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

Brooks Moore
Interviewed by Steve Johnson
Huntsville, Alabama – Unknown, Circa 2012

Steve Johnson: I am talking now with Brooks Moore, who was at Marshall Space Flight Center from 1960 to 1981. Brooks, would you talk a little bit about your educational background?

Brooks Moore: I was educated out in the country in Perry County, sixty-five miles south of Birmingham [Alabama], a little country community called Hillsboro. I often say all the education I ever needed I got at Hillsboro Junior High School. You have heard the story about all you needed you got in Kindergarten. I cannot quite say that. I finished junior high, then Perry County High School. I went in to the Army. I was on the tail end of World War II, so I did have a little setback timewise. I entered Auburn [University] in 1946. I was in Officer Training School while I was in the Navy, so I was able to finish Auburn in only a couple of years. I got a B.S. [Bachelor of Science] degree in electrical engineering. I then went over to Georgia Tech [Georgia Institute of Technology] and got a master's degree. I finished there in March 1949. Then I started

my career at Panama City, Florida Naval Research Laboratory there before I came to Huntsville [Alabama] in 1952.

Johnson: You worked for the Army when you came to Huntsville?

Moore: I worked for the Army. I came here in 1952. I joined the [Wernher] von Braun team, 120 of the Germans here. They were hiring young Americans to come in to the understudy and be a part of that team. I was most fortunate to have that opportunity to join them. It has been a very rewarding career.

Johnson: What brought you to the space program?

Moore: In Panama City, the work I was doing for the Navy, we were working on torpedo countermeasures. We were involved in torpedoes, which is sort of like underwater missiles. I had always been intrigued by flying, aircraft. One of my hobbies as a youngster was building model airplanes. I would build them by the dozens, some of them would fly. I never had a real ambition to be a pilot, but I was always interested in the aspect of flight. I was intrigued by the possibility of maybe building missiles that had long range potential. Already, even in those early years, there was some talk about eventually going into space and the rocket concept was going to be that propulsion

system. That coupled with the fact that this was in Alabama, I am an Alabama boy, and it was close to the career that I had in Panama City. As far as a major change of working on control systems down there, this just looked like an attractive opportunity to me.

Johnson: Describe what you did at Marshall when you joined during the Saturn years. In 1960, you went with the von Braun team to Marshall Space Flight Center, what did you do?

Moore: My responsibility in the early years was the guidance and control of the Saturn vehicle. We developed within my division, what it was called at that time, division of the Astrionics Laboratory. We were responsible for the sense systems, stabilized platform, the great gyros, the computer systems, the actuation systems for controlling the direction of the vehicle, everything associated with guiding and controlling the vehicle. Included in that, of course, were the computers. We flew for the first time, we had experience earlier with missile systems on the Redstone and Jupiter, but we had never used a digital computer. We did develop with IBM's [International Business Machines] support a digital computer to fly on the Saturn. Because of the complexity of the mission, we could not get by with the old analogue type.

In addition to using the digital computers as a part of our flight systems, we also developed the automated ground equipment using automated systems for the first time for checking out missiles, for checking out the Saturn launch vehicle. This was such a complex vehicle that it was very difficult to actually do the job with just people on the control panel. We found we could modify existing computers and actually use them to an automated checkout of the Saturn V. It was the ground automated checkout plus all of the flight hardware that was related to guidance, navigation, and control.

Johnson: Would you talk about the main technical challenges and the work you were doing during the Saturn Program. I guess the challenge was trying to accomplish a much more difficulty mission with using technology that we had confidence in. The philosophy we had developed in the earlier years, the Redstone and the Jupiter, was to use proven technology in every way that we could and not jump into high-tech. That may be a surprise to you that we did not go for whatever the latest trends were. We tried to use the old tried and true techniques. When we came to the complexity of the Saturn, we found that the old tried and true methods of using analogue systems and electromechanical systems as we had used on some of the earlier missile systems, we could not do the job without going to a digital computer. We were very concerned about the complexity of digital computers and the potential reliability problems.

I would say one of the biggest technical challenges we had in the guidance control system of the Saturn was developing with a digital computer that we felt confident was reliable enough that we could depend on them for the Saturn mission. With the help of our contractor, IBM, we did design and develop what we called a triple modular redundant computer. You may have heard of three sting computers, you have two and one to compare to. We were concerned that even that would not give us sufficient reliability, so we went to a concept that we called triple modular redundant that we had. Within the computer, we had seven different sections where we would vote on the pluses and minuses, the zeros and ones, at all of those stages. Therefore, we significantly improved the reliability of the digital computer. We, of course, never had a flight failure in the Saturn vehicle.

One other challenge I might say of the major components of the Saturn guidance control system was to miniaturize the stabilized platform. The stabilized platform is the technique we use as a reference system. We used gyros that would space fix a platform on which accelerometers would be mounted and also you had gimbals so you could sense the motion of the vehicle around the stable platform. On the heavier vehicles we worked on earlier where we did not have to be so concerned about weight, we used an approach that was very large and quite heavy compared to what we really needed on the Saturn. We did go to a miniaturized version of that same concept we had used on

the Redstone and the Jupiter vehicle. I would say those were two of the major challenges we had from a technical standpoint. We used the same stabilized platform concepts, which air bearing were a concept developed right here in Huntsville, Alabama. It was a carried over experience from the German team, but we were able to miniaturize that platform to test it on the earlier vehicles, like the Saturn I and IB, which were test vehicles for the Saturn V, and prove the reliability. In fact, those are two of the major components, the most critical components of the guidance and control system.

Johnson: As far as testing goes, were most of the valuable tests flight tests or did you do a lot of ground testing also?

Moore: We did extensive ground testing in all subsystems. This means in my particular area, we tested even down to the electronic component level. We used specified parts that had been tested and essentially designed for the rugged nature of what we would see in the launch vehicle. All of our systems we had tested at the individual component level and we tested at what we call the black box level. We did vibration tests, thermal tests, vacuum tests, every way we could think of to simulate the environment of flight. We even had what we called a bread board, which was a system where we pulled all of the systems together. In the case of the guidance control navigation system. We had them mounted in what we called an Instrument Unit, which was the flight

configuration of the hardware for the Saturn V. We did functional testing of that complete Instrument Unit. This was just for our subsystem, of course, but all the other subsystems, the propulsion systems and the structures, all of those subsystems did their individual testing.

Even though we relied on analyses to do the design to start with, one of Dr. von Braun's quotes was, "One good test is worth 1000 analyses." He believed in testing and we did testing at all levels. We had a lot of failures on the ground and we did a lot of upgrading and comparing to overcome those failures. On the earlier test vehicles, we did not have the phenomenal success we had on the Saturn V. The Saturn V did not just happen, it evolved from the Redstone and Jupiter vehicles. We had a number of test failures back in those earlier days, back in the 1950s. We had a number of malfunctions in flight in those early vehicles. We had good telemetry systems that we could go back and figure out what the problem was from the information we got telemetered back to us on the ground, It was an evolution sort of thig. By the time we got to the Saturn V, we had evolved to the point that we actually never had a catastrophic flight failure. We had some anomalies in the Saturn Program, but the Saturn V Program, I believe, is the only program even to date that was completely successful.

We had a Saturn I and Saturn IB Program prior to the Saturn V, which was an upgrade where we also did a lot of this testing. That was a situation where we actually combined a lot of the hardware from the Redstone and Jupiter Programs and built a larger vehicle. You might have seen the Saturn Is out a the [U.S.] Space and Rocket Center. There are a bunch of tanks you see. It is not just a single tank. Those are actually Redstone tanks clustered around a Jupiter tank. That vehicle was used to flight test some of the hardware. In particular, in the case of the guidance system, we put a passenger platform on a Saturn I and a passenger computer on a Saturn I and flew it using the old analogue techniques, but we actually got a flight test of the hardware. I think all of those testing situations, testing from every aspect we could imagine, is what led us to the phenomenal success of the Saturn V.

Johnson: Did you have to develop any new tools or come up with any new materials? Could you talk about that process?

Moore: As far as materials and tools, we had to, in the case of the design of the electronic components in particular in the flight computer I mentioned, up to that time, we had not flown a digital computer and we were concerned about its reliability. In order to build in all of these redundancies, a replication in order to assure reliability, we badly needed a new technique of electronic device rather than the little discreet

capacitors and resistors that you used to see in radios at that timeframe. This was a key contribution of IBM, they came up with a technique of screening a conducting material onto little silicone substrates, miniature. They were about a quarter of an inch square and a sixteenth of an inch thick. Using this screening technique, you could actually put the equivalent of maybe a dozen standard components onto a miniature. This was all the beginning of integrated circuits. Everything now has integrated screen circuits, almost every bit of electronics. A lot of that was done very early in the space program, and some of the present electronics is an outgrowth of that.

In the other areas of propulsion, they were constantly working to come up with new and better materials. Of course, that is out of my area of specialty, but we did work closely with the Materials Laboratory. They assisted us with their expertise with materials as far as the things we needed to do in order to microminiaturize our electronic components to make it so that even this triple modular computer that I mentioned still only weighed seventy-five, eighty pounds and dimensions of twenty inches by fifteen inches, a foot thick. To use the old technology, it would have been too heavy and too large to fly. That was where we had to depend. We shied away from new technology wherever we could, but that was a case where we were forced to it and it worked out.

Johnson: Could you talk about the pace of work. How fast did things have to be accomplished during these Saturn years?

Moore: Things moved very fast. We had the assignment to put man on the Moon and return him to Earth within the decade from President [John Fitzgerald] Kennedy. At the time he made that famous pronouncement, we were really right at the very beginning of the space program. We had only flown Alan Shepard for a suborbital flight of 150 miles, riding on a Mercury-Redstone. We had put up Explorer I, we had put up some small satellites. As far as having anything approaching the capability of putting a man in space, even in Earth orbit, much less the consideration of going into lunar orbit, we did not really have that capability. It was an all-out effort based on this challenge to put man on the Moon and return him safely home.

Here, again, we relied on the experience we had to pull together, rather than designing from scratch, a test vehicle. We use the combination of Jupiter and Redstone hardware and built what we call a Saturn I and later called a Saturn IB, which was an upgrade of the Saturn I. We used that as a test vehicle so as we advanced and developed the articles that would actually fly on the Saturn V, we had the opportunity to test fly them on the test vehicle. The pace of work was very rapid. People were extremely conscientious. I will not say we worked seven days a week. We did not work 168 hours a week. I think

it was the dedication in addition to the hours spent and the expertise that had been pulled together with the team that made it possible. To develop a vehicle like that within that timeframe was unheard of at that time.

By clustering the Redstone and Jupiter vehicle technology into a cluster and putting eight engines on it, we were able to put astronauts into Earth orbit. We accomplished that by about 1966. We were past that first step. The big step beyond that, of course, was to have the full-up Saturn V vehicle with its three stages. Prior to the Saturn Program, we had only designed and built single stage vehicles. When we got into the Saturn I and IB, we did gain experience with two stages. The first launch stage was the combined Saturn and Jupiter. With the help of McDonnell Douglas, we built an upper stage that flew on the Saturn IB stages. The Saturn V was not only a major step forward as far as size is concerned, but it was also in complexity because of the three propelled stages, five engines on the first stage, five engines on the second stage, and one engine on the third stage. That was a rather ambitious program, but with a lot of good fortune, we were able to pull it off and meet the deadline President Kennedy had set.

Johnson: How about the work hours and shifts you had to work? Did you have to work a lot of extra hours?

Moore: I worked extra hours as required. There were a lot of people, like the technicians, that were doing a lot of the hands-on work that had occasions where they had to work much longer hours than we did. We were often on a six day week. Very seldom did we go to a seven day week, except in specialized areas. This was the constant monitoring. Not only did we have key technical people to do all this work, but we had these excellent program managers who tracked the progress of all the subsystems. They had this famous expression, they used the long pole in the tent. What is it that is likely to delay us? Wherever there was a potential problem of a likelihood of delay, additional effort would be put onto those programs. One thing about the Saturn V Program that was unique is that we were not constrained funding wise. Whatever we needed to do, we were supported in doing. That is unique in the space program both before Saturn V and since Saturn V. In the meantime, we had reverted to a stage where we are not three percent of the gross national product that is allocated to space.

Johnson: From what you said, money was not a problem, but did you work to control costs at all?

Moore: Yes, we did. I should not infer that we were careless. The program managers held the purse strings pretty tight. You did not go to them for frivolous additional allocation of funds, but if they detected a program area where they could apply

additional resources, that is really what I meant. We did not consider ourselves unlimited. We were prudent, we had trained to be prudent. Back in the earlier years of Redstone and Jupiter, we were extremely austere and we had learned as a heritage to do things as well as we could, as economically as we could. Where there was a need for additional effort, like additional personnel, additional funding, even bringing in an additional contractor, in some cases we did that. When we became nervous a contractor was building a certain subsystem, we had what we call a single point failure in the system, and we would go out and hire another contractor to duplicate that.

One thing that comes to mind in my area of responsibility was the hydraulic actuators for the engines. We suddenly realized as we were well into the program that we had one company, Moog Valve Company, that was building all of our actuators. They were not a large contractor, but we realized if something were to happen in their plant, that they could cause a delay in the vehicle. We went out and found another competent contractor and actually built duplicate equipment. There were cases where we expended beyond what we would have in the earlier years where we had to take some chances. On the Saturn V Program, we tried to minimize those chances.

Johnson: Talk about the work environment. Was it a good place to work?

Moore: It was an excellent place to work. It is amazing the team spirit we had within what we call the von Braun team. It really was a team and he was the team leader. At the senior levels, like the laboratory directors, we had the key German, we called them scientists, but they were really engineers. Dr. [Ernst] Stuhlinger was probably the only true scientist among the 120. Von Braun and his key leaders were unparalleled in their expertise, knowledge, and experience in their particular disciplines. They had the very highest respect. The engineers like myself that came in later and learned from them, they made us feel a part of the team. I had nothing but very excellent relationships with all of them. I knew all 120 reasonably well. Of course, I worked with some of them much, much closer than others.

Dr. von Braun operated as a team leader in a somewhat unorthodox management approach, but he tried to get inputs from all levels. He would go out of his way to try to get the opinions of experts at the lowest level. All this was orchestrated through the laboratory directors. There were eight labs that reported to him. I was fortunate later to become one of those when my mentor, Dr. [Walter] Haeussermann, was given another assignment. During most of the Saturn development program, the eight specialized laboratories, each one had a special discipline and they had clear lines of responsibility and they delegated clear lines of responsibility. We had key engineers that fulfilled all of those obligations.

The team spirit was we were all working toward the same goal and felt like this was a unique opportunity. We always had a situation that somebody else would pick up the slack if you had somebody that maybe was a marginal performer. Here again, we were not constrained if we had to hire in some additional expert because one of the other was not performing quite as well as we would like. We had the wherewithal to do that. That gave us an environment of success that created cause for us to have the team spirit we did and have the success we had.

Johnson: Were there any dead ends in your work? If there were, how did you recover from them?

Moore: I cannot think of anything in successful programs. We did get in, and this is getting into the utilization of the Saturn in the Skylab Program, and that may be getting beyond. Skylab was our nation's first space station and it was put up by a Saturn V. In that regard, it is a part of the Saturn Program. What we did there was take the upper stage of the vehicle and convert it to a laboratory. I guess there were some conceptual changes that were made along the way with that. In the first concept, we were going to actually use that upper stage as part of the propulsion, but we found out there would be too many complications of having a stage that could be a laboratory but also carry fuel and oxygen. We went in the other direction and came up with a concept called the dry

workshop where we actually used the upper stage and equipped it on the ground as a laboratory. Skylab was a very successful program. It was put in orbit by the Saturn V, the first two stages.

A program cancellation that I would say is one of the most disappointing moments of my career was Skylab, which had served well as a space station. We had three different crews that visited that and stayed for periods of two to three months. We were gaining very valuable experience with man operating in Earth orbit over long durations. After the three missions, we had decided we would build a little tele operator that would go up and reboost Skylab to keep it in orbit so it could be later used and further equipped and serviced. We would have had a continuing space station from 1974 rather than what we did. That tele operator retrieval system, which was cancelled because of the desire to get on with the shuttle and to put all funds available to NASA [National Aeronautics and Space Administration] into the shuttle.

I think one of the most serious mistakes made by the NASA management was not to keep Skylab in orbit. We could have continued Space Station twenty-five years earlier. That was one of those areas where we had to deviate from a plan that we did not have a successful end to that story. Skylab reentered in 1979, it burned up on reentry. The management rationale was we would have the shuttle in time to go up and reboost the

Skylab. Those of us that were close to the program felt that was totally unrealistic, and it was. We were not even close to being ready to go up with the shuttle, but that was the rationale that was used. I would say that is one that sticks in my mind as one of the major disappointments in redirections that effected our situation, even up to today.

Johnson: Were there any surprises while you were doing your development work for the Saturn Program?

Moore: Every day. (Laughs) Many, many surprises starting all the way back to the Redstone. We tried to use mathematical equations to describe the vehicle and to use simulators to simulate the flight. The first flight test, we had a failure, and it was because we had not actually described quite properly the aerodynamics of the vehicle because of interpretation, wind tunnel tests, some problem of that nature. We had a lot of surprises along the way. One we had to learn the hard way is that if you have a large propulsion tank, you have to have baffles in it, or some means of keeping the fuel and liquid oxygen from sloshing. We actually had a flight failure. I say again, we got through the failures on the precursor to the Saturn V. The first time we flew a tank that was more than about three or four feet in diameter, that would have been on the Jupiter Program, we actually had that first flight fail because of sloshing, which causes side forces and caused the vehicle to eventually fail.

There were a lot of surprises along the way. One that sticks in my mind is to gimbal a large engine, we did that with large actuators, which is a hydraulic device like you would see on a caterpillar for lifting the blade. We had an upgraded version of those. The first time we tried to gimbal one of those engines on a test stand with a live firing, we found out the engine stood still and the structure on the other end took up all the slack. There was a structural design deficiency that had to be overcome. There were a lot of surprises along the way. Fortunately, we were always able, except for some unfortunate cancellation of programs, to recover any of the deviations that occurred.

Johnson: Can you talk about the difference between Marshall and the other NASA centers? Were there rivalries that you noticed?

Moore: I have extreme difficulty being objective here since my whole career in the space program was at Marshall and I am still even involved through a contractor in keeping up with what is going on out there. I think we probably had the most unique assemblage of engineering talent that existed within the agency as civil service people. Other centers certainly had scientists who were more renown. Within the expertise of launch vehicles and even on orbit spacecraft, I think we had a unique situation. One thing is the organization, we had very clear cut disciplines with senior technical people that knew, even all the way up to the laboratory director, the technical discipline in

depth. I think we had a unique management arrangement in the way Dr. von Braun managed and the way he had these large meetings where he would have all the specialists together and he would go around the table and ask everybody what their opinion was. At least everybody thought they were involved and therefore they kept highly motivated.

As far as interagency competition, there was always a very strong inter center competition between Johnson [Space Center] and Marshall. Johnson was an outgrowth of Langley [Research Center] when it was NACA [National Advisory Committee for Aeronautics]. They were the first center that organized and it was organized at Langley and then it was moved out to Houston [Texas] and named for [Lyndon Baines] Johnson. We were sort of joining the team after they were the key center that started NASA. There was a constant competition between the two laboratories, even in the concept of how we would do the Saturn Program. Johnson, they wanted to do the complete guidance and control and everything else all within the spacecraft. Of course, the concept which we had used in the past and what we felt was justified for the Saturn was to develop a totally independent launch vehicle which had its own guidance and control. The spacecraft would be a separate vehicle.

Even from those very early days, there was competition and attempts, as we saw it, to infringe on the expertise and what we had to bring to bear in the launch vehicle area to NASA. The other thing was the competition, or influence, of the fact that the astronauts being test pilots, they wanted to fly the vehicle. Marshall had always had automated systems that we had hands-off, that everything was onboard and we felt that was the way to handle this as far as the Saturn/ Apollo Program. Those were issues that were worked out at the highest level between von Braun and Dr. [Robert Rowe] Gilruth. At least with Johnson Space Center, we always felt uneasy that they were maybe trying to pull some things from behind the back.

In general, the cooperation with other centers was very good. For instance, JPL [Jet Propulsion Laboratory], we had an excellent relationship going all the way back to when we launched Explorer I. We did that jointly with JPL. They furnished the upper stages. From a scientific payload standpoint, we had very close and congenial relations with JPL and really with most of the other centers because we relied on the so-called research centers. There were several centers like Ames [Research Center] and Langley and Goddard [Space Flight Center] that were focused on research. We actually utilized them and got considerable assistance from them in certain areas. Like Langley, as far as the actuations systems we had on Skylab, we used what they call control moment gyros, huge gyros, that actually applied the force to Skylab to keep it in orbit, to keep it

oriented directly. Langley had done a considerable research effort in trying to develop a large gyro, which was unique at that point in time. We worked very closely with them and they cooperated with us and helped to supervise the development of the actuation systems we used on Skylab. I would say in general, with the exception of JSC, we had good working relationships. At JSC, though, I always felt it really went all the way to the very top as far as the jealousy, resentment, or whatever of Marshall Space Flight Center. I think there was, unfortunately, a little bit of the German heritage that was a part of that resentment.

Johnson: Talk about Dr. von Braun's involvement, both direct and indirect in what you did. Was he around a lot?

Moore: He was around an awful lot. He showed up at unexpected times. He was a hands-on guy and really believed he had to interface with employees. This goes back pre Saturn, I had not been here more than two, three, four weeks when I joined the Army. Back then we were out in the metal buildings. We were really an austere environment. I was back in the boondocks in Building 4481. I had been assigned to do some testing with a technician on a helium leak detector that we borrowed. That is what they did, they borrowed things from Oak Ridge or wherever. Dr. von Braun walked in with the then lab director of that operation. He and the laboratory director had a

dialogue going about the helium leak detector and whether it would be practical for use for testing for leaks on tanks. I could sense from the conversation that von Braun thought it would not be practical, but the laboratory director thought it could be. He introduced me and the technician and he turned to me and said, "Brooks, what do you think?" I stammered a little bit and then admitted I was too new on the program and did not want to get in the middle between him and the lab director.

I mention that for two reasons, he had a unique capability to remember names and from that day on, he knew me as Brooks. I certainly did not call him Wernher, I tell you what. I called him Dr. von Braun until the day he left. He was out and about. I remember one instance walking through the laboratory and in the hallway he saw what turned out to be a janitor with a smock on like the lab folks wore. He went up to him and asked him what his role was, what did he do to support the program. He told him he was the janitor and he said he was certainly doing a great job of keeping this place clean for these workers.

Another thing, if he was expecting some visitors and wanted to understand some details of what was going on in a lab, he would come through and we would brief him. Then he would come through and essentially do the briefing himself. He had the phenomenal knack of communication and of insight into so many technical areas that

were really not his original area of specialty. His original area of specialty and interest was propulsion and rocketry. He understood enough in the guidance control and navigation area even though he left the detailed supervision up to Dr. Walter Haeussermann who was my mentor and who was the laboratory director over astrionics before I became lab director. Dr. von Braun was out and about and always tried to make everybody feel like their opinion counted and I think that paid off as far as team spirit.

Johnson: Talk about the integration of the different parts, projects, and designs, how well your work was added to everything everyone else had done. Were you excited about how it worked? Did it all work well together?

Moore: Fortunately, we had all of these check points along the way that when you finally brought everything together, it was not as if there had not been some exposure beforehand. I am speaking particularly of the Saturn V integration into a structure, which was the Instrument Unit. This was a case where my responsibility was all of the black boxes, the individual sensors, computers, gyros, various instrumentation. When we integrated this into the Instrument Unit, that was a physical integration of making things fit together and having the wiring so everything was properly connected. We

went through a great deal of preliminary integration at all levels where we worked very closely with the mechanical people on how our boxes would be mounted.

By the way, the Instrument Unit did have a unique capability of a built in refrigeration system. It had a cooling system because of the fact that in space, we did not have the convection of air to cool the system like you would have in a low-flying aircraft. We had to have cold plates that were mounted around the inside of the Instrument Unit, which is a ring. The Instrument Unit is a three-foot high, thirty-three foot diameter ring. Inside that, we had cold plates that we mounted our instruments on. Of course, the coordination of the design of the instrument and how it was going to fit on the cold plate, all of that was worked out at the working level by people working together.

When it came together, we had some surprises, there is always an occasion of things not exactly fitting. There were some functional surprises, a few integrated things. The final integration, of course, was stacking all of the stages. That was something that you had a few surprises, but along the way, most of the mating surfaces had been checked out, so it was pretty well a routine matter of putting it together eventually.

Johnson: Describe the contractor experience in your work. You have already mentioned IBM as being a good partner. Generally speaking, was the experience of working with contractors at Marshall a good one for you?

Moore: It was good. It was good because we were fortunate to select very fortunate contractors. I think one of the key aspects of that is Dr. von Braun insisted that a contractor have a strong local presence. Of course, we could not move some of the aircraft companies from the west coast where they had their large manufacturing facilities, but wherever we could, we had a strong local presence. IBM, we selected them with rules of competition and selection. With the present rules of competition and selection, I do not know whether we would have gotten to the Moon or not. We literally made the decision that we wanted IBM. I was among the group of three or four people that went up to check them out at their plant in Owego, New York. As far as experience with flight systems they were building, some computers the Air Force had flown. We felt like they probably had more experience than anyone else with flight digital systems. We essentially made the selection and von Braun made the decision and directed to give them the contract.

Mr. [Thomas John] Watson [Junior] was the president of IBM at that time and Dr. von Braun interfaced with him directly and told him he wanted him to build a plant in

Huntsville, Alabama so we could have very, very close coordination. Not only did IBM design with us, with a very close cooperative, we had technical specialists and they had technical specialists, and we worked very closely together, but they also had the contract of integrating the other components into the Instrument Unit. That was done right here, not more than three or four miles outside the [Redstone] Arsenal where we could visit them on a daily basis and they could visit us.

Another key contractor we had was Bendix [Corporation], who built the stabilized platforms not for the Saturn. Here again, we had a continuity of experience in that we had worked with them on the earlier vehicles, the Redstone and the Jupiter. It was a team relationship that was already established. They took the designs that were done by the team here in Huntsville of these complex stabilized platforms and did the fabrication. They helped us with improving the design to make it more easily manufactured.

We had a little company that did our so-called control computer. It was an electronic communications in Orlando, Florida. They were selected because they had a good experience. That was an analogue system. Fortunately, we had clear lines of responsibility. Every black box, there was a key engineer, we had a name that that individual was responsible for coordinating the work internally and dealing with the

contractor. The contractors knew how to work with us. I would say our experience was very good as far as dealing with the contractors.

Of course, the propulsion structures people, there were some problems along the way in those regards because a lot of that work had to be done remotely at the contactor's plant. Our program manager kept on top of things. I would like to mention the program managers were well coordinated. We had one for each of the stages an then a program manager for the whole Saturn V. Where it was perceived the contractor was getting into some difficulty of schedule, and that actually happened, and I hate to call names in this regard, but North American was building the S-II stage and it became obvious they were lagging and were not going to be able to make the deadline. They were not progressing as well as Boeing was on the S-IC and McDonnell Douglas was on the S-IV-B. A team of key people from Marshall lead by Dr. [Eberhard] Rees, who was von Braun's deputy, actually went and camped out, you might say, in California for about a year to have onsite insight into that situation. They were able to recover with the help of Marshall and the management expertise and insight that was brought to bear.

Johnson: How about NASA Headquarters? Did it help or did it interfere in the work you were doing?

Moore: (Laughs) We often said if somebody showed up and said, "I am from Washington [District of Columbia] and I am here to help you," you should beware. I think it was a mixed bag. We had some very astute managers that were the head of our Manned Spaceflight, which was what we interfaced with. Dr. [George] Mueller. Let me mention him by name, he was the director of Manned Spaceflight, not at the very beginning of the Saturn Program, but during a lot of those critical phases. You probably have met him. He has been here in Huntsville several times in recent years for special events. He is still healthy enough that he was here last year, but not this year. I would say he was one of those that actually contributed. There were earlier managers, you might say, who probably did not have the technical insight that he had. There were probably some problems created by their enforcement of certain things.

One thing that comes to my mind is you hear now that the key thing is you have to have system engineers that make sure everything is going to fit together. The Saturn Program was not designed that way. We did all the systems engineering by the fact that we knew each other and we knew who the experts were, who the managers were that were responsible. About 1967, Headquarters decided that Marshall was not organized properly and they needed to have a Systems Laboratory. We had what we called eight different fiefdoms at that time, Astrionics, Electronics, Structures, Propulsion, Tests, Manufacturing, but each one of those was headed up by the key specialists in the area

and they had done quite well. They decided we had to have a Systems Laboratory, so they decreed that.

In a way it gave me an opportunity in that Dr. Haeussermann was selected to head up that laboratory and none of the lab directors wanted to take on that responsibility. They were all key in their technical specialties. We had a chief engineer, but we did not have a heavily populated systems engineering. Dr. von Braun insisted one of the laboratory directors take over that lab. They met and discussed it for hours, apparently, and Dr. Haeussermann finally acquiesced and agreed to take over the lab with the stipulation with Dr. von Braun, for some reason I do not know, he insisted I be named the laboratory director. I would say Headquarters' interference maybe gave me an advancement opportunity, which I would have been glad not to have had because I really felt it did not work out to Dr. Haeussermann's benefit. I have always regretted that because the so-called Systems Laboratory, it was too late in the program and we did not need it, in all honesty. The program managers, from an internal standpoint, it was a situation that sticks out in my mind that it was an enforced Headquarters reorganization that did not necessarily help.

Johnson: How did you feel when the Saturn V first flew?

Moore: It was greatly gratifying. I do not know how to express it any other way. It was a thrill. It was not the first one I had had. We had some other major accomplishments along the way. We had the first Explorer, the first satellite, the launch on the Redstone, and the intervening vehicles we worked on. The Saturn V, that was a unique experience. I was fortunate enough to be at the Cape [Canaveral, Florida] for that first launch. I was not in the control room though. We had two control rooms. You have a control room where all the active guys were on the panels controlling all the subsystems and then we had a similar control room where the more senior people sort of overviewed things. You never know until it is over if it was successful. As soon as it is launched, you get that exhilarating feeling and you see it, but you know there are still some critical things ahead. Until that last stage burned out, I did not feel like celebrating. It was a unique experience.

Johnson: Did you sense during the Saturn V Program that you were making history? Was that something you ever thought about or talked about?

Moore: Not really. It was one little step at a time. You got involved in it. When we got into the Saturn V Program and the gratification for having a job and assignment that you had the wherewithal to do with whatever resources you needed, it was just the job itself. It was a daily experience. There were new things all the time and it was a learning

experience. I would say I had serious doubts that we would ever get a man to the Moon and back without casualties. Therefore, I was not able to celebrate until after we got the first crew back from the Moon. (Laughs) I was fortunate enough to be there for the first launch that landed on the Moon. I did not feel like celebrating even when they landed. Of course, our responsibility was essentially over once we injected them into Earth orbit.

As far as the burden on me personally, it was relieved if we got them on a trajectory to the Moon. I did not feel like celebrating until they got off of the Moon, which was not our responsibility at all. I think one of the real pluses of the Saturn/Apollo Program was that decision to make a clear delineation between the launch vehicle and the spacecraft. The spacecraft people had enough problems of their own with the lunar lander and having to get back up into lunar orbit. I believe that management decision that was made back early in the program at the highest levels, we had such clear cut responsibilities with no need for much communication technically and even functionally across that interface between the launch vehicle and the spacecraft.

I never really realized, except in later years, that what we did was historic because I guess I was foolish enough to think we were going to continue and we had not yet reached the ultimate. We were already talking about going to Mars. I did not know that

it would happen in my life, which it obviously will not, but we were already of thinking of the next step without thinking about this being a unique situation. We were going to rise to this point and we were not going out of Earth orbit again for decades. It has taken quite a few years for the significance to sink in. Invariably, we did do something that was probably about as special as building the pyramids.

Johnson: We know how much recognition Dr. von Braun and the German rocket team got. Did the rest of the workforce receive the recognition they deserved? Do you feel like you received the recognition you deserved for your work in making history?

Moore: I did. You may talk to some people who feel the German team got more credit than they deserved. Dr. von Braun was always in the forefront and there is no doubt he was the key leader. Perhaps we could have had success without all 120 of the original team, but in a way they were all key. Some of these were people down at the hands-on technician level, some of that 120. They were not all Ph. Ds [Doctor of Philosophy]. I felt like the Americans like myself owed a great deal to that team because of the experience they had, that they instilled in us, and that they brought us along. I never would have been a part of this effort if it had not been for the German team. There are some people out there that feel like the contribution of the German team was overemphasized, but I

am certainly not one of them. I am a strong supporter and believe every bit of the recognition that von Braun got, he deserved, and that the team got.

It is interesting that the team as individuals did not really get a lot of recognition. In fact, until a couple of my friends and I started an effort to recognize the rest of the team, there was nowhere in Huntsville that the names of all of those 120 were engraved in stone or in bronze. Three of us on the Marshall Retiree Association decided that every one of those names needed to be highlighted, even down to the last technician. We actually sponsored an effort, the Marshall Retiree Association Board, and we now have a plaque under the Saturn out in the courtyard, a large plaque, twenty by thirty or something like that, that has the name of every one of the German contributors. Likewise, we have a bronze plaque inside the Davidson Center that has those names. You cannot believe the appreciation we got from the widows and from the families of those.

There were a lot of them whose names were totally unknown. They were just known as the 120 German scientists. Those who were recognized as the leaders, like the lab directors and the lead managers, they got a lot of visibility, but down it the ranks, a lot of them did not. I got more awards and citations than I would ever have expected I would have gotten. I think the Americans, as they got into key positions, and I happen

to be one of the very first. I was the first non-German lab director. We brought other people along into those intermediate supervisor positions. I believe we owed the team more, and we owed the nation more, for being a part of this team than the nation owes us.

Johnson: Compare, if you would, the challenges faced in the Saturn Program with those faced with the shuttle development stage, which you were a part of both.

Moore: Here I have to speak very candidly. I feel like the shuttle concept was a mistake. This may be something you may want to delete. I was never comfortable with concept of a side-mount crew compartment with strap-on boosters and without any way for crew to escape. As is said, I have trouble being objective because there were some things done in those early days that concentrated all the funds for the orbiter and we were limping along in a somewhat more austere situation as far as developing the propulsion systems that had to lift the orbiter. That decision to let Skylab come down and to put all the money into the development of the orbiter, to use an upgraded existing solid rocket booster, and things like that. I was very concerned from the very beginning.

The first time I saw the concept they had for the thermal, which is not my area of specialty, but the thermal coating for the wings of the orbiter was just like egg shells. It is very fragile. As many launches as I have ever seen, I have never seen one where debris did not fall off the launch vehicle. I had personal concerns from the very beginning about that concept. We actually had a lesser role, so it was less exciting. As we went into the shuttle, our area of responsibility was decreased. That is the reason I am having to say more than once that I am probably not objective. I do feel there were a lot of mistakes that were made.

We did the best with the assignments we did have. The most challenging one was that the Space Shuttle Main Engine was so complex that it had to have a digital computer onboard, literally mounted on the engine. Of the challenges in my area of responsibility, that was the one I was most concerned about. Even though we had always been concerned about vibrations, to have a digital computer that would mount on the engine and be gimbaled with the engine, that was an area of great concern. Fortunately, we never had a failure of those computers. We never had a failure on the shuttle of our systems that we were responsible for. I guess we can take pride in the fact that we did our job.

It was not as challenging and as exciting, certainly, as the Saturn V. After the first failure and realizations that we were not going to be able to make it with no casualties and then the second failure, I, frankly, blame both on the configuration. I think it could have been done differently. We made the decision to try to go partially recoverable. That was the whole concept, to save money. It has not worked out. There has been more money spent on the shuttle because of the complexity. The orbiter, the astronauts will tell you is was a great machine. It, unfortunately, did not have the protective devices that we existed on having on anything where we were responsible for the launch vehicle. I have mixed thoughts about the shuttle. I am not as proud of my contribution to the shuttle.

There are strong supports of the shuttle, and probably these comments would raise some eyebrows, even some of my friends. It is a remarkable accomplishment with two key blotches on it, and that is the loss of the two crews. That is not an insignificant sacrifice. We did lose one crew on the Saturn, but it was a ground situation. That is where they were using pure oxygen in the spacecraft. Because of that, we lost the three astronauts. I go to the Shuttle Buddies breakfast. I am supportive. I know it was a great accomplishment and Marshall's contribution was significant. I am most pleased that on the Space Launch System that is now on the drawing boards, they are returning to Saturn V concept, pure and simple. We are going back to the inline configuration with the means of a crew escape on top and I feel good about that. My only concern is the

lack of funding and the lack of support from the administration. The concept is not quite Saturn V, but it is easing back in that direction. They still plan to have strap-on Solid Rocket Boosters in the early systems, but the later phases have the possibility of having some other kind of higher specific impulse liquid vehicle.

Dr. von Braun's interest in propulsion systems was always directly related to the specific impulse, the amount of thrust you get per pound. He never really cared much for Solid Rocket Boosters because they are lower specific impulse. Even the Pershing we developed for the Army, the weapons system, was a solid. That was in the very last days of our stay with the Army. If his influence was still being felt, I am not absolutely sure we would have exactly the configuration we have of the Space Launch System. I am extremely encouraged that that configuration has the promise that we could at least let the crew have a chance of getting off. I think that is key to manned spaceflight.