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

Ron Creel
Interviewed by Steve Johnson
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Steve Johnson: I am talking with Ron Creel who worked at Marshall Space Flight Center full-time from 1969 to 1981. Prior to that, he was a co-op student from 1965 to 1969. Ron, could you tell me about your education background and what prepared you to be in aerospace?

Ron Creel: I always had an interest in high school in physics. We did not have engineering classes back then. We had physics, chemistry, and science. I was also very interested in Sputnik. I remember when Sputnik flew, I can remember walking home that day and seeing Sputnik on the news back in 1957. I had an interest in space. It worked out that when I was at school at Florida State [University] they had a cooperative education program. I was able to start working at NASA [National Aeronautics and Space Administration] Marshall here in Huntsville [Alabama]. We would work about three or four months, go back to school for three or four months in that kind of a role. I kept that up and then they offered me a job when I came out of school in 1969. I came up there and started working. The first project I was assigned to was the Lunar Rover that was beginning up.

Johnson: You were an engineer on it, correct?

Creel: Yes.

Johnson: What kind of engineer?

Creel: Mechanical. I majored in mechanical engineering.

Johnson: While you were getting your education, you were already able to work in the space industry?

Creel: Yes, sir.

Johnson: You worked on the Lunar Rover when you first went full-time. Talk about the main challenges as a mechanical engineer. And I am correct, the Lunar Rover was developed in about seventeen months? Talk about the challenges, which strike me as being numerous.

Creel: The challenges were numerous. Basically, we had a totally new environment up there on the Moon that we had a little information about because Apollo 11 had landed

in 1969 and had proven that indeed the astronauts would not sink down into the soil. There was some capability of bearing load on the soil. We basically had to start in with defining the requirements for this Rover. I worked thermal control. This is a multi-phase process here. It is launched onboard the top of the Saturn V rocket, inside the Lunar Module, actually folded up and put inside the Lunar Module descent stage, then all the way to the Moon we had what we call barbecue mode. We put the whole assembly into a rotation to balance out the solar heating and the radiation of the energy going out in space. During all that phase, we never had any temperature readings. There was not enough weight allowance to give us any temperature telemetry. We pretty much had to analyze that ahead of time, have a feeling it would survive.

Johnson: Let me stop you here. Excuse me. You had a feeling it would survive?

Creel: We did the testing, as much as we could. We never actually tested it in that folded up configuration. We did not have a thermal vacuum chamber big enough to do that.

Johnson: Were there a lot of discussions about we are not testing this in all the ways we should?

Creel: There were some of those, even some doubters. There were four contractors who put in proposals for the Rover, and they had different ways of doing things. We had to select down and we went with Boeing and General Motors to do the wheels and motor drive systems. Even the drive systems, we had some people there at Marshall that did not like the fact of using brush motors. They wanted to go to a brushless motor, but we had a concerned because the brushless motors required more electronics and more heat to take care of and more weight. We went with the simplest system that even had a harmonic drive, which some people doubted would work fully, but we tested it. We did a lot of testing and had a pretty good feeling we were going to be successful, and indeed were. We had a few issues on the Moon. We can talk about those.

Johnson: When I interrupted you, you were talking about it being folded and you had not tested whether it would survive the heat. Can you take it up there again?

Creel: We were not able to test in that folded up configuration, but the folding part was just a delivery. That is how you shipped it to the Moon. The main part is how it is going to operate once you unfold it on the Moon and actually operate it. That was a real challenge. What we came up with was an almost totally independent system that stored energy, the heat that was generated while they were driving around, in the batteries and some wax boxes. We had wax boxes, which as long as the energy is being put into

the wax box, the temperature remains fairly constant as the wax melts. Once you have done that and get through with that part of the driving, the astronauts would open some covers over some radiators and the wax would re-solidify as well as the radiators would radiate away the heat that had been stored in the batteries. We had what you call a semiautonomous system. We only had ten pounds of allotted weight for thermal control.

Johnson: I am speaking from ignorance here, why was heat a problem anyway?

Creel: As you are driving along, you are generating that heat in the electronics. You basically have three extravehicular activity periods that you had to plan for. Going the first driving period, they were going to go back inside the Lunar Module and rest. As such, you had about nineteen, twenty hours available to you to get rid of that heat that had been stored up in the first driving. We were not able to do it for all three EVAs [Extravehicular Activity].

Johnson: What was the temperature on the Moon during this?

Creel: For the astronauts as well as the Lunar Module and the Rover, they land in what is called lunar morning, which was between seventy and eighty degrees Fahrenheit,

maybe upwards of 180, 200 degrees Fahrenheit was the environment, but it gets a lot hotter. It gets a lot colder during the night time. We were not there in those periods of time.

Johnson: Losing the heat when it was 180 would be a problem.

Creel: Yes, and we did have some issues. We had done previous testing here on the Earth with soil simulants and put soil onto the radiators and came up with a method for rushing the radiators. On Earth, the data showed us they could indeed clean the radiators, but it did not work that way on the Moon. The dust really adhered to the radiators and you could not get them cleaned off with the dust brush.

Johnson: Talk about the testing on Earth of a vehicle to drive on a surface that is really tough to recreate.

Creel: Oh, yes, it is. We did have thermal vacuum chambers, primarily up at Boeing in Seattle, Washington, actually, Kent, Washington, a suburb. We took what we call a one-quarter mobility system, put it on a treadmill, and drove it inside the vacuum chamber and tested. For example, we would test it for six hours of driving, and out of a seven hour EVA period, they are not going to drive that much. They have to get around the

Moon, get to places they want to get off and take samples and do things. We tested it two to three times the environment type you would have on the Moon. We also took the forward chassis assembly, put it in a heat tub assembly, and tested that separately. We did some separate testing and then pulled it all together into a full-up, took the qualification unit, which is now at the Smithsonian, used to be out at the [U.S.] Space and Rocket Center. We took that flight-like vehicle, put it on a treadmill, also at an angle to get the solar heating right, and with individual dynamometers on each wheel, inside a thermal vacuum chamber and tested that. The flight units had a little less testing. You do not want to over test the flight units, so you put them through a shorter period of testing, but all in a thermal vacuum chamber.

Johnson: Your testing of a vehicle, at least from appearances, seemed rather flimsy.

Creel: We did give that appearance. However, there was structural testing that went on. I will tell the story here too about how that unfolding was probably the number one risk item. You think about it, as you are getting ready to go to the Moon, you get everything stored, and when you get to the Moon, you want to make sure that it unfolds and gets out of the Lunar Module because you want it to be ready to use. You do not drive it off. They did structural testing in the folded up configuration. I was up there at Boeing the

first day they successfully. They had originally planned on it being automatically unfolding. They worked out that that was too dangerous, too unpredictable.

Johnson: You would need some sort of motor system to make that happen.

Creel: That, extra weight, and/or you had to manage the dynamics. It was spring loaded. It had torsion bars and was spring loaded when it was folded up. As you went through the unfolding, it went in a phased process, the back wheels unfolded, then it went down a little lower, then the front wheels unfolded. The astronauts actually pulled on cloth tapes on a reel system. It took about ten minutes, but you gave up that ten minutes of time. Over here in the HIC [Huntsville Industrial Complex] Building in Huntsville, back early on in the program, they tried an automatic where it unfolded and it fell onto the floor. I tell the story in other places where when they got back, Dr. [Wernher] von Braun called over to Alex's laboratory and said, "We will fix this," a rhetorical question saying, "We will fix this, right?" It was obvious the automatic deployment would work.

Johnson: During that short period of time, the seventeen months when the Lunar Rover was being developed and you were doing all this testing, did anyone ever ask if the

requirements could be changed any? I have to believe things would have been a lot easier if you could have changed that a little bit.

Creel: No, and that is the secret of success. The secret of success was not changing the requirements, but locking those in and saying this is what it has to do and not varying that. This was the secret of the seventeen months, really.

Johnson: Seventeen months, did you have to develop any new tools or come up with any new materials to make the Lunar Rover work?

Creel: I would say the wax boxes were certainly unique because they had never been tested in space.

Johnson: The wax box, essentially the wax would melt and absorb the heat out of the electronics.

Creel: Right, when you were driving. That was a new technology.

Johnson: Has that been used in any other way?

Creel: I understand there are some others. I know some satellites that use some melting wax. Really, they were on the cusp at that time, in the early 1960s, of what we call heat pipes. Heat pipes are what is primarily used in satellites where they have a core gas in there that heats up and transmits the energy. It is a passive system. However, we were not that well developed on the heat pipes back in the late 1960s. Plus, we only had ten pounds. I have seen satellites that have three or four hundred heat pipes in them and obviously three or four hundred pounds.

Johnson: The driving force on the design, was it the weight?

Creel: Yes.

Johnson: The weight was the driving force behind everything you did, and, I suppose, the configuration for launch and travel to the Moon.

Creel: Right. There were certain people at Houston that packaged the Rover in there. The initial goal was a 400 pound Rover. It finally weighted about 460, but that amount of weight meant twenty seconds of hover time for the Lunar Module. Obviously, the people at Johnson [Space Center], they wanted to have greater mobility for the Rover, but it cut into their margin on the hover time. You will see on Apollo 11 and some of the

other missions, not only hover time, it is trying to see where you are going on a totally unmapped area and trying to land safely. They did move around a lot. In fact, on Apollo 11, you will see they got a warning signal because there were very low on fuel. Weight was certainly a big challenge.

Johnson: Were there things you gave up because of weight that you really would have liked to have included on the Rover?

Creel: Yes. In hindsight, when it was all over, after Apollo 17, Hugh Campbell, my mentor and senior engineer, sat there and through all the things we had done, because on a couple of missions we had to turn off the battery, battery's got hot because not many of them got rid of the dust on the radiators, but we had totally redundant batteries. As we sat there, we dearly wished that we could have used ammonia boilers, have a totally locked-up system where the astronauts would not have even had to open the covers or done anything. We did not have the weight for it. We knew there was another solution out there, we just flat did not have the weight to pursue that option. We sat there and said we got the job done, we had our minor difficulties, never influenced them having to shorten a mission because of thermal control system.

Johnson: In performance, the Rover essentially did what it was supposed to do.

Creel: Oh, yes, much beyond expectations. You can think of it like a truck too, it basically lowered the astronaut's metabolism rates. When they are bouncing around on the Moon like you see in the other three previous missions to the Rover mission, you see their heart rate was up and their metabolism rate was up, the use of their coolant was up. When they sat on the Rover, it was like you getting in your car, you get a much more benign environment and you are able to save energy. It is all about energy conservation, if you think about it, the amount of water you have to take to cool systems. They had liquid garments that had water cooling for them. All that gets back to economy of saving energy.

Johnson: Doing what it did, did it accomplish everything intended by the designers? As somebody who worked on it, do you look at it and say we did it right?

Creel: Definitely. Apollo 15 was the first mission to use the Rover. They had trailers out at the Operations Support Center, trailers where we could stay out there and totally dedicate ourselves in case problems came up. There were not big problems that came up, so they did away with the trailers for the next two missions. It was a contingency there in case we had problems, that we could stay out there. We did find in Apollo 15 we used too large of a computer program to work in between the driving period and the predictions for the next EVA period. The computer program was much too large, so

Hugh told me to get a solution that was quicker. I took the bigger computer programs and brought them down to a smaller computer program that could run in the mission support computer system. We were able to get a good response to Houston. Out at Johnson, it was the Manned Space Center at that time, they like to be able to have somebody available to answer all the questions that might come up. I think they got to the point after Apollo 15 that they realized these guys know what they are doing and we can rely upon them.

Johnson: As an outside observer, I hear what you are saying and I think it was not just a vehicle with a steering wheel and an engine. You start it, it goes where you want it, you stop, get out, do what you have to do, you get back in it and drive like someone would with a car. What you are saying is it might have looked flimsy, but it was complicated.

Creel: Yes, each wheel was totally independent in that it had its own motor system, own drive system. If there had been a problem with them, the astronauts had a tool that could reach in and disengage it and do wheeling on that wheel. They could have driven on one of the four.

Johnson: That was possible because of the much, much lower gravity.

Creel: Yes.

Johnson: Why was all of that designed into it? Were you trying to think of any possible problem?

Creel: Exactly. Like I said, we had redundant batteries. It turned out they used about a third of the energy from the batteries. Some people always ask why we did not bring the Rovers back. That is purely a weight issue.

Johnson: It was at least possible?

Creel: No, because there was no way for them to fold it back up. The ascent stage and the descent stage on the Lunar Module, we used the descent stage to put the Rover down closer to the surface. If you have been out at the Space and Rocket Center, the ascent stage is not that big. Have you seen the movies where it also blasts off from the descent stage? It really moved out.

Johnson: Essentially, putting Moon rocks inside the vehicle to come back, to leave the Moon's surface, meant the Lunar Rover was going to have to stay?

Creel: It had to stay. People always ask me that question. They also ask me if we could go back up to the Moon and put new batteries in. First off, it has now been through over 600 cycles of temperature extremes back and forth and over forty years of cosmic rays bombarding the electronics. It is pretty well fried. Plus, when you are doing orbital replacement units, even on the space station, you have to put guides in there and put the system in such that you can take the old one out. Think about doing a battery replacement on your own car. It is not trivial to take the battery out. Think about on the Moon in their suits.

Johnson: Let us get back to the pace of work. You had seventeen months from start to finish. How would you describe the pace of work? How fast did things have to be accomplished?

Creel: Fairly fast, and it did mean a lot of tour of duty, both at sites in Santa Barbara [California] at General Motors as well as up in Seattle [Washington] at Boeing. Somehow in that whole process, I also got married in the middle of it (Laughs). We shared duties. On the thermal control, we did have a good support out at Teledyne Brown Engineering here in Huntsville, we had a good team there that helped us with the modeling part. It was largely Hugh and myself going.

Johnson: You had to travel. Did you work long hours?

Creel: Definitely, probably double shifts most of the time, a lot of weekends. We did not begrudge it. It was a challenge to us and we took on the challenge. We were dedicated. There was good rewarding there. I did receive a Silver Snoopy from the astronauts, which I still cherish that award.

Johnson: That is the award that goes to great accomplishments and support.

Creel: Yes, Silver Snoopy.

Johnson: You worked long hours. You built a rather complex vehicle rather quickly. How did you control costs, or was that an issue?

Creel: Cost, Sonny would tell you this.

Johnson: Sonny Morea?

Creel: Sonny Morea, yes. I think it was in the order of nineteen to twenty million dollars was the original allotted money. I believe they spent about twice that when all costs were in.

Johnson: The Lunar Rover from design, testing, to performance was about a $40,000,000 project?

Creel: Yes, I think that is a good number.

Johnson: A lot of people would look at the vehicle and ask the question, which I am sure you have been asked, how did you spend $40,000,000 on that?

Creel: We had a lot of people working on it, several hundred people working on it. That is a lot of salaries. We had a lot of different test units built up. We also had a 1g trainer that was built up for the astronauts to train on.

Johnson: To simulate the actual gravity situation.

Creel: In this case, it was more for the operational, opening the covers, putting equipment on, practicing in their suits. They did that down at the Cape [Kennedy] in

Florida. They could drive around. It had a much bulkier motor on it and a heat exchanger system that was different than applied to the Moon. They actually had rubber tires. We had metal tires on the Rover, woven piano wire, which was a very unique and very efficient way of doing it.

Johnson: What did you start out with? That was the end product, but what were some of the?

Creel: That was proposed by General Motors to do that. They did a lot of testing on the Earth beforehand to come up with that concept. Ferenc Pavlics, who worked at General Motors, after Apollo 17, I shook his hand, gave him a hug. There were a certain amount of people at Houston and other places that doubted the metal wheels, the piano wire, metal mesh wheels. Yet, several astronauts shared with us that they never felt any danger going up slopes, they felt like they had good traction. It all worked out, but there was a lot of testing.

Johnson: In the project, were there any dead ends of things you thought would be useful that you worked on that ended up not making it?

Creel: I do not think so. Maintaining the requirements and going forward in the testing, as I said, the unfolding part was not solved until fairly late in the program.

Johnson: And it ended up being purely mechanical, by hand unfolding.

Creel: Mechanical, using springs and preloading it so that it would unfold, assisting springs and torsion bars. Once that was solved, we pretty well knew that we were on our way. Along the way in the 1970s, there was Apollo 13 when we had a doubt if the program was really going to continue. Out of a whole lot of effort, those men did survive and come back to the Earth. If they had not made it, I do not think. In fact, we were also in jeopardy of not continuing in 1970. In 1970, we cancelled the final three missions. We had a fourth Rover we had all the parts for. We were going to convert it into a dual mode Rover. They could drive it around and we could configure it so that once you left the Moon that you could robotically control it. That was cancelled in 1970. You had the Vietnam War going on, draining money, and that really caused the ultimate demise of the Apollo Program. People ask what happened. That is my view of what happened.

Johnson: During the development of the Rover, were there any surprises? It sounds almost linear, but I have seen all these different pictures of all these different ideas for Rovers. Were there any surprises even with what we ended up with?

Creel: I do not think so, no redesigns that I know of. There was also a little bit of trying to adapt and understand what the astronauts wanted as far as the hand controller. You mentioned a steering wheel. We did not have a steering wheel. There was a hand controller between the two astronauts. The angle was biased for the driver on the left. The astronaut on the right was there as a contingency in case there had been a problem and he could have driven it with his left hand. The astronauts were all right handed. The hand controller, there were several redesigns of that, three or four, to try to get it to where it did what the astronauts wanted. You have to realize they have that glove on that is a little bit cumbersome and they have a limited capability to do things. Embodied in it, we had forward power, pull it back for braking, steering left to right, all in that one little hand controller. I think cost wise, it was easily ten to fifteen percent of the cost in the development of the hand controller alone.

Johnson: Talk about von Braun's involvement in this. Did he visit your lab or your area? Was he an interested observer of the development of the Rover?

Creel: Yes, and Ferenc Pavlics tells a story there about how he got Dr. von Braun interested. He actually built a little model of the Rover and set it outside von Braun's door and drove it into his office. Von Braun said, "What do we have here?" That was a bit of the selling approach. Once it unfolded and he got on and drove around, people thought it worked pretty well. It did not work exactly right in the first one. On the first one, they did not have front steering on the EVA. Something must have happened, something got jammed up, but I think once they were driving around on the first EVA and they came back, they came out for the second EVA, they got on, and the forward steering worked. They had forward and rear steering. They could do an Ackermann, where you could turn both the front and the back and turn a circle inside your wheel base. It was a challenge, but I do not think there were any surprises along the way or any major roadblocks.

Johnson: You had seen the Saturn V, we had already been to the Moon, but we had not taken a vehicle. When we finally flew and the Rover worked as advertised, how did you feel?

Creel: A great sense of accomplishment, but immediately the challenge of the next mission, knowing it was a series of missions.

Johnson: Were there design upgrades?

Creel: A few little things. I know we had special testing we had to do. After Apollo 15, we discovered that when the wheels folded together, you had to roll back part of the fender such that the wheels would contact each other. When the astronauts got on the Moon, they physically pushed that fender extension. We lost one of the fender extensions on Apollo 15, so there was a little bit of a redesign on that. In fact, we had to take it out to Houston to their thermal vacuum chamber and have an astronaut come in. They had a chamber out there where an astronaut could come in and do things. We did hot and cold testing on that new fender extension.

Ironically enough on the next mission, Apollo 16, as you can imagine, they carried a lot of tools inside the suit in little pockets. He had a hammer in there and got it caught on the fender and popped off the rear fender. That made a lot of dust fall onto the astronauts. There was a certain amount of looking hard into that, but it was really an example of how you cannot plan everything. If you look at how they are jumping around on the Moon and moving around, they did not have great ability to stop and do things. They were trying to do their job, but they were also trying to get it done. On Apollo 16, it popped off. On Apollo 17, an astronaut popped off the same fender extension. They went back inside and figured out during the night time that the best

solution was to take some maps, tape them together, and come back out with some clamps and do a repair. We did a repair on the Moon on Apollo 17. As you think back here, they are 250,000 miles away. There is not a whole lot you can do here if you have not planned for it ahead of time, there is no contingency there, we had not planned for it.

Johnson: Looking back at the Rover from today's vantage point, is there anything you wish you had done differently in the design?

Creel: Yes, pushed for some more weight, which we probably would not have gotten, to have a closed up thermal control system. We went down to the Cape and had to council them on keeping things cleaner. You think about dust covers there and it has dust on it. If you open it up, immediately dust is going to fall off on the radiator. We had to spend time cleaning it.

Johnson: At least trying to clean it.

Creel: Try to clean it. All that time, the astronauts, that is not what they are there for, to be cleaning radiators or cleaning covers. That is the regret here. If we could have done it differently, it would have been to have it totally where they did not have to worry

about it at all. The satellites we have up there now, you do not worry. Those are autonomous thermal control systems.

Johnson: The Saturn V made history, and I would say the Lunar Rover made history also, the first vehicle design for another body in space. Did you sense that you were making history when you were working on this?

Creel: I cannot say we really were. We had a challenge and we worked such long hours, were away from families, I cannot say we had that sense. Maybe I should say that, looking back, it has been forty years, but I cannot. There was a great sense of accomplishment, but being a part of history, I do not think so much about that.

Johnson: After the Lunar Rover, you worked on some satellite projects and on the shuttle Solid Rocket Booster. Talk about what you did with the Shuttle Project.

Creel: We had a situation there where we had engineering judgement where we wanted to be able to recover the Solid Rocket Boosters from the ocean. Even after burnout, they are still smoldering and quite hot. When they hit the water, they are essentially going to create steam, which is going to push air out. They wanted to make them bob up in the water so you could do something with them. We did testing out at Marshall and took a

model up to the Naval Ordinance Lab in Maryland and did testing there where we heated up that model, dropped it in the water at different angles and different velocities to see if there was enough air in there so that it would bob and be in what we called buoy mode. That was an interesting project, partly because I made a mistake out at the drop tank at Marshall. After the first drop, we did not turn the vehicle over and let it cool and let the steam get out of there. We turned it over and it had too much steam inside and went straight to the bottom of the tank. My boss asked what was going on, and I went through the sequence, explained it to him, and he said, "That is obvious, Creel. You did not let it cool off. You over tested."

Johnson: From Lunar Rover to Solid Rocket Booster work, did ever feel that you over tested or would you have liked to test a little more?

Creel: You never think you have done enough testing on any programs. Nowadays, you would like to have more testing, but often times budget or schedule gets you into a mode where there is only so much you can do and then you have to do the real flight. In this case, I guess it was a little bit different because they were twenty, fifty thousand miles away. Here on Earth, at least, you can repeat things a little more easily. Up there, it was all or nothing. It was rewarding.

Johnson: Back to the Solid Rocket Booster, the test you did on that, was that figured out in short order, that it will do what it is supposed to do?

Creel: Yes, we pretty much proved out that indeed the Solid Rocket Boosters would maintain the buoy mode. What they actually do on the Solid Rocket Boosters in that buoy mode, they have crewmen with Navy diving suits who go down inside and put a plug in and pump out the water. Then it comes over to the horizontal so they can tow them back to the shore and reuse them. That was one of the reusable parts.

Johnson: You were doing all this before the shuttle ever flew. First time a shuttle flew and the Solid Rocket Boosters floated as advertised, was that rewarding? At that point, did you know it was going to work?

Creel: Yes, [it was] more of the latter that said it is going to work and indeed it did. I think they found they had more trouble with the parachutes getting in the way of the Navy divers than anything else. The parachutes were supposed to release, and I think the first design of those parachute release mechanisms did not work. They got out there on the first ones and here is this big parachute hanging off the side interfering with everything. They worked it out and finally got it to where the parachutes released like

they were supposed to. I took a look at that movie the other night here and they got it worked out pretty well. I do not think they ever lost one.

Johnson: You worked on several satellite projects. What portion of these projects did you work on?

Creel: Still thermal control.

Johnson: Getting rid of the heat in the electronics.

Creel: Right.

Johnson: This is for the satellite portion of the mission, the actual satellite in space?

Creel: Yes, the main one there was the High Energy Astronomy Observatory 2, which is called the Einstein Observatory. It is an X-ray facility, X-ray telescope. We actually built a facility out at Marshall with 1,000 foot long evacuated tube so you could get the source of the signal they are trying to look at. It is not as far as you have in space, but at least it is not right up next to you. You put that all inside a vacuum chamber and tested it here at Marshall. It was quite successful.

Johnson: Was it hard to get rid of the heat on some satellites?

Creel: No, not as hard because they do not have the dust, they are clean when they get up there. Hence, you could pretty well depend on the systems you have to get rid of the heat.

Johnson: Was the testing on those systems as extensive as maybe on the Lunar Rover and SRB [Solid Rocket Booster]?

Creel: Yes, thermal vacuum testing. Some things you could not fully do though. For example, other programs might have been involved with the solar arrays. You cannot unfold a big solar array inside a thermal vacuum chamber, so you test it separately. You do not actually have the full configuration sometimes.

Johnson: Which is similar to the problem of the Lunar Rover. You are not able to get it in the configuration it will actually be in, you are having to test it in parts.

Creel: Parts, but they pretty well smart to do that. Some of those solar arrays, by the way, are 150 to 250 feet long when they are fully unfolded on some of these satellites.

Johnson: After the Lunar Rover, once you were in SRB and the Shuttle Program and over in satellites, did the pace of work continue as rapid and as many long hours?

Creel: No, because often times programs, budgetary reasons or technical problems come up, get shifted in time, they get delayed. Sometimes there is a frustration that I think a lot of the satellites I have been involved with, sometimes they are three or four years later in delivery.

Johnson: There was no precedent made saying we are going to do this in X number of years?

Creel: That is right.

Johnson: Can you talk about the difference between Marshall and the other NASA centers ? Did you detect any rivalries while the different projects you were involved in were underway?

Creel: Probably on the Rover, yes. Not rivalry as much as maybe they would have had a desire to do the job themselves, but they realized that Marshall had the background of having done an awful lot of testing on mobility systems. Hence, that is why

Headquarters went with Marshall to do that. Other ones, I saw good cooperation between the NASA centers as I was working with the different centers.

Johnson: So no rivalries to speak of?

Creel: No. Once a decision is made to go a particular way, everybody toes the line and says we are going to work together. On the Rover, we worked very much with the Johnson people. I should tell you here that they had a unit on the front of the Rover that was called the Lunar Communications Relay Unit, and that was taken and fixed onto the Rover. That along with the S-band antennas was the way of them communicating while they were driving or while they were stopped. We worked hand-in-hand. The fellow who worked on that recently passed away. That is my frustration nowadays, all these friends and coworkers, we had a forty-three reunion back at the Moon Buggy races in 2011 where some of the folks were able to come, some others were not.

Johnson: Unlike many of your coworkers, you started on the Lunar Rove right out of college.

Creel: Right out of college. A lot of the others were at least ten to fifteen years older. They have medical issues now or have passed away. It is a little frustrating, but we

tried, had a pretty good reunion. A couple of astronauts came, Charlie Duke and [Harrison] Jack Schmitt came back in 2011 and had a good panel discussion. It was good.

Johnson: Feedback from the astronauts on the Rover?

Creel: They had glowing responses there. There was a little frustration that they had to try to clean the radiators. Ironically enough, it was not just our radios on that lunar communications relay unit I mentioned that was on the front end, they also had radiators they had to try to clean.

Johnson: The lunar dust apparently got on everything.

Creel: Yes. When you look back in hindsight, they only had a single dust brush, which was actually put in a hole on the front chassis of the Rover.

Johnson: It was kind of getting dust on it while it was.

Creel: It was getting dust on it, and they were also dusting themselves continuously. They tell that when they got back into the Lunar Module, they had difficulty getting

things undone, or getting them resealed up, like on their wristbands. The dust would get inside there. They also say that none of the samples returned from the Moon were pristine and maintained in a vacuum environment because the boxes they put them in, the dust had gotten into the seals. It was pervasive. Some of the astronauts' feedback was that they doubted with their suits and everything going on that they could have done any more than the three EVAs that they participated in.

Johnson: Because the integrity of their suits would have been compromised?

Creel: It would have, as well as just having to deal with it. The crewman in the Command Module rotating around the Moon, when they got back and docked the Lunar Module and opened the door, they would typically say, "Wow," because it was like a gunpowder cloud coming into the other module. They said you guys need to get clean in there before coming in, but no matter what they did, they opened the door lock and it was a cloud of gunpowder.

Johnson: You worked with contractors throughout your NASA career. Talk about the contractor experience as far as you were concerned. Was it always rewarding? Was it smooth?

Creel: Yes, very much so. As I said, Teledyne Brown here in Huntsville, the engineers there worked with us. They were our main support contractor. They were able to take and build that larger thermal model. The main contractor was Boeing, and certainly those engineers we worked very well with. After the success of Apollo 15, since there were not any major design changes, a couple of them had to disappear from the program. They had to move on to other projects. We did keep one fellow through Apollo 16, the main Boeing engineer, but even after Apollo 16, he was gone. We had the Teledyne Brown people pick up all those functions for us, doing analysis. They were very, very good. A couple of them did get to come to the reunion back in 2011. I was very happy to see them.

Johnson: Talk about NASA Headquarters. Over the course of your career, did Headquarters help or interfere in the development process?

Creel: Some interference, I will not say the name here, but there was a gentleman there that had his doubts or he had his own support contractors that were always doing analyses and trying to meddle with us. Hugh Campbell, my mentor and boss, pretty much gave me the assignment of whenever he would come to town with his people, that I was to take them and escort them around. Hugh did not want to deal with him because he got tired of it. You have your doubts and concerns and all, but do not keep

telling us that. Of course, that all disappeared after Apollo 15, the success we had there. I told you Apollo 19 got cancelled and we had the fourth Rover for Apollo 18, beginning to work on that, then it was cancelled in the early 1970s. It got cancelled because Headquarters did not have the money.

Johnson: How disappointing was that? It sounds to me like you had the new and improved advanced model all ready to go and it did not get to fly.

Creel: That is right. We were already working on that. It was frustrating to have it cancelled. Some are proposing to use the F-1 engine on this more advanced system because you had the mighty Saturn V. If you have ever seen the testing in Huntsville or down in Mississippi.

Johnson: I heard it. (Laughs)

Creel: You heard it, a million and a half pounds of thrust out of that engine and how many coolant systems there were inside the nozzle to try to keep it from melting. I have done the comparison here, our Rover weight was only .005 percent of the weight of the whole vehicle and the propulsion system for the first three stages was easily ninety-eight, ninety-nine percent of the weight of going to the Moon. Amazing.

Johnson: We know Dr. von Braun and the German rocket team got many accolades, recognition. Do you feel like the rest of the workforce during the Saturn days got the recognition they deserved?

Creel: I think so. We had a Manned Flight Awareness Program and certain award programs. I think we were fairly well compensated and encouraged to keep going. Even on Apollo 17, knowing this was the last mission, still everybody put in the best effort they could to make things work.

Johnson: When you look back at your career and projects you got to work on, especially the Lunar Rover, what do you think about that in hindsight?

Creel: I appreciate that I got to do that, I even got to go over and talk about the Rover in Russia. They invited me over there in 2004 after we had made peace with the Russians. As I think back, I have never had a project that was quite as centered and quite as focused and met the schedule and did the job it was supposed to do. I have not had one like that since. That is regret, to have it so early on in the project. I have had other interesting travels around, different projects, but never one like the Rover. Like I said earlier, at the time, it did not strike me that we were doing anything more than our job.

Johnson: I have had it said to me by many NASA veterans, especially veterans of the Saturn V days, that they could not wait to go to work when they got up in the morning. Did you find that to be true?

Creel: Yes, definitely true. It continued on into the HEAO [High Energy Astrophysics Observatory] Program and the other satellite I worked, LAGEOS, Laser Geodynamic Satellite. It was good relationship there, good work. It was that you wanted to go to work. I still want to go to work. There are frustrations with delays and different programs I am working on, testing, and/or failures. Our boss now says we learn from failures. I am not so sure about that. (Both Laugh) They put their spin on it.

Johnson: You work primarily for the military at this point, correct?

Creel: Yes.

Johnson: But in the NASA days, there were obviously failures then too.

Creel: The only one I know of is on the second Saturn V, on the second stage, there was a miswiring and one engine was going to shut off, but it forced the second engine to shut off. That meant they had to burn longer on the third stage to get into orbit. It was a

unmanned mission. They did two unmanned missions. The big deal for us was going to the Moon on the third flight of the Saturn V. They really had to bend the rules on that, if you think about it.

Johnson: I understand that maybe some folks would have liked to have tested more. At that point in the program, money was not necessarily an object, but it was becoming an object at that point. Am I correct?

Creel: Yes. They were still recovering from the delay caused by the fire that killed the three astronauts where the door was not designed right. Think about it, they had to redesign that whole door assembly on the Command Module in a fairly short period of time and still maintain the schedule. That was a big hit in the whole schedule to have that happen. I believe that happened in 1966 or 1967 and yet we still made it to the Moon in 1969.

Johnson: You said you did not realize you were making history when I asked you earlier. Thinking about it now, the president promises to go to the Moon, we make it in 1969, we have a vehicle, which is designed in quick fashion. Does all that not seem fairly historic to you at this point?

Creel: I guess it does.

Johnson: Is it hard for you to imagine that you were part of making history?

Creel: Yes, there were a lot of people, I do not want to under stress that, that did a lot of good effort. I try to carry forward, here at the Moon Buggy race and other things, that image of people. We pulled a group of just the Rover people together back in 2011. It was rewarding to see those folks. Some of them even travelled all the way from California, the General Motors people came all the way from California.

Johnson: And rewarding to know what the team accomplished.

Creel: Yes, I could see that gleam in their eye that they knew they were a part of history.