and stay away from certain frequencies. You had to control the vehicle as it flies and you wanted to be able to control it at a certain frequency that resonates with the natural frequency. That is what they did structurally. I was not involved in any of that, but it is a similar kind of analogy when you talk about fluid flow.

Johnson: How heavily was Dr. von Braun involved in your work? Directly or indirectly, was he keeping a close eye on the work you were doing?

McCool: Yes, he was very concerned about the combustion instability issue. We had a guy in Washington, a key guy came from Lewis Research Center, and he worked in combustion dynamics when he was at Lewis. Lewis Research Center [Now Glenn Research Center], they were one of the early NACA [National Advisory Committee for Aeronautics] facilities in Cleveland [Ohio]. He said that injector, being that big, you will never get it to run stable. We kept trying our contractor and so forth. We got it to run

stable, but von Braun was very concerned because it was holding us up. We had to solve that problem in order to get the engine all together and not blow them up and wreck test stands.

Johnson: It is safe to say Dr. von Braun was talking to somebody in your area all the time?

McCool: He was always involved. We had meeting and we would have to come in and prove what we had been doing. Like I was telling you before about Apollo 8, we had meeting after meeting after meeting. He was following all of these problems where we failed on Apollo 6. I was telling you about all the problems there, pogo and so forth. We had a lot of discussion amongst ourselves and he would participate in those. He would ask very penetrating questions. Then he would look around the room and ask for others' inputs. He was kind of orchestrating a lot of that. He did not get into details of design. He would come around sometimes. We had big drawing boards, all as big as this table, six feet by. Those guys who worked, that is what they did in those days. Today you use computers. They would have drawing boards up there with a parallel bar. He would look at it and say, "Why do you not do this? What are you doing?" The guy would nod to him and say, "Yes, sir. Yes, sir." He said, "Try this." He would say,

"Thank you, Dr. von Braun." He would walk off and they would forget about it. [Both Laugh] He would look at the drawing and want to know what they were working on.

Johnson: I want to ask you about the differences between Marshall and the things you did in the other centers. I am not sure how much you had to do with the other centers, but were there rivalries? Was it a rivalry thing or were you guys pretty much just doing what Marshall did?

McCool: It really was when you got to shuttle.

Johnson: Let us talk about Saturn V. Did you have much to do with other centers during Saturn V?

McCool: Mostly KSC [Kennedy Space Center]. We did not have a whole lot to do with Houston, I did not. There was a certain amount of rivalry, you are right about that.

Johnson: Did you ever notice jealousy from another center about what you were doing at Marshall or were you guys basically doing what you did?

McCool: No, not people I met. It would be propulsion guys and I had good friends down there and we worked with them. They would review sometimes, help us. They worked in propulsion. In fact, Max Faget, if you have ever heard that name, he was kind of chief engineer, I was on his original team at Langley [Research Center] when they designed the Apollo. He headed up the propulsion team. We worked very well with them. He was glad to get our inputs and everything.

Johnson: I guess what you are saying is that, basically, the centers had no problems working together in the Saturn days.

McCool: No, at least not from my viewpoint.

Johnson: Talk about the integration of all the different parts, the projects designs and all these things when they were finally put together. Did it all fit together as you expected it would?

McCool: Yes, it was very close. The engineering was very good from the NASA side and working with the contractor engineering, very good. If you go back to the early days, we had designed the first stage ourselves inhouse. We were down at the HIC [Huntsville Industrial Complex] Building, because that was the early days when

Kennedy was assassinated and then Boeing was brought onboard. We had all the design, everything was done, and we were heavily involved in the propulsion systems. All the documentation was done by our people. I think we had some contractors help us in that, Teledyne Brown was here in those days, and it worked well, us getting all that done, and it fit well. Boeing came onboard, they took our drawing, and they put their name on it. It gets built and eventually they take over the construction and starting New Orleans [Louisiana]. Of course, we built the thing in our shops to start with, integrating the engine and the vehicle and all that stuff for the first stage. That worked out well and things fit together well. We did not have any misfits or problems like that. The engineering came together well.

Johnson: Describe the contractor experience. How was the contractor experience on the Saturn Program?

McCool: Some of it was rough in the early days. Eventually the contractor wanted you to just give them the job. Von Braun and the government team at NASA felt like this was us, we were responsible, ultimately, especially for the crew and all. They just wanted you to give them the documentation, the contract, and leave them alone. Little by little, we had to establish credibility to show how we could contribute to them. I never will forget to this day, that was later on on shuttle, I was spending time at

Rocketdyne, but they accepted us. We spent months out there with them with our teams to work with them, to help them. They saw we could make contributions. I can get into specific kinds of contributions that we did, especially later on when dealing with Pratt & Whitney. This is, of course, on shuttle.

Johnson: Essentially the contractor experience as you were involved was a good one?

McCool: It was a good one. We worked very well. They accepted us. We had to establish ourselves and show we could contribute. We were not there looking over their shoulders trying to play gotcha. That was the first thing, we had to establish ourselves and our credibility so they would accept us. It worked out well, so it was wonderful. NASA could not have done the job period without the contractors. I do not mean just the primes, I am talking about all the way down to the mom and pop places making power techs and all these other components we needed, you name it. There were millions and millions of components we are talking about, you think about nuts and washers and lock washers, all that stuff. We worked really well with the contractors. I did not get involved in the cost stuff. I was not involved a bit, only the engineering.

Johnson: How about NASA Headquarters? During this period, the Saturn Program, did Headquarters help or interfere in the development process?

McCool: I think they helped a few times, some of the bosses. I did not have to go up there and argue anything. They had to go up and argue, some of the Germans. I remember one time Hermann Weidner, I was kidding him, he said, "Call me Hermann." He worked in propulsion specifically and he was going up to talk to [Adelbert O.] Dale Tischler to get some money. He had his pocket knife out. He did like that with the blade (Gestures) telling me he was going to have to deal with Dale. In other words, I knew there were going to be some strings. The Washington guy, he was the guy calling the shots. That was a funny issue he was trying to get. I think it was more in the technology area with Weidner. I did not have any problems in that. I had problems later on in shuttle, but not in Saturn.

Johnson: Headquarters, generally speaking, was okay during the Saturn Program?

McCool: It was to me. Then we got good support from places like Lewis Research Center, other centers. Langley helped in terms of structures. Lewis helped us in propulsion. Like I was telling you, Dr. Priem, he helped us in the dynamics. We had another guy that worked in the pumps. [They were] excellent people to work very close with. They helped us. They had a lot of analytical tools they had developed.

Johnson: After all this work, all this testing, how did you feel when the Saturn V finally flew successfully?

McCool: Apollo 8, to me, was important. Why? Because I was describing the problems we had and we solved all those problems. They decided to go because the Lunar Module was behind and based on the recommendation by von Braun. To see that thing be able to go around the Moon, to me, it was a divine experience. Why? Because they read the Bible Christmas Eve, Frank Borman, the guys, they read from the creation account. I have a copy of that tape where they are reading. When I think about being able to go that far in three days, almost 300,000 miles, that was a divine experience for me. Apollo 8, to me, was the one. Like I told you earlier, we had Apollo 6 with the problems, come along with 8, now we had two more, 9 and 10 before 11. 11 for sure is important because they get out and walk on the Moon. I did not have anything on the spacecraft, I had all those engines. [It was] a big part of my life and to this day, gives me goose bumps. I am thinking about them right now.

Johnson: Did you sense in the Saturn days that you were making history? Did anybody ever talk about that?

McCool: No, we talk it now, Steve, we look back and say we made history. Think about what you did. We were a part [of that]. I was thinking about that, being part of history, but knowing twelve guys walked on the Moon, guys, no women, unfortunately. We have women flying now. When you think about that and what it took to do that, that was a heck of a commitment. When you think about when he committed us, May 25, 1961, all we had done was go up and down with Alan Shepard. To be able to do that in eight years, this is 1961, eight years when they landed on the Moon, 1969, July. Then we got another mission later on that year.

I was not down there for 11. I was down there for 12. My wife, two other couples, we all went to church. We flew down and my sister-in-law, they were in Saudi Arabia, they had a house down there. We stayed in their house on Merritt Island [Florida]. It was raining that day on Apollo 12, and that is when lightning struck, scared us. One of these guys we were with, Bob Williams, we were parked on the north side of the road, and he wanted to go up to the VAB [Vehicle Assembly Building] where [President Richard] Nixon was and shake hands with him. He came back and he was wet. He had no umbrella, nothing.

Johnson: You can still feel the pride?

McCool: Oh, yes, I tell you. That is why I am glad to talk about it and talk about the team. That is why I volunteer at the Space and Rocket Center. I will be out there tomorrow. I have a crowd of thirty coming up here from Oneonta [Alabama] and some local people here that I am going to take on a tour Tuesday afternoon. I talk to Space Campers. I have talked to old guys my age who come to Space Camp about what it is about, keeping it alive.

Johnson: We know how much recognition Dr. von Braun and the German rocket team received as the leaders of the program. Did the rest of the workforce receive the recognition it deserved? Do you feel like people like you got the recognition you deserved?

McCool: Yes, we did. It is like von Braun said, "I always get the limelight. When they talk about Wernher von Braun, put your name there." That is what von Braun would tell us. He would be giving a speech. He is the one getting all the recognition, but he was the coach. He was the [Nick] Saban of [The University of] Alabama. He knew we had been the one. It was the team and he was the coach. He was the Saban, if you will, of the Apollo Program. He was involved in all of that. He was not involved in shuttle.

Johnson: Was the teamwork feeling strong at Marshall during these years?

McCool: Absolutely. You have to give him credit first because he was orchestrating all of that. He had his lab chiefs. My first lab chief was named Dr. [Adolf K.] Thiel. He was one of the original eighteen. He left to go with GE [General Electric], I think it was, and Dr. [William] Mrazek, we got recognition from them. They would come talk to us and were always putting us in for some kind of award. There was wonderful team spirit. A funny thing, Steve, I do not want to mention names, but they were different to themselves. Von Braun was close to his board of directors. I saw him throw a cardboard cigarette package across the conference table on the tenth floor and hit one of the other Germans. He was fussing at him, not mad, but he did that as playful.

There was another time, this guy was taking me out to the Test Lab, one of his key guys and one of his subordinates came up to the truck, and he started talking to him. He was talking down to him and cussing. He was talking in German, but I heard the cuss words. If it had been me, I think I almost would have had to take a poke at him. They were different to us. They never treated us that way, but they had this caste system, if you will, amongst themselves. His board of directors, there were ten or eleven of them, he was very close to them. When you get down in the bowels of the organization, it was different depending on who you talk about, not with von Braun, but with some of the leaders.

Johnson: Did you feel like your individual contribution was valued?

McCool: Yes, absolutely, I do, always. My last boss was Hans Paul. I remember going to his office one day, I do not know what it was, I kind of had the blues about something. I called him Mr. Paul, never called him Hans. When I walked in he was drawing. I asked what he was doing and he said, "I am writing a little Greek, writing a little Hebrew." Hebrew is like Arabic. It is right to left. Of course, Greek is left to right. This man knew all kinds of stuff. He was an engineer and was trying to simmer me down. He said, "Mac, do not worry about it. Think about how lucky we are. I have been through two world wars, I lost everything I had." In the first war he lost his family, all his possessions. "Here I got another opportunity. I still had my degree and was able to start over."

He kind of encouraged me. I thought about that. He had been in my house and I had been in his house when we moved here in 1963, 1964. He died several years ago. His wife was very intimately involved at the botanical garden, Inga Paul. She wrote a book out there on flowers and stuff like that. He was really good to me and really touched me. I would always call him, he was Mr. Paul, and had another one called [William] Schulze, he was his deputy for a while. William Schulze, he lived on a hermitage. He is dead, all of them are dead but the four that you know about. They were good to us,

always good to us. Not just McCool, but the others. I could see it. They could be rough on some of their subordinates, what they would do, depending on the people you were talking about. Von Braun was never that way. He was joking throwing that cigarette box. They allowed smoking at one time. They had smoking on the tenth floor.

Johnson: Compare the challenges faced in the Saturn Program with what you faced in the Shuttle Program. I understand you were not developing as many new things in shuttle as you were Saturn.

McCool: No, we were developing a new concept. We sure were. The Germans never cared for solid rocket motors. They called them powder rockets. We were dealing with that, had to do the two Solid Rocket Motors. We ended up with that after. I was involved from 1970 to 1972 in the Space Shuttle Task Team. I was a propulsion guy and was detailed to them. We had a task team that was under [William] Lucas in those days in Program Development.

Johnson: That was Bill Lucas?

McCool: Yes, he was the head of Program Development. As a part of that, he had a manager called Roy Godfrey. Roy was our guy. We had some difficult problems between ourselves and Houston. Why? Because of the leadership.

Johnson: When you say you had problems with Houston, it sounds to me like there were some center rivalries that interfered with the Shuttle Program.

McCool: It was, but it was more than that. I think it was the personalities. I hate to mention names. Once we got into the contract business, you got into shuttle, but we got a new leader, and that was Bob Lindstrom. He took over. Bob Lindstrom, I know him really well. He was the manager for the elements we had, all the propulsion elements, Solid Rocket Motors, Space Shuttle Main Engine, the big tank. The orbiter was all Houston. They had another guy at Houston, his name was Bob Thompson. You have probably heard of our Thompson, of [James R.] J.R. Thompson. He got the initials J.R. to keep the two separated when we first started out. That is another story and I will not bore you with that. I hired J.R., by the way, from Pratt & Whitney, good guy, sharp guy, good friend.

We had some emotional problems. Let me give you an example. We created a lot of it ourselves. We invited them up here and gave them a tutorial on aerodynamics. Now,

who knows aerodynamics better than Max Faget? If you look at the heat shield on Mercury and Gemini, that was his concept. When you think about aerodynamics, you come in the atmosphere at Mach 25 or whatever. They come up here and we get all our guys to give them this [presentation]. That is just going out of the way, I think. That was bad, in poor taste. I was not involved and I went to the meeting, but it was things like that that we had. There was a personality conflict between our manager and Bob Thompson, who eventually ended up being the manager of the shuttle in the early days like Lindstrom was for our elements. They worked together very well.

Johnson: It sounds like there were some differences as far as the attitude in the team build than maybe was not there for the Saturn V. Is that an accurate way to look at it?

McCool: It worked better in Saturn. Some of these are new people that have come into the shuttle from Houston and even here. We had new people that were involved. I think a lot of it was just personalities. They worked very well with us. They kept a close eye on it. For example, when we had to put the Space Shuttle Main Engines, they always had people around, what our problems were and how we were dealing with problems. There was testing we were going to do at Stennis where we had a cluster of three before we flew. All that other hardware was their hardware. In the feed system, we worked real close with them on the feeds to the valves and the size of the ducts and

all that. It worked pretty well. Lindstrom had taken over by that time, so we were able to work better with them in the propulsion systems area.

Then we had different people take over in what we call propulsion systems integration between us and Houston. In fact, the guy that was the chair of that, he passed away, Charlie Wood, several years ago, to work with the propulsion guys at Houston. It did work better, the system standpoint, but they would always work very close with us. To this day, I think there are bad feelings, particularly since we lost the *Challenger* crew. Some of the crew people blame us.

Johnson: By us, you mean Marshall Space Flight Center?

McCool: Marshall, yes, blame us because of the loss. Nature was telling us things. We were getting leakage and everybody said it was self-supporting and was not going to get any worse. Let us go fly. That is the leadership, in particular, our leaders. Of course, eventually they blame us, and rightfully so. All of us feel bad about that problem on *Challenger* because eventually it did leak. What happened when you light the two Solid Rocket Motors, first it is the SSME [Space Shuttle Main Engine] at T [Time] minus six seconds. It is asymmetrical and the vehicle actually moves twenty-one inches. It rotates over and you fire the three engines. It does that, and when it comes back, the two

motors have to light off and then it goes. When it did, it unseated the O rings between the segment and it spewed 5,000 degrees hot temperature into the hydrogen tank. We have high speed film that saw it. That was later on, we did not know it then that we had a problem with the O rings leaking. It turned out in January of 1985 for the DoD [Department of Defense], some of us were down there, and sure enough, we saw one. We get the segments back and one of our guys would be there when they disassembled it and look at the O rings. They are a little bit bigger than that pen. Sure enough, we were getting some erosion because it was really cold. In fact, in the motel we were staying in, there was ice all outside. That was January a year before.

Johnson: The *Challenger* would eventually go down because of this problem. If there is anything to take away from all the things you had to overcome in the Saturn V and the problems that would dog the Shuttle Program, is it in your mind as a veteran that this is all inherent in doing something as dangerous or complicated as space flight? Is that how you would put it?

McCool: It is, Steve, because you try to do everything you can. A little while ago when you were asking the question were we under pressure to go fly, go fly, go fly, that was the pressure, no question, with shuttle. We should have said, wait a minute, time out, let us go look at this and see if we are doing the right thing. It has its challenges, no

question about that. You are dealing with high temperatures, high pressures. In the case of the Space Shuttle Main Engine, you have 3,000 psi and you have pumps that have to get six and seven thousand psi. Some of those wells go just like that (Gestures), blow up.

Johnson: To sort of wrap this up, all the tests you have been involved with over your entire NASA career, do you feel like you did not figure out every single thing, but you did enough testing to make this complicated machinery work?

McCool: Yes, first it is analysis in the testing. In those days, particularly for Saturn, we did not have the high speed computers we have today and analytical tools. Yes, we did all the analysis and component testing, subsystems testing, and systems testing, which is what we were doing out here with the cluster in 1965, the five engines. We tested those successfully. That was a big milestone. We broke windows over in Decatur [Alabama] and we learned some things. The sound would go up and hit the clouds and come back down. You tried to do everything and learn, be methodical. There was a lot of pressure, get the hardware out, try to go fly, go fly.

Ultimately, you have to fly. That is what the business is about, but you want to do it safely. You try to cover all the contingencies, the ones you do not know about. The

temperature when we unseated the seal, no one thought about that. Hot gas came out in the case of *Challenger*. It is hazardous work. In fact, we are probably lucky that no more got [lost]. In the case of the Saturn IB sitting on the pad was Apollo 1.

Johnson: When you look back on all this, was it fun?

McCool: Absolutely. The challenge was the fun part. That is what we were all caught up in. That is why I stayed. I did not retire until I was eighty years old. I was having fun. I loved it. I loved the people, the team, the fellowship of everybody working together, sitting in that firing room down there, saying a few prayers. After *Challenger*, I met a good friend, Gene Thomas. He was the launch director on *Challenger*. He has quite a story to tell about that. We have had him in our church. He has moved just near Memphis [Tennessee], lives up here now. He has a son that is a minister. He went through some tough times. [General Forrest S.] Gen. McCartney was the Kennedy director at that time, and he had to do something to get him out of the launch director job. He met the crew, he knew all of them personally, really close. It really tore him up. I have his book and he talks about *Challenger*. James Thomas, they call him Gene. I met him when they put me in safety. I left engineering after *Challenger* to try to build a safety organization. He and I got real close. His family are wonderful people.