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

Ron Tepool
Interviewed by Steve Johnson
Location – Huntsville, Alabama – Date

Steve Johnson: I am talking with Ron Tepool, who worked at Marshall Space Flight Center from 1963 through January 1, 2012. He worked on the Saturn and the space shuttle, among other things. Ron, would you talk about your education? What prepared you to be in the space program?

Ron Tepool: My dad was a builder in Indiana and I used to help him. We were building a house one day, and it was a really nice house, and I asked, "What does this guy do? This is a nice house. How can he afford it?" He said, "He is an engineer." I decided to be an engineer. (Laughs) I went to the University of Evansville, got a degree in mechanical engineering. I went there on a scholarship. I played football at the University of Evansville. Some of my classmates were in the co-op [Cooperative] program here at Marshall Space Flight Center. I came down one day with J.C. Agnew [Name/Spelling?] to Marshall Space Flight Center and interviewed with the Test Lab. I then interviewed for a whole quarter when I was graduating from college and decided to come here and go to work.

Johnson: What kind of engineer are you?

Tepool: Mechanical.

Johnson: A mechanical engineer and you went to work as a test engineer. Let us talk about the challenges for a test engineer in the development of the Saturn V. You were responsible for testing the main engines, am I right?

Tepool: Testing engines for Saturn. It was the F-1 engine. We had two test stands here at Marshall Space Flight Center that were configured from the propellant tanks out exactly like the vehicle. They had vehicle suction lines, flight weight prevalves, all the hardware that went to the tank was exactly the same. We investigated pogo.

Johnson: Pogo, that is the fuel moving up and down and causing problems.

Tepool: Right, pressure oscillations in the feed system that generate a pulse that is equivalent to the natural frequency of an astronaut's insides. They cannot stand to go through this vibration, so you have to somehow dampen that out. We worked that. Basically, we were doing the development work for F-1 engines. The first three S-IC flight stages and the test stages were all built here at Marshall in the Apollo Program.

The T-bird, the dynamic bird, the structural bird, flight vehicle -1, -2, and -3 were all built here at Marshall. The T-bird, structural bird, and dynamic bird had fake engines on them for dynamic tests, for structural tests, things like that. A test bird had real engines. All those engines were developed by North American Aviation, Rocketdyne Division along with NASA [National Aeronautics and Space Administration]. They would ship them in here, we would fire them. We had to adjust the gimbal, the thrust, within sixth-thousandths of the center of the gimbal block. To do that, we would set the gimbal actuators on the engines, we would fire them, and then we would adjust those actuators and fire them again to prove that we were going sixty-thousandths of the center of the gimbal block. With the five engines, when you were gimbaling, you had to be able to point them exactly in the right direction to control the vehicle. Then we would put them on flight stages, we would fire the flight stage, and then ship it by barge to the Cape [Canaveral, Florida].

Johnson: The engines had been fired before they were shipped to the Cape?

Tepool: Yes, every stage that we have ever flown a man on, everyone, including the shuttle, have been tested on the ground, hot-fired.

Johnson: As a test engineer, obviously testing is what you do. Were there challenges to testing? You just said one of the challenges, but did you want stuff to go wrong, so to speak, so you would know?

Tepool: You do not want something to go wrong.

Johnson: No, but if something goes wrong, you want it to go wrong on the ground.

Tepool: That is exactly right. That is why you test, to wring out the problems. Some of them are very hard. Problems you would encounter due to zero g [Gravity] or altitude, they are hard to test for on the ground. Almost every other problem you can wring out on the ground, as far as your turbomachinery, how good it is, how tough it is, what its endurance is, how long things will last when you subject them to that kind of environment. Most everything you can test on the ground, unless it has to do with vacuum, being in space. You cannot check the flight regime because you have to hold it down to test it. We did test fly the vehicles before we put men on them, the total flight, but basically that is a test. That is what we did.

Johnson: For the Saturn V engines in the Saturn V Program, generally speaking, were they tough to make work correctly, or was the design so good that things did not happen?

Tepool: No, we had problems with rough combustion. To solve that problem. We put baffles on the injector. Then we would bomb it, make it go rough, and then make sure those baffles would dampen it out.

Johnson: When you say bomb it, you actually exploded something during the engine firing?

Tepool: Right, you screw a thing that looks like a shotgun shell in there. You crank the engine up, and then you electrically trigger that shotgun shell-like and blow it up. It makes it go rough for a little bit. The baffles on the injector would dampen it out. We had rough combustion. We had LOX [Liquid Oxygen] pump problems. We have always had LOX pump problems (Laughs), but on the Saturn on the F-1 engine, we had LOX pump problems. We had three development stands at Edwards [Air Force Base]. We had a development stand at Santa Susana [Field Laboratory]. We had two development stands here at Marshall. We probably blew up thirty engines.

Johnson Caused them to explode?

Tepool: Not on purpose. They exploded or a LOX pump went bad and they would burn up.

Johnson: You were testing them to their maximum limits.

Tepool: Right, we were testing them to max limits, gimbaling them hard, and things like that. That is the way you learn. When we started in shuttle, we had to go through that same type of thing.

Johnson: How many test firings do you figure you were a part of in the Saturn Program?

Tepool: I probably conducted 100, 150 tests myself. Then I became a branch chief and a division chief, and my people did that. When I was doing the test engineering, counting down and stuff, probably 100 tests or so.

Johnson: How exciting is a test firing? Those test stands at Marshall, just from the sound of what you did, were used a lot to fire engines. How exciting was that?

Tepool: It was very exciting. In fact, an F-1 engine burns 42,000 gallons a minute of propellant, seventeen of fuel and twenty-five of LOX. That is a lot of propellant flowing per minute.

Johnson: How long might you test one?

Tepool: They run for 150 seconds and generate 1.5 million pounds of thrust each. When we fired the S-IC stage of the Saturn V, we generate 7.5 million pounds of thrust, and we had to hold it on the ground while we were doing it.

Johnson: You are talking about the test in 1965 when you sort of rocked the whole town when you tested all the main engines?

Tepool: Right.

Johnson: What was that like? Anybody who lived in Huntsville in 1965 knew the town rattled, but what was it like being as close as I am sure you were?

Tepool: It depends. I was the engine man on the S-IC-T. They were my five engines and I had a group of technicians. The first test we ran on the S-IC-T we had all five engines

installed, but we were only going to start the center engine. Harry Johnstone was counting it down, Bob Sala [Name/Spelling?] was there, my boss was [J.H.] Joe Lundy, Wernher von Braun was there, James Webb was there, they were all in the control room. I was on the periscope looking at the main engines. Johnstone says, "Tepool, you know that purge ring you use?" I said, "Yes." He said, "I am not going to turn it on when we start."

Johnson: What is a purge ring?

Tepool: On an F-1, it was a hyperbolic start, which is when you push the propellant, when it touches air, it turns to fire. It is a hyperbolic start. When that hyperbol [Spelling?] would go into that chamber, immediately a big fire would come rolling out of the chamber and it would go up the sides of the engine, all the way up past the gimbal block, twenty, thirty feet in the air. It engulfed the engine. We built purge rings out of one inch stainless steel tubing, which had 1080 eighth-inch holes in it, fed it with 3000 psi [Pounds per Square Inch] GN_2 [Gaseous Nitrogen], and we would turn it on right before start. When that hyperbol would break, it looked like the engine was firing. That inert gas purge was holding the fire under the chamber.

Because we were only firing the center engine, the first time we had ever fired this stage, it had never been fired before, it was a brand new stage, it was the T-bird, the test bird. They were only going to tank less than a quarter of a tank of propellant, of LOX and RP-1 [Highly Refined form of Kerosene]. By doing that, that means your pressurization gas is coming in to pressurize those two tanks. You have a lot of volume to fill up because you have a lot of ullage. He was afraid he was going to run short on purge gas, GN_2. He said, "I am not going to turn it on." I said, "Okay." He said, "If you need it, you call for it." "Okay." He counted it down.

In the bottom of the S-IC stage where the five engines are hanging is two-inch thick asbestos in squares about two by two sheets that are bolted to the bottom. That is a heat shield. When you go up in altitude, the fire goes up there, and it keeps that metal from melting and tearing up the bird. Somebody had the bright idea that that asbestos is real porous and it would soak up moisture. They said we ought to shrink-wrap that so that it does not soak up moisture. Any moisture we had, we have to carry with us and that is weight. It was wrapped in a blue shrink wrap. You have seen these shrink-wrap packages when you buy something at the drug store. When we started, the fire came out of the bottom of the engine, rolled up, hit that blue shrink wrap, which I did not know what was going on, but it went white hot, so I cut it. I cut the very first test.

Johnson: You turned it off.

Tepool: I turned it off. I clicked my cut button. My boss comes walking in, flying down through there, "Who cut that test?" I said, "I did, but I will be ready to go in an hour." I took off. I walked out of the control room and all my support people were sitting out in the hall and they were giving me a hard time because they knew I cut it. I went out to the test stand, rolled the deck in. When you cut the engine, it ends up full of fuel. I drained the fuel out, put ethaline glycol in it, which is like antifreeze, in the chamber so you do not get a pulse shock when you start, put two new squibs in the gg, put a new hyperbol in the combustion chamber, rolled the deck out, and went back up the stand. We fired again.

It ran seven milliseconds longer than it did the first time because we had a program that said if one main fuel valve is open before the other one gets closed, it will but automatically because it was going to go unstable. It was a broken dish pan that caused that. We gave up that night. We went to the Officer's Club for a party. Since that was the first firing, a lot of the contractors were in town and were having a party at the Officer's Club. Dr. von Braun comes and gets me. The movie of the day was *Goldfinger*. He took me around to every corporate table and introduces me as the guy with the golden thumb of the test. That was my experience at the very first S-IC test at Marshall.

Johnson: Were test firings expensive?

Tepool: Oh, yes. It cost us another hour and a half that day.

Johnson: In any case, if you would have left it on, it would have.

Tepool: It would have been alright. It would not have cost us that hour and a half.

Johnson: You did not turn other tests off. This testing and looking for problems was a constant.

Tepool: Yes. People kind of treat things with a "if it made it through Test Lab, it was going to be fine" (Laughs) because sometimes you had to climb on it, you would have to do things you would not normally do to a flight vehicle. If it happened to your test vehicle, then. All flight engines were static fired too before they were ever.

Johnson: I think what you are saying is you were pretty rough with it on purpose. You did not want kid gloves there. You wanted it to show it would do what it was supposed to do. Did you have to develop any new tools or come up with any new materials during this test process?

Tepool: Our materials Lab came up with a lot of new materials during the test process.

Johnson: Your job was to test the new materials.

Tepool: Right. We had a group that tested the materials. I was in propulsion tests. We had a materials test group, we had a cryogenic test group, we had a components test group, we had a systems test group. I was in the propulsion systems test group. We tested engines, stages, bigger things. Of course, when we ran out of that, we would go help the component people or whatever. Our techs [Technicians], they were always making new tools. The Snap-on man came every week.

Johnson: Snap-on, like tools for automobiles?

Tepool: Right, the Snap-on guy, he came every week in his big truck full of tools and the techs would go get what they needed. If you are up on a test stand, you are seven, ten stories up, and you drop your ratchet, you cannot afford for a guy to go down the elevator, go into the bucket, look all over until he finds his ratchet, and come back to work. You just get another one and go to work. The Snap-on man came. Then there were a lot of jobs where the tooling back in the plant that built it was great, but if you

had to take it apart out on the test stand, it was tough. The techs were really good at making tools. They could modify an existing tool or go make one from scratch that would get the job done, whatever you had to do. We had a lot of that.

Johnson: I have heard stories of Dr. von Braun actually visiting a site or test stand and somebody saying they needed a tool and he would sometimes hand then the tools. Did you ever see anything like that?

Tepool: I have never seen that. Several times, he came to the test sites where I was a test engineer and I would tour him through them.

Johnson: How heavily involved was he in what you guys were doing, these constant test firings and stressing the equipment? How involved was he in what you were doing?

Tepool: Engineering-wise, not involved at all, but he was on his managers big time to get the job done, wring out the problems. If you needed something, do not be afraid to ask. I will go fight for the money. That kind of thing. He was at Headquarters a lot trying to get funds to do other things. A lot more testing could have been done, which would have raised your confidence level, but there was not enough money.

Johnson: Many people during the Saturn days would say money was not a problem.

Tepool: It was a problem. It was not a problem like it is now. It is always a problem, but not as bad as it is now or was in the shuttle years or the following years.

Johnson: Even in the Saturn V years, you had to worry about how much money you were spending on testing?

Tepool: You had to make sure you had enough to go do what you wanted to do. If you did not, you had to go ask for it. Then somebody else either had to not do something. There is only so much money allotted each year and you have to stay within those allotments to get the job done.

Johnson: You said you could have done more testing to have more confidence. In general, when we finally got to the point of launching Saturn Vs and putting men onboard, as a test engineer, if people asked you what you thought, would you say this thing is going to go great? Were you at that point?

Tepool: Yes, for the Saturn V, not for Skylab. We ran a test on Skylab that said it was going to come apart when we launched it, and it did.

Johnson: When we lost the cap.

Tepool: The panel, right.

Johnson: You knew Skylab was a problem. In general, up until that mission, by the time the Saturn Vs flew, you were confident?

Tepool: We were confident we would make it 150 seconds. Our job was to get it up there. We did not realize what JSC [Johnson Space Center] had in the Command Module and Service Module. We just had the first three stages to get them up there. We were confident we could do that. We had one J-2 cut off in flight where we burned up and ASI line, I think.

Johnson: ASI, what does that stand for?

Tepool: Augmented Spark Ignitor line. It was a propellant feed line for the Augmented Spark Ignitor.

Johnson: If it would have been up to you, if they had said, "Ron, what would you like to do," would you have tested more before you flew?

Tepool: Not in Saturn.

Johnson: What was the pace of work like during the Saturn days for test engineers?

Tepool: Let me give you an example. When I came to work here as a test engineer, the current minimum wage is about four times what a test engineer made when I came to work here, $2.56 an hour.

Johnson: That is what you were making to test the most powerful rocket ever launched?

Tepool: When I first came here, right, in 1963. I think the minimum wage now is about ten dollars, eight dollars. I was married and I had a child on the way. I bought a house here. I did not make enough money to pay the payments. Hunter and Mitchell is who I bought it from. They told me to make the construction loan payments and when I got a raise to come see them and they would close the loan. Go ahead and move in. I did. We worked enough overtime, we were working ten, twelve hours a days, and overtime on Saturdays. We rarely worked Sundays unless we really had to. We made enough money to do alright.

Johnson: To make your house payment?

Tepool: Right.

Johnson: What about the work environment? You are working all these extra hours, sometimes Saturdays, sometimes even Sunday. Was it fun? Did you not want to go in?

Tepool: No, we lived a dream here. We had a great work environment. We lived the dream up until [Barack] Obama came along.

Johnson: As a test engineer, were there dead ends in what you guys did?

Tepool: Yes. When we got done with Apollo, they started laying everybody off. They loaded up trailer truck loads of tools and hauled them out to these technical centers and schools. The state came in and got hundreds and hundreds of trailer truck loads of steel and aluminum ingots and took it away. We went to work on cold gasification.

Johnson: This is at NASA?

Tepool: At NASA at Marshall Space Flight Center after the Apollo Program. We got done, it was not after the Apollo Program.

Johnson: You were to the point where testing engines was over.

Tepool: We were done by the time they went to the Moon. We were done at Marshall.

Johnson: You had to do something else.

Tepool: We had to do something. Of course, when we got done testing the engines, we worked on the Lunar Rovers and the Apollo Telescope Mount, things like that.

Johnson: You were still doing testing?

Tepool: Right. We even did testing for cold gasification, gas refrigeration, those kinds of things, and then shuttle came along. Shuttle did not really get tooled up until about 1974.

Johnson: That was just before Skylab?

Tepool: Skylab was ending about that time. Shuttle was up and going when Skylab crashed, when they finally brought it in.

Johnson: Before you went to cold gasification, you were working on Skylab, and your testing actually showed there was going to be a problem?

Tepool: We ran a dynamic test on the Skylab module, and it had a meteoroid shield on it. That meteoroid shield fit in tight during launch. When you got to altitude, it popped out about a foot and a half. If a meteoroid hit it, it would not penetrate it and the vehicle. There was a seal on the top and bottom of that thing, a big rubber seal, that was to hold out the air when you were launching. When we ran the vibe [Vibration] test on it out in the big Dynamic Stand, we were vibrating and measuring pressure under that seal in that cavity. That seal would fail due to the vibration. It would leak. We told them it was going to leak and if it leaks, we do not know what will happen, but it is not a good seal. They said they would not hold up the launch and were shipping anyway. They launched it at the Cape and it came apart that night. We went out and looked at the sky and it looked like a train going across all the parts and pieces that were shining, coming along behind it. They appointed the same guy that made the decision to take it down there and launch it to run the investigation. I am not going to say who that was. (Both Laugh)

Johnson: The test engineers were all looking at each other saying, "We told them it was not going to work."

Tepool: That is exactly right.

Johnson: That sort of begs the question, did that happen other times?

Tepool: One other time, and that was on the Shuttle Program. We have a test stand out there in the test area called Test Stand 116. It is an acoustic model test stand. We take a one-fifteenth scale of a shuttle. We used tomahawks for the solids, had three engines for the main engines, small model engines, and fired it. We fired it into an exact simulation of the Cape launch facility, the Cape launchpad. When we did that, we measured the acoustic noise and over pressure coming back out and bouncing off the vehicle and payloads. There was an over pressure that came out of that hole almost strong enough to snap the wings off the orbiter. We wrote our report, told them there was over pressure that comes out of that hole and it is not good. We were scale, we were one-fifteenth, and they though that would not happen at full-scale. The first time we launched, we almost snapped the wings off the orbiter.

Johnson: What launch are we talking about here?

Tepool: STS-1.

Johnson: With the guys onboard.

Tepool: We never launched an orbiter without anybody onboard.

Johnson: That is what I am saying.

Tepool: They had parachutes, remember, they could shoot themselves out on the very first one.

Johnson: It is a little hard to understand. You are giving them the bad news and they do not want to hear it.

Tepool: They do not think it is going to happen at full-scale. They think it is a scaling problem.

Johnson: Then why do the test at scale?

Tepool: You can do the test at scale for acoustics. We have done that before. When we launched, they did accommodate by putting measurements at the launchpad. When we launched, we did get the over pressure, did not snap the wings off, thank goodness, everything was copacetic. That is when we came up with the water wienies. Have you ever heard of the water wienies?

Johnson: No.

Tepool: What they did was build these canvas bags and strung them across the opening at the Cape and filled them full of water. When that overpressure wave would come up there, it would hit those and the water would dampen it out and it would not come up to the vehicle. The vehicle would be gone before it would get there. It would slow it down so it could not get up there and that overpressure wave hit those wings.

Johnson: We did not do this for STS-1, but after STS-1.

Tepool: We did it for a long time, yes. Then we would put in more big water suppression systems to kill it.

Johnson: Compare the Saturn V and shuttle, if you would. Was the test program different as far as you were concerned, or was it a similar-type approach to making sure everything worked as it was supposed to?

Tepool: It was s similar-type approach except in the Apollo Program, every component was what we call qual. [Quality] tested and life cycle tested. In other words, it was tested two or three times its life. It was tested to extreme limits by an independent qual. test organization.

Johnson: Quality.

Tepool: Quality, right. It cost big bucks, big bucks.

Johnson: When you say big bucks, what are we talking about here for a test like this?

Tepool: I am not sure. When I was running Test lab, we were spending around 120 million a year and we were not hardly doing anything.

Johnson: The big tests were expensive.

Tepool: Yes, the big tests are expensive. You have 500 thousand gallons of LOX and fuel onboard. It is costly.

Johnson: Was there any static from up above about how much you guys were spending on tests?

Tepool: No, not on Apollo, not on shuttle.

Johnson: This was something that had to be done.

Tepool: Right. But then they took a different philosophy. On shuttle, instead of running all these qual. tests, they took a bunch of experts in each, turbomachinery, combustion devices, actuators, different things, and they sat them down and said, "Write down what you have to do with this component before you can fly it." In other words, it was called a development verification system. Going through development, what do they have to do to verify that it is ready to fly? These experts would write down what they thought had to be done to verify that. That was in lieu of the qualification test program. When we got ready to fly shuttle, there were several development verification engineers. Each component had a father, or a guy in charge, that had to prove. In shuttle, there were some verification engineers who were not willing to sign up for the

first flight. The program manager took it on himself, [James Robert] J.R. Thompson [Jr.], and signed the waivers to fly that stuff.

Johnson: You mean the verification engineers, they would not put their names down on a piece of paper that their this is ready to fly?

Tepool: Right, so J.R. did. That is a project manager's call. That is why he is the project manager.

Johnson: In your mind, was doing it that way a good idea? Not criticizing him, but as a test engineer.

Tepool: In my mind, not necessarily a test engineer, that was a great call politically because to get the shuttle going. Some of these guys would have never signed up.

Johnson: That is sort of how people felt for a lot of the shuttle program, they never would have signed off on it.

Tepool: Right. That was a good call to go on and do that. Technically, it probably was not that great a call because we were flying on the edge there for a few years before we got it all right.

Johnson: You were with the main engines. As far as being a test engineer, I guess it was a joy.

Tepool: It got pretty tough. We were blowing them up, having failures. We had two or three cut themselves off, torch themselves off at the gimbal block and fall it the bucket. We were having a hard time.

Johnson: Was it a tougher engine to develop than the main engine of the Saturn?

Tepool: Yes, because it is a stage combustion engine. The Saturn engines were G.G. cycle engines, which were gas generator. What they do it have a small engine running that turns their pumps. That fuel then goes overboard. On a stage combustion engine, everything you do goes into the main chamber and burns. If you have a little problem anywhere in the system on a stage combustion engine, the whole system is going to see that problem all the way through.

Johnson: A little problem becomes a big problem.

Tepool: Can become a big problem.

Johnson: Once you had done the testing and ironed out the problems, was there a problem with the shuttle engine that you thought you were not going to lick? Did you think you would just keep working and find out what the problems are?

Tepool: We used to change the LOX pump bearings every flight. When *Challenger* went down, I was sitting in a conference room going to telephone school. We got new telephones. We had it on TV [Television] as it was launching and it blew up. I swore it was the LOX pump.

Johnson: You thought it was the main engine?

Tepool: I thought it was the main engine LOX pump because of the problems we were having with the LOX pump. But it was not.

Johnson: In fact, the main engine.

Tepool: Was fine.

Johnson: Over the life of the shuttle, thirty years.

Tepool: [It was] one of the few. We had problems, but we fixed them. We never had in-flight problems.

Johnson: The testing for that, that was where you got it right.

Tepool: Right. We got it right, not me. (Laughs) There were a lot of us.

Johnson: Was there a different fell from what you did in the Apollo Program to the shuttle?

Tepool: No, it was all the same. The feel changed after shuttle, at the beginning of the Ares Program.

Johnson: As far as getting through the shuttle as a test engineer?

Tepool: By that time I was not a test engineer anymore. I was the chief engineer up in the project office on the main engine. We still oversaw all the testing that was getting done.

Johnson: When you started, it was a slide rule world. By the time you retired, computer simulations were doing some of the work, am I correct?

Tepool: Oh, yes, everything.

Johnson: As a test engineer, did you like that or did you miss the original days?

Tepool: I am still not the computer guru or geek. If somebody wants me, do not send me a text message or leave me a message on my phone. Either call me or come see me. If you cannot call me, do not be texting me or send me email [Electronic Mail]. That is not communication. That is one-way stuff. Back in the old days, if you wanted somebody, you called them. If you could not get ahold of them, you went to see them, make sure they knew what you needed and you knew what they needed to get the job done.

Johnson: On that same note, yes, you have the computer simulations now, but it sounds like you do not think the communication is as good.

Tepool: Right, that is it, it is communicating now. The simulations and everything now, that is great. Computers can do things what it took us years to do and they can do them in a nanosecond. In fact, the dollar calculator you buy at the dollar store, that was four hundred some dollars when I was in college. The very first Texas Instruments, it could take the square root, multiply and divide, it was about $450 back then. Now you can get it for a dollar.

Johnson: I know there were computers, but they were pretty primitive at the beginning, were they not?

Tepool: Yes, we had Beckman line printers. Our computer room was probably 4,000 square feet. Now everything that computer could do, you can do on a laptop.

Johnson: It was 4,000 square feet?

Tepool: Full, top to bottom.

Johnson: Let us go back to the Saturn V. When it was finally launched and all the parts went together and all the systems were integrated, what was that like to know that you helped make that possible? How well did it all fit together?

Tepool: I did not get involved in fitting the total bird.

Johnson: I know that, but as a guy who was part of it, when you saw it all go together and do what it did, what did you think?

Tepool: Just like I think now, with enough time and money, you can do anything. There was a lot of time spent, a lot of people, and a lot of money. There was no doubt I thought it would ever come together. We had the S-IC stage here, they were doing the S-II stage out in Downey [California], the S-IVB stage was at McDonnell Douglas. Rocketdyne was building all the engines and shipping them to these places. We were putting them on. We were testing, they were testing. We shared experiences. If they had a problem, they would let us know. If we had a problem, we would let them know. The real thing that was more amazing to me than technically getting the job done was how they scheduled and maintained all the logistics of making enough LOX, making enough RP-1. We were making enough high strength steel bolts that we needed. On the Saturn, we had two sets of suction lines, two sets of prevalves, two sets of that valve, different vendors making these in case one did not work. There was a lot of money spent in protecting that decade thing.

Johnson: The promise to launch within the decade.

Tepool: Right, which did not happen in shuttle. Shuttle was more we have a problem, we have to fix it, we are going to slip schedule. When we had the failures in shuttle, were down for three years with *Challenger* before they would let us go back and fly again.

Johnson: Was that frustrating when you had the problems?

Tepool: Yes, same way on *Columbia*. I was on both those investigation teams. You know what happened right away. It was a matter of fixing it. There were so many hoops to jump through to get everybody's approval and go fly it.

Johnson: Talk about the difference between Apollo and shuttle. In retrospect, did you feel like the shuttle design was a good one compared to how the Saturn V seemed to be, this is exactly how we should have done it? The shuttle, I have heard it described by a veteran shuttle worker that is was a little more complicated than it needed to be. As a test engineer, what do you think?

Tepool: It was a little more complicated. I would not have used solids. I would have used liquid boosters instead of solid boosters so you can turn them on and off. It would have been safer. With solids, there is nothing you can do. If it decides to go, it is going

and it is too late. I think the orbiter itself, we went for weight a lot instead of brute force. In Apollo, we went for brute force. In shuttle, we went for save weight, more performance, that kind of thing, which is very costly and very fragile. Originally, the shuttle was not going to have the heat shields on it, the thin heat shields. It was going to be pretty beefy and cooled.

Johnson: That was changed for weight?

Tepool: I am sure it was. Have you talked to [Robert J.] Bob Schwinghamer?

Johnson: No.

Tepool: You need to talk to Bob. (Laughs) He was head of the Materials Lab for years making all this new stuff.

Johnson: Did you work with multiple centers? I am sure you did. Was there a difference between the centers? In your mind, were there rivalries?

Tepool: Yes, competition.

Johnson: Good competition? Bad competition?

Tepool: It depended. The manned spaceflight centers competing with the science centers and the other part of it, Ames [Research Center], Dryden [Flight Research Center, now Armstrong Flight Research Center]. The manned center seemed to get along pretty well, which is JSC, Kennedy [Space Center], Marshall, and Stennis [Space Center]. The other centers, we did not have a lot to do with them, but we felt like they were spending a lot of money doing research that never went anywhere. (Laughs)

Johnson: That you could have used the money.

Tepool: That we could have used to go somewhere or do something. (Laughs)

Johnson: Did the rivalries get in the way during the programs you worked on, what you tried to accomplish?

Tepool: No. In fact, the centers pulled together pretty well. Stennis used to be a part of Marshall. The Cape used to be a part of Marshall. When I came here, Marshall did the launching, Marshall did the testing, Marshall did everything. Then they started Cape

Kennedy. The Marshall people went to Cape Canaveral to launch originally, until Kennedy Space Center was started.

Johnson: What about the contractor experience? You worked with contractors, I am sure, very often and extensively. Generally speaking, was it a good experience working with contractors?

Tepool: Yes, especially in the test world and in the propulsion world. The only bad experience working with contractors is that they are pretty good, they are working with you and their peers, but when a program gets cut, they are the first to go. You may have some people in your own ranks that are not as good as your contractor people, but that does not matter. They are the first to go. That is where it gets tough.

Johnson: Did cutting contractors ever hurt the program, slow you down, maybe?

Tepool: Maybe slow you down, but it did not hurt you. It did not make you do anything unsafe. It did not affect the flights.

Johnson: How about NASA Headquarters? During the Saturn days, during the Apollo Program, during the Shuttle Program, did Headquarters help or get in the way?

Tepool: When I came here, Marshall was more Headquarters than Headquarters was, I think. I was at a junior level, but von Braun kind of ran the manned part the way he wanted to, even though he was the Marshall director. When they shipped Wernher out, the talk on the street was that was so Headquarters could get control of the centers.

Johnson: When von Braun was in charge of Marshall Space Flight Center, you already said people were excited and that the work went well. After he was gone?

Tepool: It got tough, but it is hard to realize whether that was the influence of him or because the Apollo Program ended. They brought in Rocco Petrone from the Cape. His job was to get rid of the Germans at Marshall Space Flight Center and make Marshall answer to Headquarters. That is what he did.

Johnson: What do you think of that decision or job? Do you think that was a good idea?

Tepool: Probably sooner or later it had to happen, I would think. You cannot have one center running wild when you have ten centers around the country. Headquarters, centers, it almost all boils down to who is heading the show there, who is the center director at Marshall, who is the center director at the Cape, who is the center director at

Stennis, who is the administrator at Headquarters and then who are the deputy administrators up there. They have more influence on how things operate than just Headquarters in general.

Johnson: Did you sense during the programs you worked on, but especially the Apollo Program and the shuttle, that you were a part of making history, doing things that had never been done and it may be a while before they are done again?

Tepool: We thought we were living the dream. We were having a big time. NASA was kind of a premier agency to work for. People respected you if you told them you worked for NASA or they knew you worked for NASA. If I had known back at the beginning, I would have saved a lot more paraphernalia. (Laughs)

Johnson: The history part, you really did not think about it. Do you think about it now?

Tepool: Every once in a while. It has been fifty, fifty-two years since NASA has started. You see people that have things that people gave them from NASA and they think it is a big deal. Some of them are and some of them are not. (Laughs) There were millions of them printed, maybe. I am glad I had a career with NASA. I am very thankful that it

helped me put four kids through Auburn [University]. Now I just hope the government does not go broke before I die. (Laughs)

Johnson: We know how much recognition von Braun and the German rocket team received. Do you think the rest of the workforce received the credit due them?

Tepool: Some did and some did not. Some got more than they deserved, but that is just the way it goes. Who is the rocket boy?

Johnson: Homer Hickam.

Tepool: Homer, yes. I do not know if he even saw von Braun, to tell you the truth. He was never out there when I was out there. If you read his books, you would think he did everything.

Johnson: If you were going to bottom line your career with working on the things you worked on as a test engineer, it strikes me that you pretty much got to be where the action was.

Tepool: That is right. That was the good part. I was in tests for thirty years and I spent the last fifteen in shuttle. I would always go back to tests, see the guys. It is a certain kind of guy that wants to work in tests because you kind of get to do your thing. You have to be a little bit cocky because you cannot let people come in and say, "Why do you not do this? Why do you not do that?" You have to know what you want to do and go do it. You do not want any A students. My hardest job when I was running tests was to get a good test engineer. NASA always wants to hire A students. If a guy is a real straight A student, really wants to dig in, he does not want to run tests, he wants to develop something. He should be in a lab somewhere. He should not be out on a test stand, trying to get work done, get all of his guys lined up, tank, fire, fix, get ready to do it again, modify procedures to do that. I had some test engineers that would never run a test because they were always checking the stress guys' work, the thermal guys' work. They were doing all that rather than getting ready to run a test because that is what they liked to do. They do not make good test engineers.

Johnson: Basically what you needed were some garage mechanics who had an engineering degree?

Tepool: Right, that is right. (Laughs) That is really right. Or you needed somebody that knew a lot about a bunch of different things and was more systems oriented instead of one area.

Johnson: Where were you? How did you fit in?

Tepool: I am observant. That is my best strength. I see a lot and do not make the same mistake twice a lot. That is how you learn, by mistakes. When I came here, I did not know what a solenoid was. I did not know what anything was. I knew how to calculate stuff, I knew the engineering behind it, but I did not know how it all worked. The technicians teach you how it works. Every engineer, he is going to learn from somebody who does hands-on, some tech in some shop, some manufacturer somewhere. That is where he is learning. Book learning does not do anything for you when you get out in the world. You know where to go to find out how to fix the problem you are having, but it does not tell you how everything works.

Johnson: You had to get your hands dirty to do what you did.

Tepool: Yes. It is a good thing we did not have strong unions. (Laughs)