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

Otha "Skeet" Vaughan
Interviewed by Steve Johnson
Huntsville, Alabama – Unknown, Circa 2012

Steve Johnson: I am talking with [Otha] Skeet Vaughan, who moved to Huntsville [Alabama] in 1956 to work with the AMBA, the Army Ballistic Missile Agency. In 1960, he moved to Marshall [Space Flight Center] with the [Wernher] von Braun team. He stayed there until he retired from NASA [National Aeronautics and Space Administration] in 1999. Skeet, would you talk a little bit about your education, how the education you got prepared you to work in aerospace?

Skeet Vaughan: I went to Clemson A&M [Agriculture and Mechanical] College in 1946.

Johnson: It was called Clemson A&M?

Vaughan: It was called Clemson A&M College. I majored in mechanical engineering and was also in the Air Force ROTC [Reserve Officer Training Corps] there. I graduated in 1951 with a commission of second lieutenant in the Air Force. I graduated the third of June 1951 and on the seventh of June, I was on active duty with the Air Force as a second lieutenant in the 25th Weather Squadron at Robins Air Force Base, Georgia as an aircraft maintenance officer. Then I applied for pilot training and went to Moultrie, Georgia, Spence Field, in October 1951 to begin my pilot training. The trouble was, I had an ear condition while I was in training and I was grounded from flying from that point. I wound up working in Tinker Air Force Base with early jet engine research work. I did that for a couple of years, from 1951 to 1953, basically. Later on, I got out of the Air Force and went into the reserves. I went back to college to work on a master's degree in mechanical engineering. I completed most of my requirements for it and then went to work in Florida at Eglin Air Force Base as a weapons test engineer in 1956. I heard about the von Braun team coming to Huntsville and decided I wanted to come to Huntsville and be part of the rocket team.

Johnson: This was with the Army?

Vaughan: This was the Army Ballistic Missile Agency. We were tasked with developing ballistic missiles. My first job with them was to develop the cooling system designs for the Redstone missile as well as the Jupiter-C missile and the Juno missile. I also did aerodynamic heating studies and flight evaluation studies while I was a part of that team. Later on, we transferred into NASA in 1960, July the first.

Johnson: Which was your birthday.

Vaughan: That was my birthday. I was born in 1929, July 1, 1929.

Johnson: Let us talk about what you did when you moved to NASA in 1960 at Marshall Space Flight Center. During the Saturn days, which were just beginning, what did you do?

Vaughan: We were called the Aeroballistics Division at that point, and I was in the astrophysics group in that division. We tried to put together various environmental criteria documents for the spacecraft design, basically.

Johnson: When you say environmental, are you talking about environmental for humans inside?

Vaughan: No, the environment the vehicle must pass through, the Earth's atmosphere going into space. We had to define the specifics of radiation damage, temperature damage, aerodynamic heating information. Winds aloft are very much an important thing, and that really came into being with e Saturn because of the control systems. We had to be able to respond to these and correct for these winds as the spacecraft moved out of the atmosphere.

Johnson: My assumption is a lot of testing went on.

Vaughan: We did not do any testing. We did a lot of documentation to try to find out this information, going through weather records.

Johnson: Determining the environment is what you were doing.

Vaughan: Yes, we were determining and specifying what we thought would be the environment the vehicle must pass through. Like the winds, we had to have many studies. We launched many, many balloons from Kennedy [Space Center] and they gave us information about the wind's shears. Wind shears were very important in determining a control system design for the vehicle. It had to be able to respond to these wind shears and still stay on the flight path.

Johnson: Do you believe the studies you did, that information, is still used and applied at Kennedy Space Center?

Vaughan: It is used very much today. It was even used in the Shuttle Program. We would never have launched the Shuttle Program if we had not developed our environmental criteria documents for the shuttle.

Johnson: Talk about the main challenges you had in figuring out the environment the Saturn would have to pass through. What were the main challenges?

Vaughan: I did not specifically develop the environments. We had a team of people that developed these environments.

Johnson: I understand. For the team, what were the main challenges?

Vaughan: My area was mainly in the aerodynamics heating area in the early phases. Later on, even before I got into that, I was in the project office of the astrodynamics laboratory. That area was an area in which I wound up being assistant project engineer on the Atlas-Agena and Atlas-Centaur Programs as well as being a project engineer on the Apollo Program for our laboratory. I was looking at all the inputs that go into design. I had to make some considerations of what I thought about the environments. Environmental constraints were developed by a team of people. We had so many people in our group, you would not believe it. We had probably seventy, eighty people and each one had a specific area they tended to work on. I wound up working on the lunar surface environment. That is the area where I really did more than anything else.

Johnson: Working on the lunar surface environment, most people would think there is a vacuum and it is cold and hot.

Vaughan: That is part of the problem. The environmental criteria documents that I developed for the lunar surface operations were developed by a team of people plus myself. For example, people from the United States like to go survey Flagstaff, Arizona. I made many trips out there to talk to those people that were doing lunar geology. We developed here at Marshall a lunar geology course for people. Dr. John Rogers and myself taught that course for a little bit. We evolved this into why we want to go to the Moon and what features are interesting about the Moon. The next problem was how we would develop some system that would work on the Moon. That is where the environment comes in, your temperature, your radiation.

Johnson: What were the challenges you faced in trying to determine the environmental Moon surface?

Vaughan: A good example is for the Earth's first telescope observations we had of the Moon, we were looking at the minimum resolution, 300 meters, 900 foot craters. We had no information smaller than that of where we were going to land on the Moon. We were lucky over a period of time and were able to get the orbital spacecraft to go into orbit around the Moon. That gave us one meter resolution. I could sit at a particular landing site and measure and determine how many craters we would have, how big they would be, and how rough the surface might be. The next problem was the temperature environments, which the Moon's surface gets extremely hot, about 240 degrees Fahrenheit during the day at the equator. We had to design our vehicles for that. We had to worry about the surface roughness on the vehicle if we moved across it.

We also had to worry about the soil mechanics, what kind of material the lunar surface composed of. Based on studies done from Earth with temperature measurements and photometric measurements as well as radar measurements, we had a pretty fair idea how rough the surface might be at a very large scale, but not a very small scale. JPL [Jet Propulsion Laboratory] evolved the Surveyor Program, which would allow us to go to the Moon, land on the Moon successfully, and take photographs of the Moon, which would help us determine small surface characteristics. We did that. We were very fortunate in one case. One of the Surveyors came down and bounced about five times on the surface as it landed. Therefore, we knew the soil was a very thin layer and the the vehicle could bounce off a soft layer into a hard layer.

I came up with an idea of what we needed to do. Once we landed Surveyors, before we landed on the Moon, we needed to go to the Surveyor landing site and bring back parts of the spacecraft, like the mirrors, electrical equipment, wires, conditions, cameras, all this kind of stuff from an environmental standpoint, so we could learn something about what the environment was of that spacecraft on the lunar surface over a period of time. They did that in Apollo 12. They went to the Apollo 12 landing site, where we had a Surveyor spacecraft landed on the Moon, and we were able to bring back the cameras. That was one of my ideas. I felt very happy about that.

Johnson: You studied the environment, you came up with information that was applied to the vehicle and, I am sure, the crew suits and everything else.

Vaughan: No, we did not mess with the crew suits. That was somebody else. I strictly dealt with the surface environments.

Johnson: Once we put craft on the Moon's surface, did you find out things you did not anticipate in your work?

Vaughan: Not really, no. We did so many studies with the Lunar Roving Vehicle system. We actually started the Lunar Roving Vehicle systems in the 1957 in Project Horizon. That was ABMA development to put a lunar base on the Moon. We never got to do that.

Johnson: That was actually a secret project, am I correct?

Vaughan: That was a secret project at one time, yes. It was classified secret. Certain parts of it today are not available even though it was classified secret. I did not actually work in that area myself, but I knew about what was going on. I have some documents I kept myself over the year.

Johnson: Your work in the lunar environment was used for the Apollo landings, but your worked also helped with the designs of the Lunar Rover, am I correct?

Vaughan: Yes, my design criteria that was used is called Annex C in the Lunar Rover design statement of work. What I developed in that was four different surface models of what the Moon's surface might the like. Those designers, based on one of those models, thought it would be the best deal. We did an awful lot of studies in counting craters. Dr. [Nicholas C.] Nick Costes was a soil mechanics man. Nick and I worked very closely with developing a trafficability panel, group. We had a group of men together and we had to decide how this thing ought to be built and what criteria we should put to the vehicle designers. That is the way the Lunar Rover evolved. Everybody says, "I invented the Lunar Rover." That is not true. It was done by a lot of people.

Johnson: I suppose we could say that about most everything involved with the Apollo Program. It was a team effort, as Dr. von Braun has talked more than once.

Vaughan: It was so much effort. You did not want to do a bad job because you had a reflection on your team. That is what von Braun always said, "You are a team member. What you do reflects on our team. We know you will do a good job." He was such an enthusiastic person about that. It was a pleasure to work for a guy like that.

Johnson: Was he involved? Did he visit your lab and take an active interest in your studies?

Vaughan: Yes. You never knew when Dr. von Braun would stick his head in the door and ask you what you were doing. He was that type of person. He liked to get out and talk to people. When I had all my lunar photographs, I had an area in 4016, I would spread these photos, maps out, and he would come down with me and look at these maps. He would say, "This looks like an interesting site. Do you think we could go there?" I had that relationship with him, which not many people got to have.

Johnson: He was vitally interested in your work?

Vaughan: He was vitally interested in it. As a matter of fact, Clemson University asked von Braun to come talk. Von Braun wrote a letter back to my friend at the university that said he could not make it, but Otha Vaughan would be a good speaker. I thought that was tremendous that he would recommend me.

Johnson: I want to talk about the pace of work. You were working on multiple things during the Apollo Program. Was the pace of work accelerated during those years?

Vaughan: No, it was not really that accelerated. The idea was that we had a job to do, we had a deadline to do it, and we were going to do it. That was it. You did not mind working forty, sixty, eighty hours a week.

Johnson: You did work long shifts?

Vaughan: I worked long shifts, yes. In the Lunar Rover Area, I worked on developing the lunar surface model for the driving simulator, which we actually drove on the Moon with the astronauts. The astronauts drove on the Moon in our simulator in a space suit. From those studies, we were able to determine the single hand controller we used. We did a lot of studies on that thing. My job was to develop the surface model for the simulation. It was a lot of fun. I never had a job I did not enjoy.

Johnson: As it turned out, were your simulations pretty accurate?

Vaughan: We were very accurate. I have a document I wrote to Dr. Gasha [First Name/Spelling?] about what I thought the performance of the LRV [Lunar Roving Vehicle] would be on the Moon in 1969, before we ever went to the Moon. This document, I have a copy of it. It did exactly what I said.

Johnson: That had to make you feel good.

Vaughan: It makes me feel tremendous. I had worked so much with this thing. To get the small block-sized distributions on the lunar surface, we landed Surveyor. Surveyor had cameras, and we could actually took pictures of the block size.

Johnson: I am not sure I quite understand.

Vaughan: This is the rock sizes. When you start the mobility to move a vehicle across the surface, you have to worry about the surface's roughness, you have to worry about how many rocks you have to climb over. Can you go down that crater? Can you get out of that crater? You had to worry about slopes and things like that. What we did when the Surveyors landed, they would take photographs. We would take those photographs and would sit there and count the number of rocks within an area.

Johnson: You would count the rocks? How big of rocks are we talking about?

Vaughan: We are talking about rocks this big, five or six feet in diameter down to a very small size.

Johnson: Down to maybe the size of your fist?

Vaughan: Yes, down even smaller than that. We did this to get the block size distribution we thought might be on the lunar surface. We had the Surveyor block size distributions. We took some helicopters and flew up a certain area in Yuma, Arizona, over an area called Desert Pavement, which is nothing but layers and layers of rocks, all sizes. We took some photographs of those things, we gridded them off, and made grid structures of those things. Then we counted each block within that grid, summed all these blocks up, and got a distribution of the block. Then we overlaid that distribution against Surveyor distributions and we saw the similarity distributions were less than what we had. We knew we had a pretty good block count.

Johnson: This strikes me as a lot of detail to know how many rocks are in an area where the astronauts would be.

Vaughan: We had to do that because the problem was how big was the vehicle going to be. It can only be a certain size because we were worried about weight. We had to put it inside the LM [Lunar Module]. We had to fold it up. We had to develop what size we could get through the surface crater distribution to get to the block distributions. That is why we came up with the metal elastic wheel.

Johnson: That is the wheel for the Rover, which was a piano wire mesh?

Vaughan: Piano wire mesh, but it was not a NASA design and it was not a General Motors design. It actually comes from a design of an English guy in 1957 who was developing wheels for locomotives. He had wooden wheels and metal wheels. He was trying to come up with a better wheel design. He came up with what he called a metal-elastic wheel. He got a patent on it, but it never developed. Nothing ever happened with it. When we were looking for wheel designs for the Lunar Rover, one of our engineers at General Motors or one of our NASA engineers went to our patent office and could not find a design they liked. They went to England and found that patent and said that wheel would probably work because it meets the criteria of being able to stand the environment. It meets the criteria of being able to give up some kind of flexibility, motion, for ride control. It meets the requirement that it will penetrate in a soil and will give us a little bit of traction.

Johnson: The essential design was patented in the 1800s.

Vaughan: Yes, 1959, he got a patent in 1859.

Johnson: That was the essential design for the Lunar Rover wheel?

Vaughan: That was his design. It was a starting point. The General Motors people liked that design because it was really easy to work with, plus it could be compressed, and it met these requirements. If you used a rubber tire on the Moon with the temperature of 240-somthign degrees, it is not going to work too well. We did not want to use a pressurized tire on the Moon because if we did, if something went wrong, you could hurt somebody. The third thing is the fact that a rubber wheel would probably compress the soil. If it compresses the soil, you will not get any traction. The fact it actually did penetrate in the soil would give us some traction. The disadvantage is the fact it does penetrate the soil. From that standpoint, it does pick up little rocks, dust, boulders, and things like that. That is why we had to put the fenders on the Rover. We found that out after Apollo 11 landed.

Johnson: Am I correct that there was some fender damage a couple of times on the Rover?

Vaughan: Yes, John Young actually popped a fender off with his hammer. The point is the fact that the way we found out about the dust distribution and things like that was we built a carousel with a wheel and simulated soil mechanics, and we flew that thing in a one-sixth g [Gravity] traveler, in a KC-135. We photographed that and could see the dust patterns. On the Earth, the dust pattern goes around and straight out. On the Moon, the dust pattern does up and settles out. We knew we had to have fenders, so we put fenders on it. We were worried about the weight because we did not have that much allowance for weight, but we were able to work around that problem.

Johnson: The dust on the Moon, did you anticipate that it was going to get on everything? I understand it really got on everything.

Vaughan: I felt it would get on everything. If you watch the Apollo 11 landing site and you watch Neil Armstrong start to walk on the Moon, the first thing you notice is the stuff is like talcum powder. When you step on it, it squirt out. It is going to stay there.

Johnson: From environmental concerns for the Moon landing, you proceeded on to work in environmental systems, am I correct?

Vaughan: Yes.

Johnson: Talk about that. How did you translate what you had done with the Apollo Program and the Lunar Rovers into your next duty at Marshall?

Vaughan: The next phase was actually the Skylab Program. I wound up working in the Skylab Program developing some experiments to be flown on Skylab.

Johnson: Were these environmental experiments?

Vaughan: I got interested in weather. I am a pilot and I got interested in weather for years, lightning, storms. We got interested in atmospheric cloud physics, which I wound up working in. I am not a physicist, but I wound up being an atmospheric cloud physicist-type. I was basically studying how raindrops coalesce. We came up with the idea of flying some experiments in Skylab to demonstrate the coalescence of water drops in zero gravity. When you do water drop studies with a wind tunnel, the water comes down and the drops try to coalesce, but you have the wind messing them up, making them oscillate. That does not always work too well. We got the idea of taking an orange-colored drink and a grape-colored drink in Skylab and trying to impact those two to see how they would work.

Because Skylab does have an air flow in it, we had to have some way to control one drop. We told the astronauts to take a piece of dental floss and put a drop on the dental floss. Then they would take the second drop and flick it toward the other drop. Once they impact, we want you to photograph it. They did that. We saw the photographic evidence, which shows the drops oscillate to the right, then they oscillate that way, then they form a perfect almost square with the red on top and the black on the bottom. This is natural. You can predict these things. The fact that you could do it in zero gravity, we thought that was important, to learn something about drop coalescence. That was a Skylab experiment. That wound up being a student demonstration experiment.

Johnson: Of course you proceeded with other experiments.

Vaughan: I did a lot of work in the KC-135 Vomit Comet aircraft to demonstrate what I could do with water droplets.

Johnson: That is the one that simulates gravity with the parabolas. You flew a lot?

Vaughan: I got about 1,400 parabolas in the Vomit Comet.

Johnson: That is where you did your testing to see if your experiments would work.

Vaughan: I did a bunch of other testing besides my water drop stuff. We did some ice crystal testing.

Johnson: These are multiple experiments for Skylab?

Vaughan: Yes, but we never got to do those in Skylab. We only got to do one Skylab. My first drop dynamics experiment was done in Apollo. It was on Apollo 11. On Apollo 11, the Command Module pilot took a spoon and oscillated a water drop on a spoon, showing how the water drops would stick to the spoon. That was my first water drop experiment. That was not *my* experiment. That was Conlon's [First Name/Spelling?] experiment. They were interested in doing additional experiments if they had time. They volunteered to do one for us like that.

Johnson: You would also eventually work on experiments that flew on the shuttle, am I correct?

Vaughan: That is correct.

Johnson: Were any of the experiments you have flying on the shuttle developed during Skylab? Were those ideas that developed during Skylab?

Vasughan: No, these came later. In 1974 when the big tornadoes came through Huntsville, I was on my way back from California. I had the pleasure of watching the tornadoes develop north of our flight path. You could see the lightning and everything else. I got extremely interested in lightning. The pilot said he was going to try and land before the tornados hit Huntsville. We laded before the tornadoes came through. I came home and took some pictures off my back porch of the tornado. About three or four months later, Dr. Bernard Vonnegut came down from the State University of New York in Albany. He was an atmospheric electricity expert studying lightning for many, many years. Also, he is the first guy to develop artificial cloud seeding using silver iodine. He worked with [Irving] Langmuir, who developed the first cloud seeding with carbon dioxide drops.

Bernie came down and gave a talk. We talked a little bit after. He said, "I would love to get some kind of experiment on the space shuttle. Do you think we could do that?" He said, "I have a simple little hand-held camera system that I have been using to detect lightning with a small detector. I wonder if we could get that experiment on space shuttle." I said, "Bernie, what you need to do is give me a brief description of what you want to do, what you think it might cost, and I will put it in the system and see what happens." It happened. They needed some experiments for STS-2, the second shuttle flight. We came up with this idea of an experiments called the NDOSL, Nighttime/Daytime Optical Survey of Lightning.

The camera system was used with the optical detector. We also used a little tape recorder to record the optical pulses from the lightning. We got that data. They flew it on -2, -4, and -6 shuttles. We got nice data from that. We got optical signatures and electronic signatures of the lightning flashes, and we were also able to measure how big the flashes were on top of the clouds. The astronauts said it was extremely interesting to watch the lightning flashes, but we do not have time to do that. We do not have time to sit by and look out the window. What do you want to do next? I said, "I would like to continue what I am doing, if I could. Maybe I can develop an observation experiment where we actually observe lightning from space using the space shuttle black and white TV [Television] cameras. We will call that the Mesoscale Lightning Experiment."

Because the crew had told me about seeing lightning over very large areas, we started doing that. We started looking for lightning flash rates and how big they were so we could design a couple of satellites, which later became called the Optical Transit Detector and the LIS, Lightning Imaging Sensor. The data we developed for that was used in those two satellites, one of which is still up there now. What was interesting about it was, back in 1976 when I was flying [Lockheed] U-2 aircraft to make these observations above thunderstorms at night, one of the pilots told me he saw a lightning bolt go 300,000 feet above me, straight up. I asked if he had told anybody. He said nobody would believe him. He talked to the weather people and they did not believe him, lightning always comes to the ground. He said, "I saw it go all the way up. I had to fly over that storm in the next few minutes and I was a little leery about that." He said that is what he saw.

I took that information and wrote a paper. I asked the pilots if they had seen any unusual lightning. I got nineteen pilots that told me about seeing this unusual lightning they had seen, military pilots, civilian pilots. Now they had all retired and they did not mind talking about it. I documented the information. I took that information, went to NASA Headquarters, and said I wanted to use the payload bay cameras to look out to the horizon as we approach the storms to see if I can see some of this phenomena. In 1989, we saw what is now called the red sprites and the blue jets.

Johnson: Those are lightning bolts that do not go cloud to ground?

Vaughan: They are not lightning bolts. The red sprites, as we call them now, they occur about ninety-five miles above the top of the storm. What they look like is giant jellyfishes with green tentacles hanging down. They come down to about sixty-five miles. The reason they are there is because the nitrogen gases in the upper atmosphere tend to fluoresce when this energy charge hits them. It is like a neon bulb. You see these lined up in the sky. The next thing we saw were the blue jets, as we call them. They actually squirted out of the top of the storm and went up to about thirty-five miles above the top of the storm. These were not in color, so it did not make too much of an impression.

About two years [later], I gave a talk in Washington [District of Columbia] and one of the guys in the back row, he was from the University of Alaska Fairbanks, and he said he was studying aurora. He said, "I wonder if I could get some money to fly around some thunderstorms to record this in color?" I said, "If you can, I would appreciate it. There is no way I can get a color camera, low light level, on the shuttle to do this job and I want to know what these things are." He did that. Again on my birthday, July 1994, they flew around a thunderstorm in Arkansas. The top of that storm was over 65,000 feet. It had a tornado in the bottom of it. They took two airplanes and flew around this storm and got stereo pairs of the red sprites and the blue jets. It is fascinating. As I said, I had thirty-nine years with NASA, but I did not have a job where I had so much fun. (Both Laugh)

Johnson: If I were to ask you a question about the work environment at Marshall Space Flight Center, you would say it was pretty darn good?

Vaughan: Yes. We produced these documents, and they are the standard documents now for spacecraft design. They are still being used by NASA now.

Johnson: Of the experiments you did, I would assume the lightning experiments especially, there is probably data that has been applied toward studying how lightning relates to tornadic storms.

Vaughan: That is part of the problem we were trying to understand. By looking at the flash rates of thunderstorms over the years, it appears the symbols we have indicates it might be a cursor to predicting a tornado. The problem is, it looks like the lightning flash begins to increase up to a certain point, reach a level, and then it dies. About three minutes, I think it is, after that, there is a good possibility a tornado will touch down. We do not have enough statistical data to really prove that statement.

Johnson: Your early experiments, there are still experiments on-going?

Vaughan: They are still going right now. NASA has the LIS experiment, Lightning Imaging Sensor experiment, up there flying right now as a satellite, taking data all over the world, every minute. Now they plan to fly the GPS [Global Positioning System] Satellite, which will be a lightning mapper at geostationary orbit. That is in the works. It has been in the works now for a number of years, but has never flown yet. That is a NOAA [National Oceanic and Atmospheric Administration] project.

Johnson: In addition to your lightning experiments, you had other experiments that flew on space shuttles over the years, am I correct?

Vaughan: No, just the two experiments on space shuttle.

Johnson: Did you have other things you did after the lightning experiments, after you developed the experiments for shuttle flight?

Vaughan: No, I kept that experiment going nineteen years.

Johnson: Okay, so [there is] a lot of data.

Vaughan: Yes, we had a lot of data. We are still collecting data today.

Johnson: In the work you have done for Marshall Space Flight Center, first studying environments and later conducting experiments, were the challenges the same? Did you face a myriad of different challenges over your career?

Vaughan: You have to remember that most of the guys that worked for NASA were in their twenties, most of the engineers were in their twenties. We had no practical experience level, we had not worked long enough to develop a lot of practical experience. This was such a new challenge that it was we were going to do it, no matter what. If we fail, we will learn something from failure. That is the way it worked. We were so enthusiastic about doing it. Dr. von Braun really created so much of an interest in going to space. I know why we have lost that enthusiasm. Space today is like aviation was in the 1920s. We had already done it, why do it anymore?

[It was] not until about 1931 or 1933, when [Donald Wills] Don Douglas [Senior] built the first commercial airliners, the DC-1s, and Howard Hughes bought thirty-four of them, I think it was, that aviation began to take off as an industry. About the same time, Juan Trippe also came up with the idea of Pan American to cover international airlines. That was another factor. I think the space program today is like aviation was between the 1920s and the 1930s where we had a lot of people brainstorming, preaching aviation, but there was not a lot of manufacturing done. They were using surplus airplanes, the Ginny's and things like that. We had some designers and the government was smart enough to come up with the National Advisory Committee for Aeronautics, which really came up with the ideas of how to improve aviation. That is what we did. If you look at the space program, the early space pioneers were the X-15 guys. They were really pushing the envelope.

Johnson: The type of things you did with experiments, do you think the public understands the quantity of knowledge that applies to things like weather forecasting or judging how strong a storm is? Do you think the public understands how much information came from the space program and experiments that went up on the shuttle?

Vaughan: The problem when you do things and you produce a lot of results, everybody gets complacent. It becomes so obvious what has happened. Airplanes were taking off from Huntsville [International] Airport every day. The shuttles were taking off from Kennedy every so often, which means there is not a lot of enthusiasm about the takeoff. If you look at the first shuttle launch, how many people went to the Cape to see the first shuttle launch, [it was] a lot of people. How many people went to the Cape to see the second shuttle launch? Only about one-third of what came for the first launch. As time went on, it became everyday. It is like the 615 taking off. I think that is part of our problem. You need to reach the kids. That is what von Braun was trying to do, he was trying to reach the kids and people [and tell them] that this is your future, this is your money. They are spending your money and you are getting something. It is not all being spent in space.

The fact that we had to microminiaturize so much stuff, most people today do not seem to realize that a lot of the stuff we have today is like what Dick Tracy was in 1935 with the watch-telephone. When I was growing up, I wanted to be a space man because Flash Gordon was my hero back in the 1930s. I learned to fly before I finished high school. I have my pilot license. I wanted to be a fighter pilot and I wanted to be a test pilot, and I wanted to be an astronaut. Then my ear condition got me. After I got grounded in the military, I got very frustrated. Luckily, I was introduced to the jet engine. In the early stages, when the first jet engines were being built, we had a lot of studies. I had a lot of fun working with those engines. I ran them in test cells and watched them perform, things like that. I was very much a hands-on type of engineer, you might say.

Johnson: Everyone talks like the Saturn V days were a blank check. I know it was not that easy to spend money. Did you have to worry a lot about costs over the years from your Apollo research through your experiments?

Vaughan: No, I do not think we had a problem with money in Apollo. We had a mandate from the president to do this thing in ten years and we had a Congress that would support us. Therefore, we were going to do the job. That is what happened. Luckily, we pulled it off in ten years. A lot of times, I felt like we may not make it. It is like the idea of the Redstone, for instance. The Redstone was nothing but a modified V-2, basically. Then we went into the Redstone ballistic missile, which later became the Jupiter missile. The Jupiter missile was a very interesting project because we did not know how to receive a nose cone for long-range distance. Aerodynamic heating studies were very important. My early work at NASA in the Army was to do aerodynamic heating studies on the Redstone missile to predict what the temperature of the surface of the vehicle would be as it comes back in the atmosphere. That is what I did for a while. I had several interesting jobs that I worked on, it is just hard to talk about them.

What I did too was flight evaluation. That was the most interesting part of one of the jobs I had. Every time the vehicle flew, I had temperature measurements on most of the vehicle. I also had to try to figure out how well the vehicle performed. If something happened, what caused it to happen? That was very interesting.

Johnson: Is this what environmental force caused something to happen?

Vaughan: It was not environmental, necessarily, it was performance of the vehicle. We had a couple of cases where we had tail fires on the Jupiter missile and we had to try to figure out what caused the tail fires. In one case, it was because they had changed the launch pad configuration, the flame deflectors. Normally on the V-2, the flame deflectors had flames going out in four different directions. In one of the Jupiter launches, they decided to have a flame deflector that would only go two different directions. When they did that launch, the curtain we had in the bottom of the vehicle around the engine was ruptured by the excess pressure. The blast went inside the engine and destroyed certain equipment inside, causing the vehicle to fail. That was one of the first tail fires we had on Jupiter. That is what happened, so we went back to the first system.

Johnson: These kinds of things led to not making the same mistake in later vehicles.

Vaughan: The idea is you do not learn anything from a good flight. You learn more from a failure than anything else. If you have a failure, now you know how close you came to disaster. We were so fortunate with the Saturn V air frame. The German philosophy was always do it in a series of steps. Do the first stage, second stage, third stage. When [George] Mueller came in from Headquarters, he said, "If we are going to meet this schedule by 1969, we are going to have to fire these vehicles all-up. All stages will be hot." That was not the German philosophy, but they said this is what we will have to do, so let us do it. The third Saturn vehicle, which went to the Moon, was the third all-up stage that had been fired. It carried men to the Moon and brought them back home. My heroes are not Neil Armstrong and [Edwin Eugene] Buzz Aldrin [Jr.]. My heroes are the three guys that rode that first Saturn on Apollo 8 to the Moon and back. They really bit the bullet. They were what I call the beta testers. (Laughs)

Johnson: A lot more unknowns in those early flights.

Vaughan: Absolutely. We had never reentered at that speed with a vehicle before.

Johnson: When you look back, especially on that time, on all the studies, and you talked about studying the environments the rockets would go through, the environment on the Moon, are you in awe at the detail of the studies that were done across the board in just about every category you can think of to make sure that not only would these vehicles work, but that they would safely take people to the Moon and bring them back? Everything from the environment to the dust particles to counting rocks to all the other things, do you look at that and say wow?

Vaughan: To me, the fact we landed on the Moon successfully with the first landing was really an awe to me. I felt like we would do it, but we had not done it yet. Then we had Surveyors, which landed successfully on the Moon, so we had a pretty good idea of how these things could be landed on the Moon. The problem was how to get them home. Apollo 8 proved we could get them home by using the Earth free return trajectory. That was not a von Braun idea. He wanted to go directly to the Moon but wound up with Dr. [John] Houbolt out of Langley's [Langley Research Center] concept. Even Houston [Texas] did not like the concept too well, but von Braun said, "This looks like the best way to go. Let us try it." There were a lot of close calls we had in the Apollo Program. When you try to land a vehicle on the Moon, how close is a back pad to a crater when you land, because you cannot see where you are landing. You can only see forward. We had a couple of cases where I know the vehicle came very close to being in a crater with the back pad. If it had been, they never would have gotten off the Moon. I wonder sometimes if we did not have what I call "divine guidance." (Both Laugh) Everything seemed to work so well.

Johnson: Did you know you were a part of making history in those days, the Apollo days? Did you ever think about that, we are doing something important?

Vaughan: No. Like I said, I wanted to be a test pilot and I wanted to be an astronaut. Since I did not get to do that, I had to come up with some other things to do. As an engineer, that is what I wanted to be, a good engineer. I did not mind taking on a task and trying it. If I failed, I tried something else. When I became a lunatic, as I call it, studying the Moon's surface, I had no idea about the Moon until I started thinking about it. I started reading and studying and talking with people that did crater counts on the Moon. Dr. [Eugene Merle] Gene Shoemaker, I knew personally and worked with him. All those guys in Flagstaff, Arizona, I worked with those guys. It was a lot of fun, so much fun to go to work every day.

Johnson: Was it fun going to work every day?

Vaughan: For me, it was. I guess I am the oddball.

Johnson: No, that has been many, many veterans of the Saturn days that have talked about that.

Vaughan: It was like I said before, you wanted to do as good a job as you could. You knew we had to get to the Moon. We were going to try to get to the Moon successfully. That was the idea. Let us try to do it and do it right. Like the guy said back in Apollo 13, "Failure's not an option." [Eugene Francis] Gene Kranz said, "Failure's not an option." We are going to do this successfully one way or another. I think what is ironic is on Apollo 13, [James Arthur] Jim Lovell [Jr.] actually studied how to get back to the Moon on Apollo 8 if he had an emergency. He was able to bring that task into use to get back to Earth on Apollo 13.

Johnson: Was it as much fun in your later years at Marshall as it was during the Apollo days?

Vaughan: I retired in 1999, and we were still flying shuttles at that point.

Johnson: Still having fun?

Vaughan: Yes, I was still having fun. I did not want to retire. I wanted to try to go my fifty years, but I did not make it. I decided I would retire. They told me they were going to build the [International] Space Station. Building Space Station, you are not going to be able to use the cameras like you used before. I was using them on a non-interference time basis. They said they were going to be looking at the Space Station with the cameras, so you will not be able to do what you were doing. You will have to wait a while. I said, "If I have to wait a while, I might as well get out and do something else." Then I wrote my book. (Laughs)

Johnson: You know about the winds above Kennedy Space Center, that information is still being used. If we go back to the Moon, or when we go back to the Moon, the environment has not changed. You know about lightning on Earth. You know about all this by working at Marshall Space Flight Center, working for NASA. That is a pretty broad range of knowledge.

Vaughan: I was very fortunate to have a good boss that let me work on a lot of things. One German boss, Hans Paul, is the reason I got to go back to graduate school. He sent me back to graduate school to get my master's degree because the project I was working was a cooling system and I could use that for a master's degree. It worked out great. I got my master's degree in 1959 while I was working with ABMA before I went over to NASA.

Johnson: Did you work with other centers besides Marshall?

Vaughan: Yes, I actually did a lot of coordination. The most coordination I did with other centers was with Lewis Research Center [now Glenn Research Center] when we were working on the Atlas-Agena, Atlas-Centaur Programs. Later on in the Aeroballistics Lab, I wound up in the lunar trajectories area and wound up making trips to JPL and to and San Diego [California], GDA [Engineers]. We had panel meetings we would go to, navigation control panel meetings. We would go to those meetings and try to get all the programmers in the same ballpark with all the data. What is the radius of the Moon we will use for our trajectory calculations? We basically said there are three axes on the Moon and we will take the three axes, add them together, divide by three, and that is the radius of the Moon we will use for calculations. Things like that. We had to agree, so I had to coordinate with these people. I learned that too as a project manager.

Johnson: In your different roles working with other centers, were there ever any rivalries between the centers?

Vaughan: I, personally, had no problem working with the centers. As a matter of fact, my first lightning experiment nozzle, Marshall was really not too receptive to supporting me on it because it was such a small program. It was only about $75,000. That was the total cost of the program. I went to JSC [Johnson Space Center] to see if they would help me. I asked my boss if I could go to JSC. He said, "Yeah, go and see if you can work a deal." I went to JSC and said, "I have $75,000, and I want to fly this experiment on Space Shuttle. I need this, this, this, and this. Can you help me?" The guy said, "What do you want us to do?" That was it. They built my amplifiers for me for the system. They did the environmental qualifications for the system to fly. They found a tape recorder that was on Skylab, which I did not have any money for, and they gave me that tape recorder. I used it.

Johnson: A tape recorder from Skylab ended up being a tape recorder for a shuttle mission?

Vaughan: Oh, yes, on the second shuttle mission. I did not have any money to buy all the stuff, but they helped me considerably. They did all the qualification testing and then I got a chance to go to the Cape and take the hardware into the Space Shuttle and demonstrate it to the crew, things like that. I never had a problem, but I never had a problem working with JSC in the early part of the Apollo Program because I was interested in the lunar surface and they were interested in the lunar surface. I knew a lot of the lunar surface people at JSC. I was on a lot of the Apollo debriefing teams so I could learn some information about what was going on during the Moon landings.

Johnson: Talk about your contractor experience. You mentioned several contractors that you worked with.

Vaughan: I did not have any problems with contractors.

Johnson: Was the contractor experience, as far as you were concerned, a good one?

Vaughan: It was really good. We had a really good relationship with the Lunar Rover Program. As far as I was concerned, I said, "Here is the document. Use it." (Laughs)

Johnson: How about NASA Headquarters? Over your career, did NASA Headquarters help or hinder things?

Vaughan: We had a good relationship with Headquarters.

Johnson: We know how much recognition von Braun and the German rocket team got. You worked in the Saturn V days, like many other people. Do you feel like people like you, teams like the one you were working on, got the recognition they deserved in those days?

Vaughan: There are two ways to look at it. You always hear the statement "German rocket team." The German rocket team was only 110 Germans and over 3000 Americans. It is really the German-American team, but you never hear about that. I felt like I was part of the team, so it made no difference to me whether it was American team or German team. I just felt like part of the team. That was the thing von Braun really got people interested in, I think, the fact that you were part of a team that was going to do something.

Johnson: You have mentioned a couple of times that von Braun made people feel like they wanted to do a special job, do their very best. How did he do that?

Vaughan: He talked to you. Like I said, he might come up behind you and start talking to you. He was that way. I was very fortunate because I found a copy of his book called Das Marsprojekt. I called up Bonnie [Holmes] , his secretary, one day, April 1957, I think it was. I said, "Bonnie, would Dr. von Braun autograph a book for me?" She said, "Yes, bring it up here to me." I took it up to Bonnie. About a week before Christmas, Bonnie called me and said Dr. von Braun wanted to talk to me about the book. I went to his office, walked in, sat down, and we talked for a little bit. The way he autographed my book was interesting because he said, "Merry Christmas to Otha H. Vaughan, Jr., Christmas 1957, Wernher von Braun." That is the way he operated. He was just that way. He did not make you feel like you were smaller than him. You felt like you were a person he could talk to. It is amazing when you think about it, the fact he had all these things he was doing. You have to look at von Braun from the standpoint that he was a dreamer and he put the dream out and everybody grabbed it and ran with it. That is what happened.

It is like the Rover. We had a 12,000 pound Rover going to the Moon on Project Horizon, but there was no vehicle to carry it. We were going to stay on the Moon for thirty days. That was called Molab [Moderate Capacity Mobile Laboratory]. We never got to build it. Then Molab evolved into the big MTAs, the big Mobility Test Articles. Then they evolved down into the Lunar Rover.

Johnson: Has there ever been a leader that you have worked for that even approaches von Braun, a center director or someone who could have his arms around an entire program and yet be able to have the personal touch?

Vaughan: Von Braun is an awful hard man to top in terms of running a program. He is just that way. I do not know of any center director from von Braun down that did the same kind of job that von Braun did, even though they had the responsibility. [James Robert] J.R. Thompson [Jr.] was a good center director, but he moved on to something else. A lot of the center directors move on. They do not stay very long.

Johnson: You still have your enthusiasm for space, do you not?

Vaughan: Yeah, I would go right now if they would let me. I would take a ride in the shuttle right now, if you would let me. I would have gone a long time ago, but I did not have the qualifications.

Johnson: Do you wish you could come up with the environments a spacecraft might encounter on Mars?

Vaughan: We have a pretty good idea of what Mars is like right now. We have had landers. We have a lander going now. The little vehicle has been there over a year. It surprised me it lasted as long as it has.

Johnson: Would you like to count the rocks in the landing site on Mars?

Vaughan: I would love to be associated with the Mars Program. I would have loved to have been associated with that one, but I did not make it.