NASA Johnson Space Center Oral History Project
Edited Oral History Transcript

George A. Weisskopf
Interviewed by Sandra Johnson
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Johnson: Today is October 24th, 2019. This interview is being conducted with George Weisskopf for the NASA Johnson Space Center Oral History Project in League City, Texas. The interviewer is Sandra Johnson, assisted by Jennifer Ross-Nazzal, and we're also joined by his wife Kathy. I want to thank you for talking with us today and agreeing to do this. I want to start out by asking you to talk about your background and a little bit about your personal history, where you came from, and your education, and how you became interested in aerospace.

George Weisskopf: Okay, let's see if I can summarize that, not take too much time. As a young boy I grew up in the Northeast. I was born in Staten Island, New York, lived there until I was about seven or eight. Then the family moved to Baltimore, Maryland, and we lived there from 1951 to 1957. I completed my first year of high school in Baltimore. I was always interested in airplanes and model airplanes, building planes, I was fascinated by flying.

I had an uncle who was an engineer, worked for Grumman Aircraft for his whole career, so that might have been part of it. He took my dad and I to one air show at their plant in Bethpage, Long Island, and he took us on a tour of the plant. I can remember getting to sit in the cockpit of an unfinished jet fighter, and I was sitting on a wooden box in the cockpit of an unfinished jet fighter, but I thought that was so neat.

I was always fascinated with flying and airplanes. After my freshman year in high school my father's company that he worked for, a company called Will Scientific, [Inc.]—they were a small laboratory and instrument supply company that sold instruments and laboratory reagents to high schools, colleges, laboratories, commercial laboratories—his company moved us to Rochester, New York, which was their home office, and that's where I finished high school and did my first two years of college at a local college.

I knew I was interested in flying. When I was a junior in high school, I thought I really want to go to the Air Force Academy. I really want to become a pilot. That was my dream. Much to my dismay, I started having eye problems, and had an eye test and discovered my eyesight was not good enough to qualify me for a pilot, nor was it even good enough for me to be a navigator, so I was quite dismayed and unhappy about that.

I was talking to my uncle, the one that was the engineer at Grumman, one day. He said, "Well, George, if you can't fly them, you could always become an engineer and build them." I thought, "Hmm, that might be interesting." Then I set my goals on engineering.

I am the oldest of five children. My parents are both deceased back in the late '90s. In other words there were five of us, and my dad sent us all to private Catholic high schools. I'm cradle Catholic. Our finances in the family were always tight, although we kids never felt like we were poor or anything. We didn't lack for anything.

When it came to going to college, there was the University of Detroit [Michigan]. There is the University of Detroit still, it's called [University of] Detroit Mercy now. They've merged with a girls' college. It's in Detroit. It offered an engineering program and a co-op [cooperative education] engineering program, and I'm sure you've heard stories about co-op programs, where you can work part of the year earning money and then go to school the other part.

The University of Detroit had arrangements with colleges around the country where it would accept transfer credits for all your basic preengineering courses, so that allowed me to go to Saint John Fisher College in Rochester, New York, and live at home for the first two years of college, which of course saved a lot on living expenses, and complete all my basic preengineering requirements. Then in my junior year I transferred to the University of Detroit and started into their co-op engineering program, which in total is, or was at that point, a five-year program on a quarter system. You would go to school for 13 weeks, work for 13 weeks, school for 13 weeks, for three years.

I started there in September of ’62 at the University of Detroit, and I had 13 weeks of school, and the school would find you—I of course chose aeronautical engineering—the school would try to place you with a company or industry that was working in your chosen field of engineering. I thought whoa, General Dynamics/Astronautics in San Diego, [California]. I’d never been to the west coast. In November of ’62 I went out there for my first co-op assignment, with another fellow aeronautical engineer.

That was a fascinating time too. My first co-op assignment, working on a drafting board, working on little, I think they were insulation spacers for the Centaur upper stage of the Atlas [booster rocket]. General Dynamics at that time had the contract with NASA to build the Centaur upper stage, which was the first liquid hydrogen/liquid oxygen-powered rocket.

The purpose of the Centaur upper stage at that point, it was being built to send the Surveyor spacecraft [lunar lander] to the Moon, so this was already connected to the lunar program, although I didn’t know that I would end up working at NASA someday. In the early days the question of going to the Moon was, “Well, what’s the surface like, can we land, are we going to sink in the dust?”

Initially, and I don’t know who had the contract for that, but they sent several Ranger spacecraft. The Ranger spacecraft just went in and impacted, and they took pictures right as they were going in and crashing. They did have some information of what the Moon's surface looked like up close. Of course they didn't have any information as to the bearing strength of the surface, was it all powdery, because the spacecraft crashed.

They had a follow-on program that they were planning, Surveyor spacecraft, which were going to soft-land on the Moon, and they would be able to take pictures after they landed, they'd be able to see whether they sunk into the dust, as some scientists thought. That's what the Centaur was being built for. I worked over the course of three years from '62 to '65 on various increasingly more complicated assignments with them. I think—I'm trying to remember now—the last assignment I had, I think I was working in their wind tunnel, reducing data, doing what the *Hidden Figures*[1] people did, in other words sitting there getting raw data, plotting it on graphs, and that sort of stuff. Also, two of my assignments was working on separation latches.

The Surveyor was connected to the interstage adapter. You had the Atlas rocket, the Centaur rocket, an interstage adapter, and on top of that sat the Surveyor spacecraft. The Surveyor spacecraft was held on to that adapter by these three separation latches. They were springs and when the latches opened, the springs would push the spacecraft away.

The latches were actuated by little explosive charges. What they were is they were very much like a piston in a car engine. It was a hollow piston and the bolt from the top on the Surveyor stuck down in there and was grabbed by three little lugs, and when the piston would be forced down the lugs would open, and the springs would push it free. I worked on the design and the testing of those latches for a couple of my co-op assignments. Little did I realize that later on, one of the Apollo missions, Apollo 12, would actually land very close to one of those Surveyor spacecraft, and the astronauts would go over there [to the Surveyor]. I think they took

[1] *Hidden Figures: The American Dream and the Untold Story of the Black Women Mathematicians Who Helped Win the Space Race,* by Margot Lee Shetterly

the camera and some other things off of that very spacecraft and brought it back. That was an interesting connection.

But I enjoyed my time out there in San Diego and the experience working there. Then when I finished my undergraduate program, at that point I was doing fairly well in school, and I thought I wanted to go to graduate school, and I was looking around, where I could go to graduate school and what were my options. I was thinking I could get a PhD and be a university professor. That was my thinking at the time.

I had met Kathy already, and so I knew I was very much interested in this young lady. I applied to various graduate schools to see what options were available to me, and I think MIT [Massachusetts Institute of Technology, Cambridge], University of Michigan [Ann Arbor], maybe Stanford [University, California], and I think there might have been one other. I did get offers from all of them. When I got the offer from the University of Michigan it was a NASA traineeship, and they would pay my full tuition. They gave me a stipend for living expenses. There was even an additional stipend, not much, if I was married. Well, I had been thinking about asking this young lady to marry me, but I hadn't really decided.

But going to the University of Michigan, she was still an undergraduate at Marygrove College, which was about a mile and a half from the University of Detroit down McNichols [Road]. I got to meet her at a mixer. It was a springtime fundraiser that her college always put on. It was like a carnival, stage show, mixer dance. You could go to the booths and go to the stage show and go to the dance and meet young ladies.

I had decided to go to that with one of my roommates that night. I went to the stage show, and unbeknownst to me, she was in the stage show but her name wasn't listed in the program. She was a last-minute walk-on or drag-on you might say. They brought her on stage because they needed somebody to fill in between a singer and a piano player that weren't keeping in time, and so she was up there with her mandolin playing the part of an Italian street minstrel dressed in baggy pants with little beret on and a painted-on mustache. That was the first time I saw her.

Then I went to the dance afterwards, and I'm kind of shy anyway, but I was standing there thinking well, you're at the dance, you want to meet some girls, you got to go ask them to dance. I saw these three girls standing together over there and I walked over to them. I thought well, let's see, I got to say something clever, right. "Well, I'd like to dance with all of you, but I can only dance with one of you at a time," some dumb thing like that.

It worked. I danced with her first and then I danced with each of the other girls, and she's the one that stuck. In other words I'd met her, and I was getting pretty serious about her. I would make weekend trips from the University of Michigan. I didn't have a car at the time; I took a bus from Ann Arbor to downtown Detroit, it ran through the little town of Ypsilanti, Michigan, because that was one of the stops on the way. Anyway, decided to take a bus from there. I was very comfortable taking the bus out to the college, and we'd go out on a date, and I'd do the reverse trip to go back home at night.

Then after about two years at the University of Michigan, one thing happened to me, I didn't listen to my faculty adviser well enough, and I ended up taking an advanced calculus course, which I had to take. He said, "You should probably take it in the engineering department."

I said, "I'd like a little more theory."

He said, "You can take it in the math department if you want." Big mistake. I got a C.

When you're in graduate school working for a doctorate, getting a C or C plus or whatever it was, it was a C something, and so it took me a while to bring my average back up. After two years in graduate school and talking to my faculty adviser, he said, "You might want to try transferring someplace else to do your doctoral prelims."

There was a young man, I don't remember his name now, that was a year ahead of me, and he took a job with NASA after he'd gotten his master's degree. NASA sent him back to the University of Michigan on a recruiting trip, so I went and saw him at the recruiting. "Oh, George, you ought to come down. We got all kinds of jobs. We really need you blah blah blah." So I finally decided I've had enough graduate school, I think I'll work for NASA.

By that point I was very much fascinated with the space program, even more so than flying. I had seen enough in my days working as a co-op student to realize that if you wanted to work in a program, especially a program like NASA, if you worked for NASA, you could work on the program as long as the program existed. If you worked for a contractor, well, I'd seen contracts come and go. You either moved or you went and worked on whatever.

If I went to work for Boeing, I might have been working on a NASA contract, I might have been working on something else. I decided even though NASA, salarywise they were the lowest offer I got, but benefitwise, their benefit programs in the long term were pretty good. It wasn't really much of a decision anyway. I probably would have gone with them anyway.

I'm glad I did, because I had a wonderful career out there. I tell people there are times when I look back at it and think I was very very fortunate. I just happened to be at the right place with the right skills at the right time. They needed people that had my skills and there was lots of work to do. I don't regret it at all.

There were times I think a number of us young engineers—some of us did have wives, and I had my first child within a year, our son Michael—who didn't have a wife and child at home to worry about supporting and taking care of, you almost would have paid NASA to let you do that work, because it was so exciting. *Star Trek* [television series] was all the rage among the space fans on TV, and here we were really doing it. That's the backstory, I guess, if you will. That's how I got into it.

JOHNSON: When you first started working for NASA—and I notice on here that you had an internship at [NASA] Goddard [Space Flight Center, Greenbelt, Maryland]. Is that what you're referring to? Or are you talking about when you came to Johnson?

GEORGE WEISSKOPF: No. Actually the summer between graduating from University of Detroit and starting graduate school at the University of Michigan, I wanted to work and make some money, and I was looking for a job. I was able to get this summer internship working for Goddard Space Flight Center. It was only for about eight or nine weeks by the time I went down there and found a place to stay and started working and then had to be at the University of Michigan to start graduate school in late August.

But it was also an interesting experience. I worked in their Sounding Rocket Branch which was out in Beltsville, Maryland, just a little ways from Greenbelt. You might liken it to some of the facilities we used to have at Ellington [Air Force Base, Houston] versus working on site. We were not on site at the Goddard Space Flight Center. The Sounding Rocket Branch was in these outbuildings over in Beltsville. I worked there. I was working on deriving the mathematical formulations for different nose cone shapes because they were building the sounding rockets that they'd launch from Wallops [Flight Facility, Wallops Island, Virginia], and I think they might have taken some up to northern Alaska, doing upper atmosphere research. They wanted to optimize the shape of the nose cone to minimize drag and maximize the altitude they could get to.

JOHNSON: So you'd already had a little bit of working with NASA when your friend told you, "You need to work for NASA." Did that help make up your mind?

GEORGE WEISSKOPF: I don't know. I don't think so. I don't think that was so much as made up my mind to go to work for NASA. What made up my mind was I was just fascinated with the idea we're going to the Moon. Gemini was ongoing at the time. Mercury had been completed. Gemini was ongoing. I was an avid follower of all those events and missions.

JOHNSON: If he was recruiting, what was the process? Did you then apply and then have to come interview?

GEORGE WEISSKOPF: I did apply, and I applied to NASA. I applied to I think TRW, [Inc.] and maybe Boeing and I want to say General Electric in Pennsylvania and maybe Bell Aerospace in Rochester, New York. In my mind I think I'm confusing [the timeline]. I think I did some applying for jobs right after I finished undergraduate, and then I did some more when I—because I know I remember writing some letters to people that offered me jobs and saying, "Thank you for the offer but I've decided to accept this offer for graduate school. I would be interested in considering interviewing you again later."

But when I came to work for NASA down here NASA wasn't paying for interviews. They just offered me a job. I suppose I could have come for an interview. TRW offered to bring me down for an interview too. I had already made up my mind. If I got an offer from NASA I was going to work for NASA because I didn't want to get into the situation where I would be working for a contractor on a very interesting program. The contractor loses the contract, it's time for the contract to be renewed and a different contractor is selected, and I didn't want to get into that mode of operation.

JOHNSON: When you decided you were going to move down here, it was a big change for both of you to move down to the Houston area, and that was in 1967.

GEORGE WEISSKOPF: In 1967 I can remember—this is going to sound silly but it's true. The man that offered me the job was Ron [Ronald L.] Berry in Mission Planning and Analysis [MPAD], and he was a branch chief at the time. He called me and he made the offer and he said he'd like very much if I could come to work for them and was asking me if I had any questions. I don't remember all the questions, but I remember this one silly question. I said, "Well, what's the climate like down there? Is it green?" Because I'd never been down here, I had no idea. I'd been out in southern California. Out in southern California it's very much semiarid, and it's green, but it's kind of this olive drab green, eucalyptus trees and a lot of scrub growth, brush and things. It's lush where you have a park like Balboa Park in San Diego, and everything is watered and irrigated.

I can remember as a co-op student when I would return home from my co-op, my assignments out there always were in the winter months and the summer months. When I would return home before going back to the University of Detroit, or even coming back to Detroit, the brilliance of the green was so startlingly different than it was out there. I was asking, "Is it green?"

He chuckled and said, "Oh yes, we get lots of rain. It's very green." That's all he said. He probably wondered, "What's he asking about that for?" Because I really like the green. I didn't want to live necessarily in an arid area.

We got engaged the year before that. I think after one year of graduate school.

KATHLEEN WEISSKOPF: In October.

GEORGE WEISSKOPF: In October'66; '65 I graduated, so it was October of '66 when we were engaged, after a year.

KATHLEEN WEISSKOPF: We were engaged for two years. We were married in '67.

GEORGE WEISSKOPF: So maybe it was '65 then. Yes. I guess it was '65. The years are going by, I forget this stuff. Where was I?

JOHNSON: You were coming down here.

GEORGE WEISSKOPF: Okay, yes. We were engaged to be married in November and I completed my requirements for my master's degree in the summer of '67 and accepted the job here. I had a report date, I still remember it, August 14th.

My first car I had I bought from her dad. He sold me his secondhand car. He even cosigned for the loan at the bank for me. I didn't have much money to my name. In August of '67 we drove. We were going back home to my folks' house and Kathy was going with me. We drove from Ann Arbor to Rochester, New York, and then we drove from there down through Pennsylvania, visited my grandparents, and then drove to Hamilton, Ohio, which is where Kathy is from. Then she went back to the University of Michigan from there, I drove on down here and started work August 14th and was hunting for an apartment. I found an apartment here in League City about six blocks from where we live right now. It was a brand-new set of apartment complexes then. Rented a one-bedroom furnished apartment.

KATHLEEN WEISSKOPF: We had no money.

GEORGE WEISSKOPF: Then I started work at NASA and my branch chief was very nice. He said, "Well, George, if you're getting married in November." He knew that, when I accepted the job, I told him I'd be getting married in November. "Here I'm starting work, boss, but I'm going to need a week off." He said, "You won't have much vacation time by that point, but if you want to work comp time you can do that."

He let me do that. I'd work up there till six or eight o'clock at night most nights, so I built up enough hours that I could take off a week to fly up to Ohio and get married and come back down here.

JOHNSON: Then come back to that same apartment.

GEORGE WEISSKOPF: Come back to that same apartment.

JOHNSON: That's where you both lived at first.

GEORGE WEISSKOPF: Yes, that's where we lived. We lived in that apartment complex. We moved from a one-bedroom about the next summer.

KATHLEEN WEISSKOPF: I got pregnant on our honeymoon, so we needed to have a room for the baby, so we had to have a bigger apartment.

GEORGE WEISSKOPF: We went to one that was like a one-bedroom with a studio, so we could make that a nursery. Then we lived there for a couple more years, and then we moved to the two-bedroom apartment.

KATHLEEN WEISSKOPF: I had a second child.

GEORGE WEISSKOPF: Yes. Once we had the second child then we said, "It's time we got to find a house."

JOHNSON: Is that when you bought this house? You've been here since.

GEORGE WEISSKOPF: Yes. Been here ever since.

JOHNSON: Let's talk about those first days at your job and what your assignments were and what you were working on when you first came down here in August of that year.

GEORGE WEISSKOPF: When I first came down to work, I can still remember the office. I was on the third floor of Building 30 in the office wing, not the [Mission] Control Center side, and I was on the far back northwest corner. I shared an office with about four or five other engineers.

Probably like a lot of young engineers when you first come to work, I worked in—what did I say here? I think it was the Lunar Mission Design Branch. I've got that written down here. My section chief was Ron Berry. Mr. Pete [M.P,] Frank was the branch chief and John [P.] Mayer was the division chief.

My coworkers were Jerry [Jerome D.] Yencharis, Lee [Gorden L.] Norbraten, Roger [H.] Sanders, Robert [S.] Davis, Laz [Lazarus] Gonzales, and Robert [F.] Wiley. What I started to say is the initial assignment for most new engineers is "Here's some documents, why don't you take a look at these and read these."

As I said, I was reading a lot of NASA documents, internal notes pertaining to the design of the Apollo mission, learning a lot about NASA acronyms, learning in particular about the planned trajectory for the Apollo missions, and the various maneuvers required to follow the intended trajectory.

I'd gotten very interested in undergraduate and graduate school in orbital mechanics. That fascinated me, the idea of what kind of a maneuver, what do I have to do to put myself on a path that's going to intercept some other object, be it another planet or in this case the Moon, at some time, some distance in the future. To make Apollo work, that had to be done very precisely. If I'm in orbit around the Earth, in what direction do I have to point my rocket, and when do I have to turn the engine on and turn it off in order that I'm going to intercept the Moon at some point in time in the future. But not just intercept it, intercept it such that I can again turn my engine on and slow down and get captured into orbit around the Moon.

It all sounds somewhat simple. In actuality you have the Moon's gravity, the Earth's gravity, the Sun's gravity, and to some small degree the gravity of the other planets, as well as the effects of the solar wind on the spacecraft. There's a lot of little factors that have to be accounted for if you really want to get to where you want to get to at the time you want to get there. The machines, the computational ability that we had in those days, there were mainframe computers. UNIVACs [Universal Automatic Computer]. I think they were 1106, 1108 type computers in Building 12. Then they had the mainframe computers which I think were IBM 360s that ran in the Control Center. But for the engineers, there were no desktop computers, no handheld calculators, no digital watches. None of that. Not that digital watches would help much.

But what we had available to us sitting at our desks was just slide rules, pencil and paper, and in our branch, we had one of those Friden calculators that were electromechanical calculators that rolled around on a little cart, and by golly, the greatest thing it could do, it would take square roots to a couple of decimal places as opposed to what you could eyeball with your slide rule.

The section that I was in, we were tasked with looking at the key maneuvers to get the spacecraft from Earth orbit into lunar orbit and then back to Earth again. Those were the translunar injection maneuvers, the burn you had to do to get out of Earth orbit and on a trajectory to the Moon. Then there was the lunar orbit insertion [LOI] maneuver, which was the burn you had to do to slow down enough that you would get into an orbit around the Moon.

Then there was the trans-Earth injection burn, which was the burn you had to do to speed up to get out of lunar orbit and send you back to Earth.

I don't remember the name of the branch offhand, but there were other groups that were looking at okay, what about the powered descent, what do I have to do to fly the descent down and land on the Moon's surface and take off again and come back to orbit and rendezvous with the spacecraft. As well as other groups that were looking at the launch trajectory. In other words the Saturn V lifting off from Cape Canaveral [Florida] and getting into orbit around the Earth.

The area that I particularly ended up working on was the lunar orbit insertion maneuver.

JOHNSON: When you came in '67, that was just a few months after the Apollo 1 fire. Do you want to just talk for a minute about how or if that affected your work, since you were working on that trajectory work? Talk about maybe the atmosphere at the Manned Spacecraft Center at that point and what you basically walked into.

GEORGE WEISSKOPF: I guess that's a hard question for me to answer because I don't know what necessarily the atmosphere was like right before that. I know that as a student I was following it. I was very much dismayed and disheartened by the fire. I think even by August that the nation and NASA and the government had decided okay, we're going to fix this problem and we're going to go ahead. I think everybody's attitude was there was a lot of work to be done. The fire was terrible, and it was a big setback. The hardware problems that caused it needed to be fixed and rectified. But as far as the trajectory issues, that was what we were focused on, and we couldn't do anything in our area about the hardware problems. We had to make sure we got the trajectory stuff right.

I can't say that I have any recollections of a mood one way or the other. The only thing I can remember was that we were going to do this, and we had work to do. We needed to get on with this, solve these trajectory issues.

JOHNSON: How about the early unmanned flights? Were you involved specifically I guess with different flights and different missions as far as those early ones? Or were you just doing work in the background to make sure that everything was going toward the right direction as far as the trajectory?

GEORGE WEISSKOPF: The unmanned flights, no, I was not involved in any of the unmanned flights. I think all of the unmanned flights for Apollo were just Earth orbit. They were just testing the Saturn V rocket out. I don't remember even being very much aware of the problems they had.

They had one issue with the oscillation and the thrust, the pogo oscillation that was quite concerning in the Saturn V, and I think I may have heard about that. But again we were so focused on trying to solve our problems that we figured well, they got problems, I hope they can fix it.

JOHNSON: You've got Apollo 8 on your list. Do you want to talk about that mission and what you were doing at that time?

GEORGE WEISSKOPF: Yes. By that point in time I had become familiar with some of the programs, one of the programs in particular called Apollo Reference Mission Program, which I believe was written by one of the NASA contractors, TRW. It ran on the UNIVAC computers in Building 12.

The other thing we did leading up to the missions that I can remember working on was we were given the documents that Draper Labs had, where they developed the guidance equations that they were going to use for the onboard computer for the Command and Service Module, and that was the computer that actually controlled the execution of the burns, the lunar orbit insertion burn and the trans-Earth injection burn.

We were studying those equations and how they had programmed them, with the objective of—in other words NASA wanted us to say does it look right to us, and could we use any of that in what we were doing. We were verifying their formulation and their implementation of the guidance equations. That was one of the projects we were doing.

Then the other project was using our computer resources, the UNIVAC computers and the programs that we had available to us, to make numerous simulated trajectory runs. We would be given a state vector, which is basically a statement of the position and the velocity of the vehicle at the end of the translunar injection burn for example. You have the speed and the direction of the spacecraft and the mass of the spacecraft. Then we could put that information into our computer program and use that through a process called numerical integration of propagating that state of the spacecraft ahead in time, taking into account the gravitational effects of the Moon, the Sun, and other perturbing forces, and basically stepwise propagate it out for however many days and see where we ended up near the Moon. Then we would have a target of what orbit we wanted to get into around the Moon. In other words 60 by 120 or 60 by 60, a circular orbit, in a certain plane over the Moon's surface. We would do a hand calculation as an initial guess of what the delta velocity would have to be, in other words what direction would we have to point the rocket engine in and how long would we have to fire it in order to slow down and to get into that orbit.

We would use that as an initial guess, and then this program would sit there and try that and see how close it came to the target we wanted. Then it would go back and adjust that initial guess, and it would keep doing this, iterate a number of times, to gradually figure out exactly what we would need to do in order to get to the target we wanted. We would make many such runs to see well, did we get into the orbit we needed to be in, and then also how much fuel did we burn.

Because one of the critical things was you might get into the perfect orbit, you burned up all your fuel doing it, well, now you have nothing left to get back to Earth with, so that's not good. We would always try to maximize what we called delta V remaining, the amount of fuel we had in our tank after the burn. We tried to optimize the burn. Meet our targets, but optimize the burn, so we had as much extra fuel left over for getting back to Earth or other contingencies as we could.

That all went into helping to publish a mission plan. The mission plan for let's say Apollo 8 would have all this information about what times the burns would take place, the particulars of the burns, how the vehicle would be oriented, and how much fuel was being expended, how much delta velocity, and what your trajectory would be after the burn.

It helped build up a timeline. This information went into or was compiled together with similar information about the launch from the Cape, the insertion into Earth orbit, the coast in Earth orbit, the translunar injection burn, possible midcourse correction burns, lunar orbit insertion, and all of that, to produce the mission plan that the planners would use in the Control Center to do their simulations to train to. It was kind of like a reference mission plan.

Of course the actual true mission, things would always be a little bit off from what you had planned. That was the nominal plan. That's what we were involved in doing. I remember when they had letters for the missions. I think Apollo 8 at that point was called C. Then there was a version called C-prime. That was when we weren't supposed to talk about it, but we were planning for the lunar trip instead of just an Earth orbit, because they had gotten into the situation where their next—Apollo 7 proved out okay, the Command and Service Module work, we're in Earth orbit, we're checking out the Command and Service Module, and of course this is the redesigned Command Module after the fire. Then the intention was originally I believe to have the LM [Lunar Module] and get into Earth orbit with the LM and check out the LM before we ever went to the Moon.

But my understanding is that they were having schedule problems with Grumman [Aerospace Corporation] and with the LM and so they weren't going to be able to meet that schedule, and somebody came up with—I think you've probably heard all the stories. I don't remember hearing the stories at the time. They were suspicious the Russians were going to beat us to the Moon, and somebody came up with the idea well, we don't have the LM, but we've got the Apollo Command and Service Module, and they work, and we've got the Saturn V, and the second stage and the third stage. It all works. Why don't we try to go to the Moon?

I think our managers—more than us working engineers, we felt like oh yes, we're ready, let's do that. I think the managers were like, "Gulp." Because theoretically all these calculations all looked good on paper, they all did what we said it was going to do. There's always the question if we do this, there's a big reward but there's also a great big risk, because we've never done this before. We're taking people very very far from Earth and we're counting on these engines to fire and perform the way they're supposed to perform. If they don't, then we have another big tragedy on our hands. It was a big risk, but it was very very exciting to work on.

JOHNSON: How closely did you actually watch the mission? Were you following it as everything was going to see if it was following that plan?

GEORGE WEISSKOPF: Oh yes. I think I've written in my summary here that for that particular mission an engineer, Bob Wiley, who was a little bit more senior than myself, although he had started work not that much sooner than I had, he and I were I think the two main people working the LOI maneuver. It was another man, Dr. Quentin [S.] Holmes, I think he was also working on it.

But for that mission Bob Wiley was assigned as a staff support person in the Mission Control Center. He wasn't working in the flight control room, the MOCR. He was working in one of what they called staff support rooms [SSRs]. There was a flight dynamics staff support room that dealt with the major maneuvers of the mission, and you had your engineers like myself and Bob Wiley and Bob Davis and Lee Norbraten and others would be assigned to work support shifts in that room to basically man consoles there and look at the upcoming maneuvers and advise the flight dynamics officer as yes, that looks good, or no, I'm concerned about this. Basically a resource for the flight dynamics officer to go to and say, "Hey, how does this look? Are we good to go?" and that sort of thing.

For the Apollo 8 mission, we were still trying to be as sure as we could about the design of the trajectory and the maneuvers and that it was all consistent, because the actual execution of a maneuver is controlled by the onboard computer, and the onboard computer had some ability to actually compute the maneuver itself. I think the way the early missions worked for sure is they computed the actual maneuver targets. In other words, ignition time, spacecraft orientation, burn time, all of that was computed on the 360 computers in the Control Center, and was read up to the crew, and the crew would program that in through their little hand pad that they had, DSKY [numeric *display* and *keyboard*], into the onboard computer [Apollo Guidance Computer]. Then they'd let the onboard computer execute the maneuver.

We had a program that was computing the maneuvers on the UNIVAC computers, what they should be. The Flight Control Center had a computer computing the maneuvers that were actually going to be read up to the crew. Then there was the onboard computer that was executing the maneuver. We felt much more comfortable with the fact that we had the programming for the computers in the offline system, if you want to call it that, in the UNIVAC computers. That was programmed by a different set of engineers than the engineers that programmed the ones in the Control Center. Yet they were solving the same problems.

You have two sets of programs independently programmed on two different computers running the same problem and coming up with a solution. If you have that, and the solutions agree, you feel a lot more comfortable that there's not a programming—unless there's some common programming error—that what you have is the correct solution.

What I was assigned to do was we had this facility in Building 30 in the admin [administration] wing side called the ACR, Auxiliary Computing Room. Our job there was to run all these maneuvers in the background using the UNIVAC 1108 computers or 1106 computers and compare our solutions with the solutions that they were getting in the Control Center, and saying, "Yes, they're the same." I don't remember ever seeing any big differences.

That would have been a "Whoa, wait a minute, we've got a problem," if we had found big differences.

That's where I was working for the lunar orbit insertion maneuver for Apollo 8. I remember because I remember talking to Bob Wiley in the staff support room, giving him our final set of updates. After I did that then he called back over to me in a little bit and he said, "Hey, George, I got a badge for you downstairs. If you want to come on over here." I was able to be in the staff support room for the LOI maneuver.

JOHNSON: That's wonderful.

GEORGE WEISSKOPF: For the very first one. That was very exciting, because we knew that Control Center gave the final set of maneuver numbers to the crew, and then we lost contact with them before the maneuver ever happened. So, the Control Center gave them the information, they put it into their computer, and then they went behind the Moon, and then it was like okay, if it goes the way it's planned to go, they'll come out from behind the Moon at this point in time. If the engine doesn't fire at all then they'll come out faster, because relative to the Moon they're in what's called a hyperbolic trajectory, so they'll come zipping out much sooner. If it fires too long or in the wrong direction, they might never come out, which means they crashed into the back side of the Moon, or they're in the wrong orbit when they do come out.

That was the only piece of information that the Control Center could look for, that acquisition of signal. If it happened exactly when we planned or very close to it then we'd say, "Ah, it worked." I want to say it might have been a couple seconds late, but it wasn't very long. But everybody was very much relieved when that happened.

JOHNSON: Yes, I can imagine.

KATHLEEN WEISSKOPF: The longest short time in my life.

GEORGE WEISSKOPF: You were at home with Michael. My dear wife. If it wasn't for the wives that were taking care of the kids, we never would have been able to do it.

JOHNSON: Especially like you said, you were monitoring that mission. Those are long hours. That's not your normal 9:00 to 5:00 job.

GEORGE WEISSKOPF: No. That was the other funny part that happened afterwards too. I don't mean to be offensive to anybody. When Madalyn Murray O'Hair said, "Oh, you went to the Moon at Christmastime just deliberately." That's the geometry of the Moon and when the Moon is in a certain position in its orbit. We don't control that other than which month we go, I suppose. The month was driven by they were trying to do it as quick as they could, because they were afraid the Russians were going to scoop us again.

JOHNSON: But it was an impressive mission to most people, because people were watching it, and being on Christmas Eve and the message made it special.

GEORGE WEISSKOPF: Yes. Then the stories, I don't know the truth of all the stories, vis-a-vis how did they choose that. The story was they were told, "Well, pick something meaningful." I think the wife of one of the astronauts suggested that. I really don't know the truth of that. You may have more insight into some of that. It was very impressive, yes.

JOHNSON: It's an interesting mission. A lot of people that we've talked to have described it as the most important Apollo mission, because like you said, not knowing if they were going to come back at the right time at the right moment and trusting that plan.

GEORGE WEISSKOPF: There were a lot of people. We were maybe brash and overconfident young engineers. That's the calculation. If we do that it'll work. It'll work. Of course it'll work. It's just got to work. The trajectory was the easy part. I think back to all the engineers that worked on the hardware, and all the hardware problems that they had. If you have a trajectory, you have a mathematical calculation, sure, that's all good, but you've got to execute that. If you don't execute it—and executing it depends upon the hardware you're using—if that hardware has a glitch or fails, you can be in all kinds of very bad situations.

One of the things they did on most of the Apollo missions was the initial trajectory when they left Earth orbit after the TLI [translunar injection] burn, they were on what's called a free-return trajectory, which means that if your TLI burn is accurate enough and you don't have to do too many—you can still do maybe midcourse [corrections]—but theoretically if you do the TLI burn right, then you'll go out. And even if you don't do anything out here, the Moon's gravity will bend you around and you'll fly away from the Moon and you'll be again pulled in by the Earth's gravity, and you will come back into Earth orbit. You'll intersect the Earth and you'll have to go through reentry, and you may have to tweak your reentry corridor or you'll burn up. It won't be the case that if you don't execute your LOI burn then you're going to go flying off into an orbit around the Sun and your life support system isn't going to keep you alive for very long and that'll be that, you'll have a monument in space.

Most of the missions were designed with what they called a free-return trajectory. To get to some of the lunar landing sites—I couldn't tell you without going back and looking at the mission plans—we got confident enough in the hardware that we were willing to go into a non-free-return trajectory to reach certain lunar landing sites.

JOHNSON: You mentioned you were young and brash. I know especially in the Mission Control room I think the average age was 26. Was it the same in the support rooms and in your work?

GEORGE WEISSKOPF: Yes. Very much so.

JOHNSON: It is very young when you think about it.

GEORGE WEISSKOPF: You might remember in some of the publicity about the 50th [JSC anniversary], they interviewed Poppy [Frances M.] Northcutt. Poppy Northcutt worked on the return to Earth trajectory console in the staff support room. I remember she worked for TRW. She was a very nice, very nice person. She was very young, very good-looking, and of course she attracted a lot of attention from the young engineers too. That was just normal.

JOHNSON: Yes, it was a young group of people.

GEORGE WEISSKOPF: We were. We were all very young and eager, I guess, to see this happen. This was a fantastic adventure.

JOHNSON: I notice on your note you were on Apollo 9. You were the LOI specialist.

GEORGE WEISSKOPF: No. Not Apollo 9. If I put that—I was working trajectory for Apollo 10 and 11 at that point.

JOHNSON: Okay, let's move into those missions. For Apollo 10 through 12 you were in the staff support room.

GEORGE WEISSKOPF: I was.

JOHNSON: Let's talk about that. We've had a lot of descriptions of what the Mission Control room looks like and what the atmosphere was and the feeling inside those rooms during these missions, especially when we get to Apollo 11.

But if you can just talk through also what it was like to be in the staff support rooms, and how that worked, and something about how it looked, and the atmosphere, as well as the work you were doing in there during those missions.

GEORGE WEISSKOPF: Okay. As I summarized here, for Apollo 10, 11, and 12—10 was the full-dress rehearsal for Apollo 11, and 10 occurred in May of '69. Apollo 11 was in July of '69.

On those missions my work leading up to the missions and during the missions was pretty much the same as it had been for Apollo 8. Spending a lot of time running trajectory simulations on our UNIVAC computers in Building 12. Attending simulations. In other words there would be a number of sims leading up to the mission, full-up sims, some of them were full-up sims involving the crew down at the launch complex basically where they'd go through and simulate all the steps of the mission without actually of course firing any of the engines or doing any of that. Just practicing.

There would be problems that would be thrown at us by people that controlled the simulation, in other words trying to prepare the crew and the flight controllers for any number of different kinds of contingencies.

Running premission trajectories, participating in simulations, comparing our trajectory solutions with the trajectory solutions that were coming out of the Mission Control Center computers, and just basically rehearsing the mission, like you're rehearsing for a play. You do it many times, so it becomes second nature to you.

The staff support rooms were laid out very similar to the main MOCR [Mission Operations Control Room]. The one I was in, anyway, I shouldn't speak to all of them, but the one I was in, the flight dynamics staff support room, wasn't—in the MOCR they're tiered, different tiers. In the staff support rooms it was just all on one level. The main Control Room was in the middle of the building. Then the rooms around the side of the Control Room, off the hallway to the side of the building, that's where the staff support rooms were located.

As I remember in the flight dynamics staff support room, I think we had two rows of consoles. The LOI position was on the back right-hand console. That's where we sat. Midcourse correction, LOI. I don't know who was in there, but there were people in there during a TLI maneuver, translunar injection maneuver, and I'm sure there were people in there also supporting the other major maneuvers of the mission.

Of course the consoles were black-and-white screens. There were communication loops that you could select which communication. You wore headsets, old headsets plugged in like a phone jack into—there were several plugs along the front of the console. A number of people could sit there and plug in, and depending on which loops you selected you could listen to different groups of controllers talking.

Of course when you were on console, some of them you had to monitor all the time, like the flight director and the flight dynamics officer who we were directly supporting, so that he could communicate with us. We could listen in on some of the others.

We could call up. There was also little phone wheels that you could dial different channels, and you could call up different displays on your black-and-white TV screen that were being generated by the Mission Control Center computers. They were generating maneuver solutions for this maneuver or for that maneuver. Or you could dial up displays that had to do with different vehicle systems or statuses. Of course, being focused on the trajectory aspect, we were mainly focused on the maneuver displays. The solutions that were coming from the Mission Control Center computers relative to the maneuvers, the ones that we were assigned to work.

You could make hard copies of a particular screen if you wanted to, because as you were progressing through the mission, they would periodically run let's say, "Well, what's the LOI solution looking like now?" The computers would run the trajectory ahead and see what the LOI maneuver looked like and generate a display saying, "Well, based on our current trajectory if we do no midcourse correction this is what the LOI burn is going to look like. This is how much fuel it's going to use." They would generate that several times in the course of the mission just to see how things were progressing, and to determine whether they wanted to do a midcourse correction or not, or needed to. You could make copies of those displays.

How did you get your copies? We didn't have copy machines like we do now. The copies were printed down in the bowels of the building someplace. I don't even know where. Then they were put into these pneumatic tube canisters very much like you find at banks when you drive up to a bank and you can put something into the credit union or whatever. They would be routed to whatever console requested them.

In our staff support room there was one station up to the left front of the room where all of those tubes came out. All the consoles shared that, so you'd go over there and pick up your copy. Similarly, if you wanted to send something to one of the flight controllers in the Mission Control Room, you could put it in there, and you knew what console to address it to, and it would go through the routing and pop up at his console. I remember that. Seems like kind of antiquated system by today's standard, but that's how it was done.

The other thing that I do remember was as I say I was always nearsighted, and I was wearing glasses. Big heavy-framed glasses back in those days. These headsets, you'd be issued a headset at the beginning of the simulations, and it was your headset and your responsibility to turn it back in when the mission was over. Some of them would—after sitting there, you'd be assigned generally, you'd be on console for about 8 hours. That headset pressing your ears against your glasses. It got to be torture.

Some of the flight controllers, the ones out in the control room, had better headsets with the little pieces that went in your ear. But most of the ones we had were the big old earmuff style.

The other thing that was interesting about it, and that took a while to learn how to do, was when you were listening to multiple control loops on the audio at the same time, the volume was about the same.

You know how when you're in a big crowd, a gathering, you can listen to conversations and focus in on a conversation, but I think what's happening is you focus in on a particular voice and a volume off in this direction or in that direction. You can follow the conversation. But when it's all coming to you at the same volume at the same level, and they're unfamiliar voices, and you're trying to listen, "Okay, is that—," it was a little difficult at first because it was like all this chatter. To learn to listen for what you needed to listen for was a bit of a challenge at the beginning at least for me.

Myself, Bob Wiley, Roger Sanders maybe. Actually we could find out. The Manned Spacecraft Operations Group Association has published a book. They published a book for the 35th anniversary. It has a summary of all of the missions, and it has a summary of all the console assignments, who was on which console position at shift one, shift two, shift three. That would say which shift I was on. I think I was on second shift for Apollo 10 and 11 and maybe 12. That has the actual shift assignments in there.

I shared the responsibility with the other engineers in my branch that were assigned to work LOI console, and we sat there on the console. It was very interesting because you could follow the mission real time. You were right there. We weren't in there 24 hours a day. We were in the staff support room for our shift and then we were off.

Are you familiar with that book? You probably are. They've got copies of it.

ROSS-NAZZAL: Volunteers, right?

GEORGE WEISSKOPF: Yes. That was a lot of work to put that together.

JOHNSON: Yes. It is a lot of work.

GEORGE WEISSKOPF: Somebody had the manning lists someplace. I wouldn't necessarily say everybody's—there may be people's names that got left off because they didn't have a complete list.

ROSS-NAZZAL: Actually I had a conversation with Jack Knight about this before the anniversary, because I asked him, "Well, is this really accurate? Because this is based on who was going to be there, who was assigned." I asked him, "Well, is it possible to actually get a list that says for sure these were the people?" He just said, "No, this is what we have."

GEORGE WEISSKOPF: We had access badges for the Control Center, and I'm probably not the only one, but I saved my access badges for the Control Center. I have those souvenirs of what missions I was assigned. Because you had to have a pass in order to get into the Control Center side.

JOHNSON: You said you thought you were in shift two for 10 and 11 both?

GEORGE WEISSKOPF: Yes, I'd have to look back. One shift was pretty much like the other. For the missions, once the LOI maneuver was done, we were finished as far as what our assignment was in the Control Center side. Of course we still followed the mission as closely as we could.

For Apollo 11, I don't remember how it came about, but we were told that if you had an access badge and you wanted to come in when the landing was scheduled, they opened up—I believe Apollo 11 was controlled from the third floor MOCR during Apollo 11, because they had two floors—they opened up the MOCR on the second floor of the Control Center. They drove all the big screen displays with the same displays that were being used in the MOCR that was controlling the mission, and we could go in and we could sit there at the consoles. I was sitting at one of those consoles, I don't remember where, watching the big displays during the Apollo 11 landing, and I could see the velocity and altitude plots showing them coming down to the surface. That's where I was able to be there.

Then I can remember, I think it was late on a Sunday afternoon and I walked out of the Control Center after it was over later that evening. I walked out and I looked up and there was the Moon, and it was sort of like, "Oh, really? Really? Are you up there? Let me get a really big telescope and see." It was so surreal, so amazing, to think they really did it, they're really up there getting ready to walk around.

JOHNSON: Were you able to hear the loops in that other room?

GEORGE WEISSKOPF: Yes, they had the audio, yes.

JOHNSON: That's exciting. I imagine the atmosphere was similar to what the others were experiencing, cheering and excited when it happened?

GEORGE WEISSKOPF: Oh yes. I think everybody was very very relieved. Ha, they're down. Because it was very tense at the end. Being an engineer that was very much involved but yet not really involved, I didn't have any direct involvement. I'd talk to some of my coengineers and hear some of them talking about it. But as far as the descent maneuver, I was focusing on my part, they were focusing on their part. Watching that and listening to it, it's like, "Ah."

KATHLEEN WEISSKOPF: You were on shift two for Apollo 11.

GEORGE WEISSKOPF: Yes, that's what I thought.

JOHNSON: Were there any other memories or anything about those three, 10, 11, and 12? You mentioned 12 of course the Surveyor [Moon lander], they landed close to that. Since you had something to do with that.

GEORGE WEISSKOPF: Yes, that was interesting too, that they were actually going to get to go over there to one of the Surveyors and cut some of the pieces off and bring it back. Their concern, or their interest, was this thing has been sitting on the Moon for, I don't know, four, five years. Let's see what the space environment, the lunar environment, has done to some of the materials. They were very much interested in the effects of space on various components.

They were able to do that. As I remember, they landed a little bit long on that one, a little bit past it. I remember [Charles] Pete Conrad, he was the commander on that one. Listening to the loops when he was coming down for the landing, and he was so excited. "There it is, there it is!" Something to that effect. I think he was a little bit amazed that wow, it's really there, I see it.

That was one of the interesting things too, in order to get to a particular landing site on the Moon, we could compute the trajectory through numerical integration, but the models that they had developed of the Moon's gravity field, a simple-minded view of the Earth or any of the planet bodies is it acts gravitationally as if all the mass is concentrated at a point in the center. The Earth isn't really that way, and neither is the Moon, and neither are most of the other planetary bodies. They have what they call mass concentrations.

You think well, what difference does that make? It doesn't make any difference when you're thousands of miles away; it's still pretty much acting as if all the mass is at the center. But as you get closer to it, these mass concentrations, these gravity anomalies if you will, affect the trajectory. If you're trying to pick a very precise point on the surface, and you're going to be orbiting the Moon for a number of orbits before you get there, you've got to know about these mass concentrations. Otherwise your trajectory is really wandering around and you're not going to end up where you think you're going to end up.

One of the things that we got out of Apollo 8 was they got some better idea of the fact that the Moon had these mass concentrations. They still didn't have a very good idea of where they were and how big they were. They kept trying to refine that. In Apollo 10 we tried to get into an orbit that took us exactly over the Apollo 11 landing site, and they got more information about the mass concentrations.

That helped us refine our targeting for Apollo 11. But even so, even on Apollo 11 we were a little bit off. But Apollo 11 gave us a little bit more information. Then by the time we got to Apollo 12 they felt confident enough that okay, we're going to try. If we want to go to the Surveyor and pick it up, we know where it is, but we got to be able to predict and do our guidance well enough that we actually end up there when we land. They did, so they were very happy about that. That proved out their models.

JOHNSON: You weren't in the SSR for Apollo 13, is that correct?

GEORGE WEISSKOPF: No, I wasn't assigned. Of course this happened on the way to the Moon.

JOHNSON: Talk about that mission and the accident, and what you were doing during that time, and what you remember.

GEORGE WEISSKOPF: This is kind of funny, a little bit of a backstory. Valerie? No, she wasn't born yet, was she?

KATHLEEN WEISSKOPF: She was born in May of '72.

GEORGE WEISSKOPF: And Apollo 13 was in April of '70. We were living in the two-bedroom apartment already. We had just bought our first TV. A secondhand TV, mind you, black-and-white.

KATHLEEN WEISSKOPF: For $25.

GEORGE WEISSKOPF: We had that. We thought good. For Apollo 11 we had gone to one of our neighbors there at the apartments, another young couple, they had a TV, and that's where we got to see the first steps on the Moon. For the landing I was up in the Control Center, but I was home by the time they got to do the first steps. We were over there watching the grainy TV pictures.

But for Apollo 13 we had a TV. Now we were going to get to actually see it on our own TV. I think Apollo 12 we watched it on the neighbors' TV too. We were at home watching the news report, and we get the report about the accident. It was before I was supposed to go in and be on console. I thought oh, no. I thought well, I better go up there and see whether there's anything I can do.

I can remember having a chalkboard talk with my branch chief Ron Berry at the time, and we were discussing. It was still early. They didn't know exactly what the situation was. The return to Earth people, Bob Davis and I think Lee Norbraten and Poppy Northcutt probably, they were even more focused on it because whatever was going to be done was going to have to be a return to Earth maneuver, and they were just trying to figure out what the best way to do that was.

You wanted to help, we talked about different possibilities, but what could we do? At that point, they were still trying to assess how bad is the damage, can we use the Service Module propulsion, what are we going to have to do? We're going to have to use the LM. That brought up all kinds of questions because the engineers from Grumman had to get involved.

The descent stage on the LM wasn't designed to fly the whole spacecraft around. It wasn't designed to fly with the Command and Service Module attached to the other end of it. I think some of the engineers had decided that they wanted the interface, the docking adapter, to be able to take the stresses of either engine firing, and that was fortunate, so that they were able to use the descent stage. But my own feeling was just one of like, "I want to do something, but what can I do?" There's nothing. It's a hardware issue, it's not a trajectory issue at that point. What can we do with the hardware?

They had—you know the rest of the story—all kinds of problems, like we don't think we can trust the Command and Service Module, because we've had to shut the whole thing down, because we're running out of power. We've got to save the batteries. The thing is getting cold over there, so we got to move over here and live in the LM.

Turns out when they took those pictures, when they got back close to Earth, it's probably a good thing they didn't, they probably wouldn't have been able to use the Service Module engine at all. They were worried about possibly I guess other explosions too. All the problems that developed with the carbon dioxide in the LM, because the LM wasn't designed to support but two people and here we had three people in there, and they were in there for a much longer period of time, and all of that engineering of adapting the canisters for removing the carbon dioxide to fit on the LM system, I wasn't involved in any of that. It was all fascinating. It would have been fun to be involved, but didn't have anything to do with trajectory, had to do with hardware.

JOHNSON: I notice on what you wrote down it looks like because of Apollo 13 it was decided that you should develop some alternative mission plans, trajectory profiles.

GEORGE WEISSKOPF: Yes. There was another engineer. His name was Rocky [D.] Duncan. He's still alive. I remember talking to Rocky, and I think one of his assignments—he had been looking at alternate mission plans for earlier missions. We had so much success with 8 and 10 and 11 and 12 that they pretty much decided we don't need alternate mission plans. Then NASA got to thinking after 13 the most important thing then was saving the lives of the astronauts.

But I think what happened was that management realized things can go wrong, and what if we are on our way to the Moon like we were on 13 and something goes wrong with one of the systems. They get into the LM and they check out the LM to make sure it's working. Suppose you get into the LM and you're halfway to the Moon and you're checking out the LM, and the battery is dead. We're not going to be able to land. Oh. Now we've spent all this money, we're all on our way to the Moon, what can we do? Should we just turn around and come back home right then? Or if everything else is working, can't we use some of our instruments to gather some data for the scientists and get something, so it doesn't look like we totally wasted all this effort?

That's when the subject came up again, and I was asked, "Well, see what you can do with your trajectory programs. What kind of orbits can we get into around the Moon that we might be able to get some useful information?" As the missions advanced, scientists were getting to put more and more instruments on the Apollo Command Module. You probably remember in some of the later missions after they left lunar orbit and were headed back to Earth, they would do a spacewalk and go outside and retrieve film and stuff from some camera equipment that was mounted I think on the side of the Service Module behind the Command Module.

That was the goal, was to develop some alternate mission plans that we could use if we couldn't execute a landing. I was tasked with generating some of those plans. I think for Apollo 14 and 15 and maybe 16, someplace I think I have the internal notes that I published that have these proposed alternate plans.

My one memory about them was one of the most ambitious plans—and I don't remember which mission it was for. It was assuming that there was one of these contingencies on the way to the Moon, but you still had a completely good Command and Service Module. What's the possibility in going into a polar orbit over the Moon's poles, and staying there for a few days and getting back?

The main question there was how much fuel is it going to take to get into orbit. Assuming we dump the LM, if the LM is useless and we can't land, we just get rid of it, then we don't have to push the mass of the LM and all its fuel around, so we have a lot more delta V capability with the fuel that's in the Command and Service Module than we would if we had to carry the LM with us. Can we get in a polar lunar orbit?

I came up with a proposed mission plan, and I got to present it to Dr. [Robert R.] Gilruth and all the astronauts in the big conference room on the 9th floor of Building 1. It was like "Gulp!" All of these important people sitting around and looking at my alternate mission plan. I honestly don't remember what their conclusion was, whether they would have been willing. Technically it was feasible to do it from a performance standpoint. Whether they would have really done it I don't know. Fortunately we never had to use one of those alternate mission plans.

For the later missions that was my primary job pre-mission, to develop these proposed alternate lunar mission plans. I don't know that they even simulated any of them. I don't think so. As the missions progressed and they got more and more confident, we were now confident that the computers in the Mission Control Center were generating the right lunar orbit insertion maneuvers, the right trajectory maneuvers. We would still always run our offline programs and compare the solutions. The demand for having a staff support person sitting there basically to back up the flight dynamics officer became less and less required.

I think we always had somebody. Toward the latter missions, I'd have to look at the manning list. It might have been just for one or two shifts on the way to the Moon, and then the LOI maneuver was done.

JOHNSON: You've got here that you were doing some other work, around the time everything was being canceled, or right before it was being canceled. You were working on an investigation from the trajectory standpoint of what would be possible if you wanted to establish a permanent lunar base.

GEORGE WEISSKOPF: Right. I think that was within our division, and our branch chief Ron Berry and then one of our section chiefs, Jim [James R.] Elk, had talked about it. Again we were young engineers. I don't think this came from NASA Headquarters or anything. I think it was just an internal study. We said, "Well, now that we're successful in going to all these places on the Moon, we were thinking that the next thing is to propose putting a lunar base someplace and doing a little more extended exploration. Upgraded rovers perhaps."

We were saying, "Well, okay, how would you go about doing that?" When you're trying to take stuff into space, and even further, to the Moon, you're always concerned about the weight, the mass, and how much fuel you have to expend. There are ways to optimize trajectories and maneuvers to minimize how much fuel you have to spend to get someplace.

We were looking at various options for if you had a lunar base, how often and how frequently would you take missions back to the Moon to resupply your base. We were developing trajectory programs and analyzing various approaches to doing that because we were thinking that was the next thing that we were going to do. We were trying to be prepared. That's all that really was.

JOHNSON: Of course those later missions were canceled. Talk about after the cancellation. Did you move right into working on Skylab?

GEORGE WEISSKOPF: Actually the cancellations were a total shock to a lot of us young engineers. It was like "What do you mean they're canceling? We were successful. Why are you canceling?" It's not like we were a failure. We aren't going to waste any more money on you, you failed. You did it, we don't need you anymore. There were I think three more rockets that we could have flown.

JOHNSON: Were you concerned as far as layoffs?

GEORGE WEISSKOPF: Oh yes. I was involved in the RIF [reduction in force], that first RIF, where they actually did a federal reduction in force. In my case, they divided you up into what they called retention registers based on seniority and job category and things, and I was low man on the totem pole in my retention register.

Probably nothing would have happened, except that the young man that I worked a lot with, Bob Wiley, he decided this was a good time, he wanted to get a graduate degree, he was going to leave NASA and go back to school and get his graduate degree.

I guess they said, "Well, if you're going to leave, why don't we RIF you? You'll be RIFed. Then you'll get some separation benefits." It wasn't as simple as that. I was the lowest person in that grouping. If he was going to be RIFed, they couldn't RIF him, they'd have to RIF me to make a slot available. Then since I was higher than somebody else in another retention register in another division, then they would have to RIF that person and give me his job. I got a letter saying, "You've been RIFed but you have bumping rights for this person." I remember going home to Kathy saying, "What do I do? This is horrible. I don't want to take somebody else's job. What should I do?"

My boss Ron Berry called me and said, "George, we got to do this because this is the rules of the civil service. But Bob is going to leave. This won't happen." But I still had to respond to the letter. Did I want to take somebody else's job? Kathy and I had a discussion at that point. I said, "Maybe NASA is not the place to stay then. Maybe I ought to look for a job elsewhere."

She said to me, "Well, what do you really love doing?"

I said, "I love working here."

She says, "Well, then we ought to stay here. If they eventually fire you then we'll worry about it then." So we did.

But it was a shock, because I guess again being young and naive and not really understanding how the federal government and all the civil service processes work, it was just like why are you getting rid of all these people that just accomplished this great goal. It just didn't make sense, and there was so much more we thought we could do.

JOHNSON: Were you aware of the work that was going on for the Shuttle in the background? Had you heard about that?

GEORGE WEISSKOPF: Not at this point. Not at that point. There were some engineers I'm sure that were thinking the next step, what to work on next. In our area we were thinking we're at the Moon, we're going to keep going back to the Moon and establish a lunar base.

But then of course the Russians, their counter I guess to our success was their Earth orbit space station and long duration. Of course there were people thinking about that too, about how we could have a space station as well. That's where Skylab came from, and there were I think a couple of proposals for Skylab that we could either have what they call a dry workshop or a wet workshop. They would use what would be the third stage of the Saturn and either launch it with fuel in it and then try to retrofit it on orbit into a space station, or they would launch it dry. In other words use the structure, the tank, as your space station, and build all the internals that you needed and use the Saturn V to launch that into Earth orbit along with the Apollo Telescope Mount, the Earth Resources Experiment Package [EREP], which was what I ended up working on, and that was launched in '73.

JOHNSON: Talk about that. You were involved on that Earth Resources Experiment Package. What were you doing?

GEORGE WEISSKOPF: Let me see how best to describe it. The purpose of Skylab was to have a long duration space environment for humans and then also to do science. They outfitted Skylab with that. They had an air lock where they could stick stuff outside and expose it to space, and I don't remember all the experiments they had intended for that. They had the human experiments of just the astronauts, the medical experiments of living in weightlessness for extended period. Then they had the Apollo Telescope Mount, which was a solar telescope with its own set of solar panels, and they had the Earth Resources Experiment Package, which was a set of multispectral—which means they could scan different areas of the Earth's surface in different areas of the electromagnetic spectrum and get information from that about what they were looking at. That was called the Earth Resources Experiment Package.

I don't remember how they determined what instruments were going to be on there in terms of visible pictures and other wavelengths of the electromagnetic spectrum, but they had several different instruments that had different capabilities. They designed that set of instruments and they took proposals from principal investigators, scientists at various universities and research facilities around the country and maybe around the world, saying, "What would you do with this? What would you like to do? Submit your proposal. How would you use this experiment package to get interesting data?"

There were I don't know how many hundreds or thousands of proposals that came in for data that scientists would like to inquire. Then okay, we have the experiment package designed to be on Skylab, we have all these requirements, that's very nice. Now we're flying in orbit around the Earth and we have human factors people wanting the astronauts to do health and life sciences experiments. We've got solar people wanting them to use the telescope to get information about the Sun. We have these scientists wanting data about various sites on the Earth through the Earth Resources Experiment Package.

How in the world do you manage all that? They took a group of engineers, and since at this point we had a number of people in my division that okay, these people are engineers, programmers. By that point most of us were pretty good Fortran [programming language] programmers. Here's your problem. The flight control people need help with the Earth Resources Experiment Package. A number of engineers in our division were assigned, and we were led by Dr. Quentin [A.] Holmes, and I've listed some of the other people on the paper there that I can remember. We were assigned to help this group in the Flight Control Division come up with a way to mechanize the acquisition of the Earth resources data for the scientists.

Quentin designed an early database where we took all of the requirements that came in from the scientists. Generally the requirements, they were broken down into which instruments do you want data, what's the location on the Earth, what are the environmental conditions under which you want your data taken—do you want it to be nighttime, daylight, how much percent cloud cover, certain time of the year, Sun angle—we were able to code that up in a very compact form using—actually we coded it up in the fields on a punch card initially. We had I think 10,000 punch cards we had loaded. We created this database on UNIVAC computers in Building 12. We even had some concern about if we load all this data in, then we have to verify it all. Are we sure? That was the first job, to get all the data into this database.

Then we had people working on the trajectory aspect of it that said on any given day what sites around the Earth are we going to overfly on that day with Skylab? Again, Earth resources was just one of the experiments that was onboard Skylab.

We had to share time with the astronauts. There were only three there and sometimes they had requirements to be pointing at the Sun with the solar telescope, so your instruments for Earth resources might not be pointing at the site on Earth when you were—so it was a balancing act.

What ended up was that certain days were designated as okay, this day—and I don't remember how many days a week were scheduled to be Earth resources experiments passes. We had people that would look at the trajectory, look at the database of sites we had requirements for, and say, "Okay, on this day we'll be overflying these sites." Then we would look at what were the requirements for those sites, and sometimes they were conflicting requirements of different instruments.

We would come up with a plan for an Earth resources experiments pass, or several passes of which instruments would be turned on when over what sites, and we would use our database as our source of requirements for that. Then the night before the EREP day we would have a briefing from the weather people in the Control Center, and they would give us worldwide weather. What's the weather going to be over the sites that we're going to be flying over tomorrow? Then we would compare that with the requirements that the PIs [principal investigators] had given us as to whether that was going to meet their requirements.

Initially, it was all a paper system. This was going to be very unwieldy to work, so that was my first experience in working with a computer terminal. We actually had some computer terminals by a corporation called Hazeltine, and they were a greenish screen. That was what I was doing for that prior to Skylab, was writing a computer program that would online real-time access this database of requirements and show you what they were for each of the sites. Then once the pass had been completed, we would go in there and update the database online using this terminal to keep track of what we had accomplished, so that when we were planning future passes we could say, "Well, we've gotten 50 percent of the data he wanted, so we can do some more." Or "No, we've pretty much gotten all the data he asked for, so we can mark that site as completed."

During Skylab, once we had the software implemented, I worked in the staff support room for the Earth Resources Experiment Package. Again it was shift work. We would sit there, and when we had passes coming up, we'd be planning these passes. We had a phone bank actually where PIs could call in and give us updates to what their requirements were, so we'd listen to those and try to optimize the amount of data we could get from the time we had dedicated to EREP.

JOHNSON: You said you had shifts. Were they just normal 8-hour shifts or were they 12-hour? Do you remember?

GEORGE WEISSKOPF: I think they were 8-hour shifts. I think we had 8-hour shifts. I don't know that we did it—the Skylab missions, I think the first one was like 28 days, and then it was 54 days, and maybe 84 days the last one. I don't remember whether we were in there, whether we were manning those consoles for the whole mission, or whether we had off days when there were no EREP activities planned.

What I do remember is we were assigned shift work, that much I do remember, working three shifts, because they rotated us. That was my first real experience with extended shift work. I'd be working either the swing shift or the graveyard or the daytime shift, and then we'd maybe have a couple days off. It didn't sync up with weekends or anything.

The worst part of it was my system never could get used to—it was like two weeks on this shift, two weeks on this shift, two weeks on that shift. My digestion and sleep cycles never could get—I started having real stomach issues then, and I think it was all because I'm eating breakfast at different times.

KATHLEEN WEISSKOPF: I'd be fixing supper for him and breakfast for the kids at the same time.

GEORGE WEISSKOPF: That was my first experience with shift work, and I guess my really only extended experience with it. It was interesting work, but that aspect of it, you can keep it. I would have much preferred to be assigned a single shift and stay on that one shift for the whole mission as opposed to rotating shifts like that.

JOHNSON: Skylab did last a long time, like you said, so that really was NASA's first experience with long-duration flights, and it didn't just affect the astronauts, it affected the people on Earth. Did you work Skylab throughout the whole program?

GEORGE WEISSKOPF: Yes, I worked all of Skylab. Then after Skylab was over, I'm sure they were planning for ASTP [Apollo-Soyuz Test Project] at that point, but I was not involved in ASTP at all. What I got involved in then was the realization again. Shuttle was coming down the pipe at that point. The early plans for Shuttle were very much more ambitious than what actually turned out to be the case. They were talking about we'll be flying the Shuttle every two weeks.

Up until that point mission planning and analysis, as the name kind of indicates, was our job, to develop mission plans for the missions. Analyze and plan for the missions. It was very much a labor-intensive process, wasn't really all that automated. When people started talking about a mission every two weeks, it was clear to everybody that we can't keep planning the missions the way we're doing it, we've got to come up with a much more automated way of doing things.

Various people were proposing different types of computer systems that we could use to do a much more automated approach to mission planning and analysis. I'd gotten very much into computer programming at that point; that was pretty much my full-time job, programming and modifying computer programs. We started with several different systems.

First off, we had one of our contractors, TRW, a gentleman there, Sam [W.] Wilson was his name, he's deceased now, very smart man, very expert in areas of trajectory mechanics, orbital mechanics, he had developed a basic program called the Mission Design and Analysis Subsystem of this mission planning system. They were talking in terms of a big computer system to do mission planning, and then part of this design was something called a Mission Design and Analysis Subsystem.

He had built the prototype of this that ran on a—trying to remember. Was it a Perkin-Elmer? It was a computer system that actually TRW was renting time on. It was a time-share computer system. In the early days of needs for computer systems, a company wouldn't necessarily go out and invest in buying their own computer. They would have programmers write programs, but there'd be companies that would let you rent a certain amount of time on their mainframe computer, and you could either use a teletype terminal or later on it got to be graphic type terminals. But you would be connected to their computer system with your terminal, and then you could run computer programs, without having the overhead of having to invest in buying the computer system and the staff to maintain the computer system.

There was a company, I don't remember the name of it, I might be able to find it, that had offices down on the Southwest Freeway over there off of the 610 loop area, because I can remember going to visit their offices a couple times, but they were the computer that was hosting this Mission Design and Analysis Subsystem program that Sam Wilson had written.

We started with that. It was a set of computer programs that could compute and perform—simulate I should say—various trajectory maneuvers, rendezvous maneuvers, orbital plane change maneuvers. The kind of stuff that you had to do if you were going to put something into orbit and maneuver it around.

Then we decided we wanted to build something in house, and so NASA invested in a Hewlett-Packard minicomputer, more than just a desktop calculator, which were becoming prevalent at that time. This was a true computer that could have terminals, and we began to develop a series of programs for various aspects of orbital maneuvers, rendezvous maneuvers, launch window planning, the kind of stuff you have to do in order to plan trajectories.

We had IBM engineers doing the operating system for that computer, and a number of us engineers building the application programs. We were developing a concept where a number of engineers could simultaneously be on this computer, different terminals, simulating different maneuvers, and taking the results of what they had done and sharing them on the computer, so that one of them could design the launch window and the insertion maneuver into Earth orbit, and he could pass the state vector that represented the insertion state vector for the vehicle to the next guy, who would then simulate an orbital rendezvous maneuver, and build up a trajectory plan for a whole mission that way.

Whereas before we had people that had launch programs, they ran them on the computer, they generated printout, they had their state vector, they gave that physically to somebody else, the piece of paper, they punched it in their punch cards, the next program to do the next maneuver. You had a lot of these individual computer programs programmed by different groups of engineers to do certain aspects of the trajectory, but transferring the data from one to the next—and an actual mission of course is a continuation of states and maneuvers, and it was all manual.

We were saying, "We can't do this if we're doing a mission every two weeks. We've got to have an automated way." That's what we were working towards from the trajectory standpoint. This was called the Flight Design System-1, FDS-1. We built that, and it was a successful enough prototype that the Mission Planning and Analysis Division decided to go ahead, and I guess the directorate above that decided okay, we're going to build a Flight Design System-2, which is going to be our operational system for the Shuttle when the Shuttle becomes operational.

It was a bigger computer system. It was called a Perkin-Elmer minicomputer, but it was a mainframe computer. They actually built a separate facility in the first floor of Building 30, the admin wing, to house that computer system. We bought graphic CRT terminals, big screens, where you could draw graphs of trajectories and other things on them as well as do numerical output, and printers to print out documentation.

We began to build up that same concept of multiple engineers simultaneously working on various aspects of a mission but able to save what they did and pass it along to another engineer or make it accessible to another engineer, and all of the engineers would have access to all of these individual computer programs that knew how to talk to each other automatically.

One program could take a set of inputs and compute a set of outputs. Those outputs could be saved. They were in a format such that another program could easily pick them up and read them as inputs. You could chain these together to simulate a whole mission trajectory and produce a final product. That was called the Flight Design System-2.

We had the same team of IBM engineers writing the operating system. Because basically what we had was we had an operating system running on top of the native operating system of the Perkin-Elmer computer that allowed all of this interchange between people working simultaneously. Each person could have their own completely separate partition where they were doing their data. Their data would never get mixed up with the data that somebody else was doing, even if they were running the same program.

We built that and got that operational. Then for a while the Air Force, they were planning to have their own Shuttles and launch from the West Coast. In order to satisfy their, I think it's called black requirement, they had a very high security requirement on their mission plans, because they didn't want the Russians or anybody finding out about that stuff. They actually built in the first floor of Building 30, admin wing, an exact replica of our mission planning system on the Perkin-Elmers. A complete other system in an electromagnetically sealed room which nothing could go in and out of. You had to take everything in by hand.

We helped build and check that out, and then the Air Force canceled that part of the project, so I don't know what ever happened to that room. My job during that time was I was a contract monitor monitoring and responsible for what the IBM engineers were doing, but really that was one of my most enjoyable periods, because these IBM engineers were such professionals. They took me under their wing. I knew Fortran programming and I knew trajectory mechanics and I knew orbital mechanics. I could do all that kind of stuff. When it came to actual computer operating systems, I didn't know hardly anything. In order to do what our design called for, they had to write this operating system on top of an operating system, and they needed training in the internal mechanics of the Perkin-Elmer operating system.

I went to school with them at a Perkin-Elmer facility, where we spent weeks learning the ins and outs of the Perkin-Elmer operating system. Then I got to the point where I understood very well what they were implementing in terms of this operating system for the Flight Design System.

Then we had a team of engineers both in house and contractor. I think we had some Lockheed Martin or some McDonnell Douglas engineers, what we called processors, writing various programs that did various aspects of the mission. I really don't know how many processors we had. I was responsible for some, as well as working with IBM. I think I was doing that until about, let's see, 1985 or '86.

JOHNSON: Even after Shuttle started flying.

GEORGE WEISSKOPF: Yes. We were still refining and developing that. We made a delivery of that system to Aerospace Corporation out in El Segundo, California, and trained their people on it, because they were picking up the Air Force work out there, and they wanted to use it.

Okay. I think I've run out of that. I told you about the Shuttle era.

JOHNSON: Yes, you were talking about up through '84 you were working on that Mission Design and Analysis Subsystem, FDS-2.

GEORGE WEISSKOPF: All the way up to ’86. During that time, as I said, when I first started out my branch chief was Ron Berry. They reorganized the branches after Apollo. I ended up, I don’t remember the name of the branch [Mission Analysis Branch]. I might have written it down here somewhere. But my branch chief was Bob [Robert H.] Brown and my section chief was Jerry Yencharis and the other section was Robert S. Davis. There’s lots of Davises out there.

I shared an office with three other engineers, Roger Sanders, Lazarus Gonzales, and Lee Norbraten. My first officemate when we had a separate office of our own back during the early Apollo days was Lee Norbraten. He and I shared an office space. He’s a little younger than I am. He came to work at NASA about six weeks before I did. He was from the Miami, Florida, area. But over the years it was interesting because for so many years all through Apollo and Skylab the four of us were in the same office together.

It was an interesting mix of people. I’m a cradle Catholic, Roger is a staunch Baptist, Laz Gonzales is Church of Christ, and Lee Norbraten is nondenominational, so during lunchtime we had some interesting theological discussions.

During the 50th reunion we all got together and sat together at our MPAD reunion at the same table, and during the big reunion out at Space Center Houston we were able to sit together at the same table. But Roger Sanders retired and moved up to East Texas. He and his wife live in Nacogdoches. Laz Gonzales and his wife live out in Alvin [Texas]. Laz in his retirement is actually a full-time minister in a church out there and his wife is a minister also, and he’s done prison ministry.

JOHNSON: Oh, that’s interesting.

GEORGE WEISSKOPF: One or two years ago one of Laz's sons, and I don't remember his name, was a state legislator for the state of Texas, and when they opened one of the legislative sessions Laz, he was a minister at this point already, he was invited to give the invocation at the state legislature.

We formed a pretty close bond, the four of us. Probably in 1975 it would have been. In the fall of 1975. We all liked the outdoors, and we in our office discussions said, "We ought to go camping. I like to camp. We ought to go camping." So we planned a weekend camping trip and it was to Pedernales Falls State Park, which is up west of Austin on the Pedernales River, and it was in October.

We took off work early on Friday and we drove up there, we all met at the park, and a cold front came through. It was a beautiful clear night, but it got bitterly cold, below freezing, and we had our own tent at that point, and we had borrowed sleeping bags. Our youngest daughter Rita was a baby, less than six months old. She was in the sleeping bag with my wife so she could nurse her.

My son was the only one that had his own sleeping bag that was a fairly decent sleeping bag. My daughter Valerie and I were freezing. We ended up getting in the same sleeping bag together trying to keep from freezing. We had a good time. It was a successful camping trip. We all were scraping ice off of windshields and water buckets the next morning.

JOHNSON: That's camping in Texas. You never know what the weather is going to do.

GEORGE WEISSKOPF: You never know what the weather is going to be. During that time Robert Brown, when we were originally coming up with the idea that we needed this Flight Design System and the mission design part of it, Robert Brown was my branch chief. Let me see. What else was I going to add to that?

Then after we got more into the group of us that were developing software for the Flight Design System, they again reorganized the branches, and Elric [N.] McHenry was our branch chief in the Software Development Branch, and he had under him Bob Davis was the Section Chief that I reported to. Ernie [Earnest M.] Fridge was the other section chief in the branch. The branch was divided up such that Bob Davis and his team was working on the development of this Flight Design System-2, and Ernie Fridge and his team was working on mainframe computers, programs that did the high-fidelity final computations for mission trajectories. They had more fidelity and more accuracy in their computations than the Flight Design System.

The Flight Design System was good for roughing out and doing the initial planning. Then the very detailed computations for maneuvers were finalized on the other aspect of it. We called it the—I can't think of the term, have to look it up. System X and system Y we called them, I think. There were other names associated with them.

We came across another interesting aspect when we were developing this Flight Design System, because we would build various processors and the operating system, and we would say, "Okay, we're ready to release this to the users." After a lot of testing we released it to the users. Users would start using and of course invariably they'd find bugs and problems, and they would write reports on them. We would have to investigate them, and we would have to fix them. Then we would have to release updates.

This got us into an awareness of configuration control of the software. How do you manage the software so that somebody says you have a problem, you go investigate the problem, you fix the problem, how do you make sure that you don't introduce other problems, or the new version is that latest version? We became very much involved in developing a system of checks and balances, record keeping to do this software configuration control. That was something that we learned as we were doing it. In other words this is something you have to have.

If you're going to manage and provide to somebody a software system, then you need a way to manage change to that system and keep very good records of what you've done so that you can back things out or you can find what the source of the problem is. When the system grows large that becomes a large problem.

That was the thing that I was doing at the end of my work in the Mission Planning and Analysis Division, because by the mid 1980s they were talking about a space station, and Space Station Freedom as a program. One of the things they wanted to be able to do for Space Station Freedom was to have very good control over all the software that was going to be put on the station and used for managing the station. The idea was put forward that we ought to have a unified software environment for the development of all the space station software, so that you have a way to manage it and control it and maintain the configurations, maintain the records of the software changes that are made and why they're made.

A proposal was that we develop a software support environment for the whole space station. The man's name was Jim [James L.] Raney. I think I read something recently that he has passed. But Jim Raney was the one not in MPAD, but he was in the Spacecraft Software Division [SSD], I think. He put forward that idea and the plan was approved. Bob Davis, my supervisor, was recruited by Jim Raney to come work for him. Since we were involved heavily in the development of the Flight Design System, Bob was a good person, if he was interested, to pick to work on this new system. It wasn't long after that that basically the work we were doing on the Flight Design System was becoming very routine, it was kind of maintenance work. So I thought well, maybe this would be a good thing for me to do too. Bob had talked to me about it, and I went to work for Jim Raney.

The space station support environment from '86 to '93 initially was a lot of requirements work, producing the requirements documents that could be used when NASA issued a request for proposal to build this software support environment. My particular area of that was the user interface aspect of this computer system. I'm sure that you're probably familiar if you've worked with software programs. It's very frustrating to users when you work with this program, and this program does it this way, this one does it that way, and another one does it another way. Or they release a new version of it, and now you can't do what you did before because they moved it someplace else.

We were aware of those kinds of problems and wanting to make a consistent user interface across the whole system, even for crew members that would use it, was our thought, using software onboard. We wanted to have a common user interface we called it. We wanted it to be user-friendly, something that was intuitive, easy to learn.

We had some in retrospect I would call them pretty grandiose plans for what we wanted this system to do. We put together over the course of a couple years a big thick requirements document of what the system had to be able to do, and it was put out for bids, and it was bid on by a number of contractors. Eventually there was a group led by Lockheed Martin, PRC [Planning Research] Corporation, and SAIC that formed a team that won that contract. After they won the contract and they started working on building the system, then Bob Davis and I were—again the branch structure had obviously changed. We were under Bill Raney and then Jackie [L.] Fisher for a while, and then eventually Janet Bell became our branch chief.

Bob and I each had major responsibilities with two other engineers for monitoring what the contractor was doing. In other words we would attend lots of status meetings, review lots of documents, and write evaluation reports. To be perfectly honest, there were a lot of wonderful engineers, really sharp people working for the contractors, but it wasn't very well managed, and it was so frustrating to us, because we'd point these things out to them, and then we'd have to write these evaluation reports.

The evaluation reports went up and it affected the award fee that they got. We got crosswise with the project manager a couple times because he didn't think we were being generous enough in our evaluation. We were very frustrated because we realized we were spending over $100 million on this project, and it's like come on, people, we don't want to have Congress asking us why we messed up.

It was rewarding work, but it was different work. I was more of a hands-on person, I liked it better when I was in there understanding the programs and helping to advise or doing some of the programming. When it was very far removed and I felt like I'm trying to pull hens' teeth to get this contractor to tell me, "Okay, well, what's really going on here? Why aren't we?" I didn't like that job so much. It's a different kind of work.

Some people are really very good technically and other people are really good being coaches. They know how to find the talents of the people they've got on their team and to bring those talents to the best. I liken it to being a good coach. A good coach knows how to do that. Some people just seem naturally gifted with that. Other people, they're good at hitting home runs or whatever. I guess what I'm trying to say is I enjoyed the work, I enjoyed the people I was working with, but it was frustrating because we weren't getting anything accomplished, or it didn't seem like we were getting accomplished what we wanted to get accomplished.

Eventually that all came to a head not just for the SSD but for the whole project, because the whole space station, the cost kept going up and up, and early years of the [President William J. "Bill"] Clinton administration they were ready to cancel it, and it came within one vote in Congress of getting the whole Space Station Program canceled. There were major redesigns, and Kathy can tell you about it because she was working at NASA at this point and supporting JSC's redesign effort.

But anyway, when that happened, when they redesigned the whole Space Station Program, all of the work that we were doing on the software support environment including all the hardware that had been bought, that was all—the term they used was novated. It was handed over to Boeing in the redesign. That basically set a bunch of us loose, and that's when my work transitioned. I moved into the Engineering Directorate at that point, and I was working in the Avionics Systems Division. I believe Irv [Irvin J.] Burtzlaff was our division chief at the time.

I was working for—I think his name was [Walter E.] "Sam" Ankney, who came out of the Flight Software Division; he was my branch chief. I think my section chief was Mike [Michael A.] Brieden. That was a transition, but it was a good transition for me, because I got back into an environment where I was learning something new and doing more hands-on work, which is what I enjoyed the most. I think the reason I enjoyed software engineering over the years a lot was because you got to design, you got to build, and you got to see the results of what you built, whether it worked or it didn't work. It's not hardware engineering, but it's the same sort of thing. You design something, you have an idea and a concept, and you try it out, and you get the satisfaction of seeing your idea come to fruition. I guess we can wrap this up pretty quick probably.

In the early '90s I was working on something. Let's see. What's the best way to say it? The next thing I have on my list is the Orbiter Interface Unit [OIU]. Working in the Avionics Systems Division was an engineer named Dan [Daniel A.] Harrison. There was a requirement when they were building the [International] Space Station [ISS]. The Space Station's onboard communication bus, the electronic connection between the systems on the Space Station, was using a technology, a protocol called 1553, which is a military communication protocol. That's different than the protocol that's used in the Shuttle systems. They knew that we're going to use the Shuttle to build the Space Station. The Shuttle is going to go up and dock with the Space Station. How are we going to talk to the computers onboard the Space Station when the Shuttle is docked to it? We want to be able to talk through the Shuttle systems.

The Shuttle systems though don't communicate 1553. They have their own proprietary bus. Dan Harrison proposed, "We can do this job in house. We can build a box that'll be in the Orbiter that will know how to talk 1553 to the Space Station side, and it can translate and talk to the Shuttle buses on the other side of the connection." He had a team of hardware engineers, electrical engineers, designing the computer box, the OIU, and I was involved in the software aspect of that, helping to write the software for the OIU, designing the operating system for the OIU. There were other engineers designing the—I think there was I think three different computer boards in there.

This was an opportunity for me where I had never done—other than the little bit on the Flight Design System with the Perkin-Elmer computer—had never done any low-level machine language programming of operating systems in a computer. They basically said, "Well, we're using this chip and here's the book on this chip. We can buy an off-the-shelf from a German firm, a piece of software that's called a boot loader to basically initialize the computer when it comes up and knows how to read from an external device, much like your BIOS [basic input/output system] on your desktop computer.

That was a lot of fun. I was a little nervous of whether I could really do this, because I had never done it before, but it seemed straightforward enough. I got to work on that and get that operational on the OIU.

Then I got to program in an entirely new language, another language that I had never dealt with, which was very intriguing to me. It was called LabVIEW and it's a graphically oriented programming language produced by National Instruments out of Austin, Texas. It was designed for people developing computer interfaces for laboratory equipment. I found it very intuitive in developing user interfaces and writing programs, so I proposed using that for a piece of ground support equipment for the OIU that was to be used to load software loads, because they would put different software loads into the OIU for each different Shuttle mission that was going to dock with the Station. I developed that set of ground support software that ran on a little IBM laptop, and I developed it using the LabVIEW language. Then when we got it working, we turned it over to the people at the Cape that did the maintenance for each mission on the Shuttle.

The OIU was still flying. There were two OIUs in the aft part of the flight deck of the Shuttle. I guess it was the side by where the ladder came up. That's where the two units were. They didn't have any big fancy flashy displays. There were two of them and they were for communicating with the Space Station systems when the orbiter was docked to the Space Station, and as far as I know they were using that all the way up through the last Shuttle mission.

Then following that, when they launched the Space Station, initially the Russians put up their Zarya module, and the U.S. put up the Unity module, and that was in November of '98. The Russians put their module up first. We came up with the Shuttle and docked the Unity module to it, and then left it unmanned. That was the situation that led Dan Harrison to propose—and the program wanted some way when the Shuttle wasn't there and nobody was on board to be able to talk to the systems on board this nascent or early version of the Space Station that was up there that was being built up, until it was manned and had its permanent communication system on it.

They developed this Early Communication System called ECOMM which consisted of a reworked OIU unit that was customized to handle a different communication protocol. Because now where there are two docking ports on the Unity module, one on either side, in those docking ports they mounted a small flat panel antenna array that could talk to the TDRSS [Tracking and Data Relay Satellite System] satellites and thereby communicate to the ground.

What that system gave them, when the astronauts went up on that mission in November of '98 to put the Unity module to the Zarya, they also installed this Early Communication System so that when they left NASA was able to still watch what was happening onboard this Unity module-Zarya combination and get some information back to the ground.

I think at one point the system was very instrumental in helping solve some problem the Russians were having. I don't remember the details of that. That system again, a couple of engineers I worked with were Helen Neighbors and Bob [Robert V.] Ling that worked on writing the software for the Early Comm System. Again, it was a lot of work, but it was a lot of fun because you could see what you were doing, and you could see how it was being used. I always found that rewarding when you got to work on something and you got to see it fly. I realized about this time how fortunate I had been over the years in having been an engineer that got to work on so many things that I actually got to see fly, where there were engineers that worked on a project, the project got canceled, put their hearts into something for two years, gets canceled. That can be very frustrating, because you do all that work, nothing came of it.

I had some experiences like that too with the SSD and then again later on I put that X-38. That was the next project we worked on. A very young dynamic engineer, John [F.] Muratore, and I think he may be working for SpaceX now, but he had this concept of basically a winged reentry body, the X-38 [experimental reentry vehicle], that was going to be docked to the Space Station permanently so that when there was no Shuttle there and there was an emergency astronauts could hop into that thing and fly back and land on a runway someplace.

They had done a lot of work on that already when I got onto the project. They had done drop tests out at Edwards [Air Force Base, California] from [Boeing] B-52s [Stratofortress], and they were perfecting, because it was a reentry vehicle that came in and then it had a parasail that would be popped out instead of a parachute. They could steer it with that parasail down to a landing on a runway.

We were building the first prototype flight vehicle. Again it was an in-house project. NASA's plan was to design and build and prove out the concept, and then basically contract out the work of building the flight vehicles. We were building the vehicle that was going to be taken up to the Space Station as a prototype, and then they canceled the program.

My work on that project was helping to build a simulation system that could be used to test out all the flight computers and software for the X-38 and test it out on the ground. We had a lab in Building 16. I guess the interface between 16 and 16A. That's where the lab was.

Helen Neighbors was building flight software, and myself, and some of the other engineers. Let me think of people's names now.

Brad Loveall was the group lead, and there might have been people from Draper Labs again that were doing some of the operating system software, because it was a very complicated software system that they were proposing and designing for the X-38. There were going to be five computers, all doing the same computations, and the computers would compare the results they were getting, and if two of them or three of them detected something that was fishy with one, they'd vote that one out of the group. Again it was to be a very automated system, so that the astronauts could just hop in the vehicle in an emergency, push a button, and it would fly itself back to Earth. They wanted to be very sure that it was going to work, and that was the reason for all the redundancy. We had a full suite of flight computers there that we were setting up in computer racks and having all of this communications, in conjunction with terminals that software engineers could sit at and evaluate how the programs were running, simulate faults to make the system think it had a problem. We were quite far down the road on that when that got canceled.

JOHNSON: I imagine that was a major disappointment.

GEORGE WEISSKOPF: Yes, it was. The funny thing is now you've got this company called Sierra Nevada Corporation that is building essentially the same thing. I think that's the reincarnation of X-38.

JOHNSON: It was a good design. It was the funding, I would imagine.

GEORGE WEISSKOPF: Yes, the money.

KATHLEEN WEISSKOPF: Politics.

GEORGE WEISSKOPF: And money. Money is always the issue on these things, because they do cost. You can't deny it's a lot of money. Even now I don't know what's going to happen with Artemis [Program] and all of this. I hope it goes through. There were people even back during Apollo, "Oh, we don't need to do that. We have all these poor starving people we got to take care of. Don't do that." You can't deny you always have people that need help. If you say, "I'm going to not do any of this until nobody in the world is starving or poor," you'll never do it then, because it just doesn't seem like the other problem is going to get solved by throwing money at it. I don't mean to get up on a political soapbox.

JOHNSON: Do you want to talk about that last thing you have on your list, the Advanced Resistive Exercise Device?

GEORGE WEISSKOPF: Yes. I might as well, because that's where I ended up. When X-38 was canceled, NASA already had another project going, the Advanced Resistive Exercise Device [ARED] for the Space Station. The engineer was developing software for the ARED. It's an interactive system where the astronauts have this exercise device but there's also a computer screen that they interact with to find out what is their prescribed exercise routine for today or for the week, and then they perform those exercises and it logs data about what the machine senses the forces on their body are during their exercise.

There's a good bit of software there, and there were two aspects to developing that system. One was the flight software that runs on the tablet computer. I don't know what kind of a tablet computer they have there now. What we were working with was an early flight-rated tablet Windows-based computer. The software that he was developing was being developed using LabVIEW, so my branch chief, Rick [Richard E.] Coblentz at the time, said, "George is now free because he's not working X-38 anymore. He knows about LabVIEW. Maybe we can get him to help out on that. You need some help over there." So I got assigned onto that.

Initially they were building the ARED hardware and they wanted to test it out on the ground, so they wanted to run the hardware through a lot of physical cycles to simulate wear and tear on the system. They built the prototype hardware, and they built machines that would actually—you wouldn't have a person standing there 24-hours-a-day lifting this thing up and down to put it through hundreds of thousands of cycles to see how well the machine was going to stand up to wear and tear. They had another machine that was doing that. They wanted to be able to control the machine that was driving the exercise equipment, and they also wanted to be able to collect data from the exercise equipment, so they needed software for that. I ended up using LabVIEW to write two sets of software to test out two different aspects of that machine so that they could run it through many tens or hundreds of thousands of cycles before they ever delivered the flight hardware onboard.

After I had done that, then I got into helping with the finishing up the flight software, and at the end I was basically the sole person doing the flight software and the testing of the flight software, configuration management, and releases of different versions of it, and taking the different versions and preparing them for installation on the Space Station.

When I left, I basically turned over all the documentation on the system, the configuration management of the system, and the final test plans to the engineers that came after me.

JOHNSON: That's after you retired, 2007?

GEORGE WEISSKOPF: That's when I returned, yes, 2007.

JOHNSON: Throughout your career, technology definitely changed through 40 years of being with NASA.

GEORGE WEISSKOPF: Oh yes, yes. From slide rules and Friden calculators to handheld calculators. I can remember the first Hewlett-Packard calculators. To the early desktop computers, to the e-mail systems and all the technology we had at the end. It's of course gone even beyond that now.

JOHNSON: Working with that technology, you were a firsthand witness on everything that changed as far as with computers.

GEORGE WEISSKOPF: The first programmable computer that I worked with in the office was an Olivetti 101 Programma, made by Olivetti Corporation, which I guess they made business machines. It was a desktop unit probably about that wide, that deep, that high. You could program maybe 150 computer steps in it, and you had a 2-inch-wide magnetic card about that long that you slid into the top. That's where the program would be stored. When you wanted to run the program again, you loaded the program from the card, and then you could run your calculations. There was a little digital display that gave you the results.

I watched it evolve from that to the Hewlett-Packard handheld calculators, and then Hewlett-Packard began to produce some desktop calculators that had bigger screens on them, and you could write more complex programs, and you could store the programs on magnetic mini cassette tapes. It had digital plotters that went with them, and you could plot results.

Even the beginning of Apollo, one of the other experiences I brought with me to work there was that when I was at the University of Michigan there was an early company pioneering this concept of time-share computing, and it was called Compushare. I'm pretty sure that was the name of the company. It was based in Ann Arbor, Michigan, they had small mainframe computers, and as they were developing their business the company I guess was very astute. They had a relationship with some of the professors at the University of Michigan and said, "Hey, if you've got some students that would want to learn computers and computing time, we'll give you so many hours of free computing time." Developing this business, this idea that this was a way to do computing.

One of the professors I had had some time, and he gave us some assignments and said, "You can use these teletype," they were teletype machines. Using teletype machines to write Fortran programs. The programs were written and submitted and run on this Compushare computer over a telephone line. You basically had a modem that sat on top of the desk. You called up the computer, when you heard the beep you put the phone in the cradle, and then you got a sign-on or log-in prompt and away you went.

When I came to work at NASA, I might have mentioned what my experience had been with my boss. That company, I don't think it was necessarily the result of me coming to work here, apparently NASA was interested in possibly buying some time on their computers for NASA engineers. When my boss found out I'd done work on their computers, "Oh, well, good, here, why don't you see what you can do with this?"

I was programming simple orbital mechanical equations. Nothing complicated, what they call a two-body problem where you assume that planetary bodies act as point masses and you just have one or two of them. You can solve, there's closed-form solutions to your equations, and you can run parametric studies of various maneuvers and what kind of orbits they result in. I did a little bit of that, but we didn't really use that at all on Apollo. It was just more of what can you do with this.

It's pretty limited, because we'd have to try to put much more complex numerical integration programs, and we would have to be able to develop different gravity models and solar wind effects and all of that. We already had some of that in the mainframe computers in Building 11. It wasn't worth trying to replicate it on this smaller, less capable computer over a slow speed data link over a phone line.

But it was a harbinger of what was to come, with computer terminals and what you would be able to do. We saw some more of that advance in Skylab when we were doing the Earth resources experiment database. Initially when I was writing the database program, I was doing it over a teletype terminal. Then we got those Hazeltine terminals, which were alphanumeric terminals. We weren't doing any graphs or anything on them, but they were alphanumeric displays, monocolor, green. I guess green was considered to be easy on the eyes. Small screens. Nonetheless, you had a keyboard and a screen, and you were interfacing to the computer, and a program running on the computer, and you could do a lot of things that way.

Much more convenient than writing your program, getting somebody, or you sitting at the keypunch machine, punching up keypunch cards, and submitting your run. Then you'd wait until they ran it, and then you'd go get the printout. Then you'd look at the results.

Or there were experiences early on where a number of us engineers had them, we were in a hurry, we got to get these runs submitted so we can have the results tomorrow. We'd get everything punched up and we'd submit the decks at the end of the day, get ready to go home, and oh no. Run back over there. Beg the operator. "Can I have that back? I know there's a mistake in there. I want to correct one thing. I forgot to change."

Or the worst, where you'd go the next morning. You get it and you look at it. Wait a minute. Why did that change? You look over the inputs. "Oh no, I forgot to change the inputs." A waste of a whole computer run.

Whereas when you had terminals, and you could run things immediately, that was a lot easier process.

JOHNSON: Quite an evolution in technology.

GEORGE WEISSKOPF: Yes.

JOHNSON: We appreciate you doing all this for us today.

GEORGE WEISSKOPF: That's the least I can do.

KATHLEEN WEISSKOPF: We appreciate what you are doing.

GEORGE WEISSKOPF: NASA was very good to me for so many years. It was a wonderful career. Towards the end I guess I would say my boss wanted me to stay now that we were getting the Constellation Program coming online. I got involved a little bit in helping to start write some of the requirements documents for that. He wanted me to take a lead role in some area, and I thought about it and thought about it. I'm thinking about retirement. I didn't want to say it, but I could kind of sense from my experience over the years that everybody's enthusiastic about this now, and if you're going to go do it you got to be enthusiastic about it. Looking at the political landscape, I just don't think this is really going to go anywhere.

It's hard to be really enthusiastic about it when you don't feel like you really have the backing of the country. You've got a backing of some small faction, and they're in office now, they're all gung ho. In two years from now there's going to be another election.

JOHNSON: Yes. Things will change.

GEORGE WEISSKOPF: Things will change. I hate to say that because it's sad. It's hard for engineers to keep doing that. My advice to engineers at the end, my own feeling I had come to, was I can't control these other things. So long as I can be learning something new and trying to do the best job I can on what I'm doing, I can't control whether the politicians want to continue this or not.

But I can sleep well at night if I feel like I'm bettering myself and I'm doing something worthwhile that's useful. That was my advice to the young engineers, some of whom I've seen get very frustrated when they work so hard on a program and it gets canceled. I worked on that, it got canceled, I worked on that, it canceled. I say, "Well, but are you learning something? Are you developing your skills and doing the best you can?" That's all you can ask of yourself or anybody can ask of you.

JOHNSON: When everything else is controlled away from you, you have no control over it.

GEORGE WEISSKOPF: Right. Another reason I really wanted to work on the space program and work for NASA as opposed to a contractor. While aerospace and missiles and rockets and flying and planes always excited me and interested me, I didn't like the idea of I'm really doing a good job building this missile that's purpose is to kill somebody someplace.

I know we live in a world that we have to defend ourselves, but that doesn't excite me like let's go to the Moon or let's explore.

JOHNSON: Exploration is much more exciting, that's true.

GEORGE WEISSKOPF: I think that one of the genius strokes, maybe not intended, but as a result of Space Station Freedom getting canceled and bringing in international partners is yes, that makes sense. We think these people are our enemies. Or we don't like what they do. If you get to know anybody on a personal level and start working with him, you find out they're just like me. What are we fighting about?

If we take our resources instead of building weapons to kill each other, use our resources to go do grand exploration of the universe, or of our solar system let's just say, isn't that a lot better? You make a lot of friends that way too. I think there's probably a lot of friendship between Russian engineers and U.S. engineers that have worked for years and years on these programs, regardless of what the politicians do at the top. I think that's one of the real benefits of the space program, and I hope that continues on regardless of whether we go to the Moon in 2024 or 2028. I hope we do go back to the Moon. There are some people that say, "Oh no, we got to forget the Moon, we're going to go to Mars."

But I tell people I don't think that's a good idea. The reason is if you've ever camped, which I did a lot of, if you buy new camping equipment, do you go to the farthest remotest desert where there's nobody around to try it all out and see if it's going to work, where you're out of communication, you're miles from home, nobody can help you? Or do you go someplace close by first and get comfortable with it?

Space Station is doing that now for us, whether a lot of people realize it or not. We're learning how to build systems that keep people alive where you have a closed environment where you're responsible for water, air, everything for people to function.

You're going to have to do that on the way to Mars, at Mars. Six months there, maybe a year at Mars, with our propulsion technology. Wouldn't you rather try to prove those systems out in Earth orbit? Then maybe on the surface of the Moon where you're just a couple of days away.

Once you've done that for a few years, then you're pretty confident. These things have worked out. We know how well these systems perform, how they break down, what the life cycle of them is. We're comfortable with them. Then you feel much more comfortable about going off all the way to Mars and being gone for maybe three years, where nobody can help you.

JOHNSON: It's a long way home.

GEORGE WEISSKOPF: That was another interesting aspect too of I think Apollo 8. It was the first time people had gotten way out there, and they could see the whole Earth, and it kind of began to look a little small.

When people go off to Mars it's going to look even smaller. It's going to look like you looking at Mars at night. It's a little dot up there. That's home. I think it'd be fascinating to go to Mars and go to the surface of a lot of these other places, but I can't quite imagine living there. I love greenery and I love the feel of the breeze on my face and the sound of running water. None of that on Mars or the Moon.

JOHNSON: A lot different environment, that's for sure.

GEORGE WEISSKOPF: The science fiction things which are maybe someday going to be reality, terraforming Mars or building these huge domes where you have all of that inside the domes. Or perhaps you've seen some of these concepts of space stations that early on they'd build a huge cylinder, maybe a kilometer in diameter and several kilometers long, and then you would get that cylinder and you'd rotate it on its axis.

JOHNSON: Gravity.

GEORGE WEISSKOPF: The outer edges, the inside surfaces would be like one-g, and then you'd build cities and towns in there, and the whole thing would rotate. Sounds like a nice concept. You could even experience weightlessness there because you'd go to the ends, and you'd climb the ladder to the axis of rotation.

JOHNSON: It's something to look forward to.

[End of interview]