NASA JOHNSON SPACE CENTER ORAL HISTORY PROJECT
ORAL HISTORY TRANSCRIPT

WILLIAM E. RICE
INTERVIEWED BY REBECCA WRIGHT
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WRIGHT: Today is March 18th, 2004. This interview with William E. "Gene" Rice is being conducted in Washington, D.C., for the NASA Johnson Space Center Oral History Project. The interviewer is Rebecca Wright, assisted by Sandra Johnson.

Thank you again for making time for us in your busy schedule.

RICE: My pleasure.

WRIGHT: We'd like to start today by asking you how you came to work for NASA in 1962.

RICE: I was working at Ling-Temco-Vought in Dallas, and I was a propulsion engineer. I had been working in the Advanced Weapons Department, doing a number of studies on advanced weapons for the military, DoD [Department of Defense] and Air Force, ranging from Mach 4 ramjets to search-and-rescue submarine chasers for the [United States] Navy, that kind of thing. But the last project was a throttleable liquid rocket engine for the Army, called Missile A.

A fellow that I worked with there was [Hubert P.] Hugh Davis. Hugh left and went to NASA, down at the Manned Spacecraft Center [Houston, Texas] at that time, and one day I got a call from Hugh and he said, "Gene, we need you to come to work for NASA. We need someone to manage the Lunar Module [LM] descent engine," which was a throttleable liquid rocket engine. So I thought about it a while and decided that sounded very good. This was the fall of 1962, and I think I started sometime in October of 1962.

Now, when I got there, things had changed a little bit. They had hired some other people into the office, and they needed somebody to manage the fuel cell and reactant [electrical power] system for the Lunar Module. So I agreed to take on that task, although I didn't know much about fuel cells. I didn't know much about cryogenic liquid oxygen and liquid hydrogen tanks, but I figured with a background in heat transfer and thermodynamics and that sort thing, that would be a nice challenge, so that's how I came to what's now Johnson Space Center.

WRIGHT: Could you describe for us the environment and the atmosphere that you entered into? As you mentioned, already things were changing before you got there. So how were you able to get a grasp on what you needed to do and start moving in that direction?

RICE: Interesting question. The people that went there in '62 went to various buildings around the southeast part of Houston. There was no Manned Spacecraft Center; they were building it. But we were in a location called Office City on the Gulf Freeway. There's where the Apollo Spacecraft Program Office [ASPO] was located. The program manager was there and this little group that Hugh Davis formed for propulsion and power [systems development], was located there.

It was an exciting time. We had to learn a lot about the mission, what we were trying to do, and get the contractors on board to build the hardware, write the requirements, so it was very, very intense activity.

WRIGHT: This was a completely nondefined area of career, and you left one that was a pretty safe and secure area. What were the reasons that you decided to join this group of pioneers in the aerospace business?

RICE: Well, because [President] John [F.] Kennedy had announced that we were going to put a man on the Moon by the end of the decade and return him safely to Earth, and that just sounded like an exciting thing to be part of.

WRIGHT: Share with us how your task, the new task that you were given when you got there, how you were able to bring that into reality, and what were the challenges of making that happen?

RICE: [The Apollo Spacecraft Program Office] selected Grumman Aircraft Corporation to build the Lunar Module. Pratt & Whitney Aircraft and Beech Aircraft [Corporation] were part of the team. Pratt & Whitney provided the fuel cells and Beech Aircraft was to provide the cryogenic tanks.

So we spent a lot of time on the road. We spent a lot of time with the contractor, developing the specifications, reviewing the design. With the Lunar Module, weight was paramount. We had a spacecraft that had to travel to the Moon, go into lunar orbit, descend, land on the Moon, leave part of it there, come back to orbit, rendezvous with the command and service module, and get back to Earth. So there were a lot of aspects of the mission that had to be worked out in detail. We would travel Bethpage in Long Island [New York], twice a month.

We made many trips to Hartford, Connecticut, to Pratt & Whitney, to review the progress on the fuel cells.

So it was learn as you go, but apply the experience and expertise and knowledge that you'd been trained for up to that point. This was a relatively young group of people, late twenties, early thirties, coming from industry, from people that had worked on DoD projects. But they recognized that we had to work as a team. It was not an individual effort. Everything had to work as part of a system. Our subsystem had to fit in and be part of the bigger spacecraft system, so that was the challenge.

We also knew that people's lives depended on it working, working right, and working well for the entire mission. It was a fourteen-day trip out to the Moon and back, and the hardware had to be reliable; it had to work.

Now, probably a year and a half after I got to the Center, a decision was made to replace the fuel cell cryo [cryogenic] system with batteries. Basically, the decision was based upon reliability, not weight. Batteries were going to be heavier. Fuel cell technology, in those days, was pushing the state of the art. This had not been done before. Pratt & Whitney was working on a fuel cell for the command and service module, which was a much larger device than what we needed for the Lunar Module, and was much heavier than what we could afford [on the Lunar Module].

But those things were going on in parallel at Pratt & Whitney. We had the command and service module power system fuel cells and the cryo tank development for that as well as the Lunar Module. So, we cancelled the contracts for the fuel cells for the Lunar Module, and I went over to the Engineering and Development Directorate, [Propulsion and Power System Division], as Chief of Power Generation Branch, under [Joseph G.] Guy Thibodaux and [Richard B.] Dick Ferguson.

So that was my stint in the Apollo Spacecraft Program Office. It was a very active, very intense period of time, with a lot of travel and a lot of working with the contractors to find the solutions. Every time there was a problem, a failure, get in, find out what's the cause of the failure, how do we fix it, how do we get on with the program.

WRIGHT: You talked about all of these contractors and NASA working as a team. How was the trust built up? Every contractor had its own obligations and their bottom line to worry about. How were you able to make sure that there was a trust built in there that people were relying and being accountable to each other?

RICE: You found out pretty soon who you could trust and who you couldn't, and these were professionals. The Grumman engineers were very professional engineers. We found that throughout the Apollo Program. The amazing thing about when you would go to a contractor's plant and go down on the floor, go down to the production line, go down and look, you saw people, craftsmen, people who had the skills, the know-how, the expertise. I don't know whether we have that today, but my observation then was that we had the best, and we had a mission, we had an objective and a goal that everybody understood. It was a simple goal: we're going to land two guys on the Moon and we're going to return them to Earth.

So personal goals and objectives were pretty much put aside in that era, because we knew we had to work together and we had to solve the problems to meet the goal and meet the objective. Think about it. From 1962 to July 20th, 1969, which is barely seven years, we did it.

So contrast that to [International] Space Station [Program], where we started in 1984 and this is 2004, and it's only partially assembled, with two people on board, sort of in a caretaker mode.

WRIGHT: It was a different time.

RICE: Very different time.

WRIGHT: Tell us how your job roles changed when you became Chief of the Power Generation Branch.

RICE: Okay. Very interesting. This was a research and development organization within E&D [Engineering and Development]. We had responsibility for overseeing and doing the subsystem management for the command and service module. I moved to an organization that had about thirty-five people, but ASPO had gone to a subsystem manager concept, where they put the subsystem managers in the technical organizations rather than in the program office. They had the [technical] support team there to help them do their job. So I not only had [responsibility for] the subsystem manager for the Apollo electrical power system, but I had a group of engineers that were doing R&D [research and development] on [other electrical] power systems.

We [used] a wide range of energy sources [including] solar, chemical, and nuclear, and both static and dynamic conversion devices, like fuel cells and thermoelectric generators, and [dynamic conversion] devices, like the Brayton Cycle. Brayton Cycle, it's like a jet engine, except you close the cycle for space. You can operate it with different energy sources. We were looking at solar as a possibility, where you have a solar concentrator that provides the heat source for things like Brayton Cycle. Now, we've never used it in space, but we were doing R&D.

I had a couple of contracts with General Electric. They had a polymer membrane fuel cell that was used on Gemini. It had some problems with burn-through of the polymer and so forth, so that wasn't the best way to go, but I wanted to further investigate that technology. Also, Allis-Chalmers came up with a concept for a fuel cell for the Shuttle that was different. It had an asbestos membrane between the cathode and the anode, and we funded that for a while. Then Pratt & Whitney came in and said, "We want to be part of the Shuttle fuel cell program."

So I said, "Well, I don't want a 'me too' answer, like G.E. [General Electric] or Allis-Chalmers. You go get a clean piece of paper and here's what I want. I want five times as much power as the Apollo fuel cell and I want five times the life, a 5,000-hour life," because by that time we had about a thousand hours with the command and service module fuel cell. I said, "And I want it to weigh half as much."

And they went off and in about six months or nine months, they came back with a proposal. We funded it, and that's what's flying on the Shuttle today. But they did; they came through. In fact, they did a little better than five times as much power. It's like a seven-and-a-half-kilowatt unit rather than 1 kW. The command and service module fuel weighed 250 pounds, produced 1 kilowatt and had lifetime of 400 hours, which we extended to 1,000.

So that's one of the accomplishments that I feel very good about, and it was used as an example of how research funding can be used to develop technology at a very low cost as opposed to getting into a program and having many units in the pipeline. We developed that fuel cell through a series of failures, fixes, failures, fixes, but at a very small cost relative to what we had spent on the Apollo Program fuel cell, because we had many units out there in the pipeline [when failure occurred].

We also conducted some research with Lockheed [Aircraft Corporation] on a solar array that could be folded up and extended in space. It used a scissorlike mechanism, a truss mechanism, to deploy a solar array that was basically on a polymer blanket. It was a 12.5 kilowatt solar array. If you look at the Space Station and the solar arrays, in the final configuration there's going to be eight panels, basically using the foldout array that we developed at Lockheed back in the late sixties.

So it was a way to take a small amount of funding from a vehicle called RTOP—it was Research and Technology Operating Plan, I think was the terminology—and this funding came out of a group in [NASA] Headquarters [Washington, D.C.] that I think was originally OART, Office of Advanced Research and Technology, and then OAST, Office of Advanced Space Technology. It was their job to advance the state of the art. It was their role to conduct research at the field centers, so I would get relatively small amounts of funding, but to fund ideas to see whether there was merit to those ideas. That was the fun part!

Once the Apollo lunar landing was successful, people started scratching their heads and saying, "Well, now what do we do next?" And they decided, "We'd better conduct some scientific experiments while we're up there." So they started a program called ALSEP, Apollo Lunar [Surface] Experiment Package. We needed a power system that would work on the Moon. The choices were solar, nuclear, or chemical, and static or dynamic conversion devices, and we basically homed in on a radioisotope thermoelectric generator that was under development by the Atomic Energy Commission. [It was called] SNAP-27 [Systems Nuclear Auxiliary Power]. It was called Space Nuclear [Auxiliary] Power. Plutonium-238-powered RTGs [radioisotope thermoelectric generators] [had been flown] on [other] satellites, so we were pretty confident in the technology. That was another [project that] we worked through the [NASA] Headquarters [offices] to the Atomic Energy Commission for development of the SNAP-27 generator for ALSEP.

WRIGHT: Since you brought up SNAP, we could talk about it for a few minutes. Tell us how that process actually turned into the RTG regarding your division; what concerns that you might have had working with this nuclear fuel capsule.

RICE: Plutonium-238 is pretty benign. You can carry it in your pocket. It has a fairly short half-life as isotopes go, but the form we were using was not that hazardous. The hazardous part would have been if we had a launch failure and there was a fire and the canister was compromised and [small] plutonium-238 particles got into the atmosphere and you breathed it. It was thought to cause [lung] cancer, but it might not [manifest itself] for twenty-five or thirty years. But the exposure to the American public was of great concern, and a lot of analysis was done to ensure that it was protected. For launch, we contained [the Plutonium 238 fuel rod] in a carbon cylinder that was enclosed. It would have survived a launch failure, and it would have survived a reentry into the Earth's atmosphere from orbit [if the mission had been aborted]. [Those were] the precautions that were taken. But as far as being hazardous for us to be around it to test it, no, and most of the testing was done at [the] G.E. [plant in Valley Forge] Pennsylvania.

WRIGHT: How vital was the SNAP to the success of ALSEP?

RICE: Without it you really wouldn't have had any power to the experiments. It was small. I think it was 90 watts at the beginning of life. Now, of course, that degraded over time fairly slowly, but, yes, ALSEP operated much longer than it was designed for. It worked for many years, providing data. So, yes, it was an essential ingredient of the ALSEP program.

The other thing I think that I've read, heard, or maybe dreamed up, but we were in a race to the Moon with the Russians, and we knew they were building a spacecraft to try to go there. The fuel cell power system that we had on Apollo had a tremendous weight advantage over batteries or other power sources. Solar arrays were too kind of fragile and so forth. Part of the reason, I will say, that we were able to beat the Russians to the Moon was because we had fuel cell technology and they didn't.…

WRIGHT: Would you share some of the testing procedures and how you proved that the fuel cells were going to be reliable?

RICE: We would bring fuel cells into our thermochemical test laboratory and run it through regular mission power cycle for 400 hours, which was the design [mission] life. That's what it had to do to do the mission. But then we would also run it off limits. We would change the parameters to see what kind of margins of safety we really had. We would run it longer than the 400 hours and see how much life it really had. So we tested and tested and tested. We tested at the single [cell], at the individual fuel cell level, but we also put a complete system of three fuel cells with the cryo tanks at [NASA] White Sands [Test Facility, White Sands, New Mexico] in a vacuum chamber and ran the entire system as a system before we [sent the Apollo Spacecraft to] the Cape [Canaveral, Florida] [for testing and checkout].

We would do extensive pre-flight testing when we got to the Cape, on the CSM [Command Service Module] to make sure everything was working there. So, yes, test. We spent a lot of money on testing, because the reliability philosophy that we had for Apollo was we basically were looking for four nines reliability, .9999 reliability.

Now, how do you prove that? Well, you test and test and test, and to have confidence in the results of a test, you have to have a minimum of thirty units, because we're looking at 1 over the square root of *n,* where *n* is the number of samples that you have. So we had, I think, thirty development fuel cells at Pratt & Whitney that we ran through tests before we went to production.

It's expensive, and that's why we probably don't do that to that extent in NASA today. We test, but we changed to kind of a different philosophy for Shuttle and Space Station. Rather than have some arbitrary reliability number that we were trying to prove we could meet, we went to a design philosophy that said for critical systems we must have the ability to fail-operational, fail-operational, and fail-safe.

So for systems like environmental control life support, you'd have basically three redundancies so that you could lose one system, fail the next time, and then fail-safe so you could get home. Same way with the computers on Shuttle. There were three general-purpose computers on Shuttle, but they also had a fourth, backup flight computer, built by a different manufacturer than was building the others, with software provided by a different software provider, because you can have common-mode failures. You can have a failure in one system that propagates, or you have a similar failure, failure mode in the other systems, then it wipes out all your redundancy. So the design philosophy is for noncritical systems, fail-operational fail-safe; for critical systems, fail-op, fail-op, fail-safe. You still have to test, but you don't have to do the extensive testing that you do to prove some arbitrary reliability number that you can never prove.

WRIGHT: Testing was such a major part of so much of what you did. At some point while you were at JSC, you were given the task of developing testing facilities and constructing those as well.

RICE: Yes, I went from the Power Generation Branch over to work for Aleck [C.] Bond, who was Assistant Director for Chemical Mechanical Systems, and he had a number of test facilities that supported the Structures and Mechanics Division, Propulsion Power Division, Environmental Control Life Support, and it was my responsibility in that job to basically see that we had all the resources that we needed and that we would upgrade or enhance the facilities as needed to perform the tests that might be required in the future. So when I talked to Aleck Bond about taking the job, I said, "I don't know anything about these facilities."

He said, "Well, did you know very much about power systems when you took that job?"

I said, "Well, not a lot."

He said, "Point made." So I left Power Generation Branch and took the job as Chief of Laboratory Operations. Northrop Services provided the technicians, the technical and maintenance people, to build up tests, conduct tests, prepare test plans, and post-test reports.

So it was kind of interesting. I got to see all the facilities that we had and see what they could do, and talk to the people and understand what their needs were. We had a big vacuum chamber (Chamber A) that you could put the entire Apollo spacecraft and Lunar Module stacked [together] in it. You could simulate [the space environment conditions such as] solar radiation; vacuum; cold and hot [conditions] and so forth.

We had another chamber, called Chamber B, that was man-rated, so you could actually suit the astronauts up and send them in to do testing. We could put the [complete] Lunar Module in there.

WRIGHT: Did you find, based on your research, that additional facilities needed to be constructed or changed during your tenure there?

RICE: Not in that job. I went from there to the Engineering Division, and there I had all of the physical plant maintenance and operation, but also had the responsibility for construction of Shuttle facilities. [For the Shuttle Program] we did identify the need to have a mockup laboratory for Shuttle and for Shuttle payloads. That was Building 9A. So I let contracts for construction of 9A. We also were doing some [modification of] some rocket test stands at White Sands Test Facility and were doing some major facility modifications at Downey, California, where they were going to manufacture the Shuttle, and at Palmdale [California], where we were going to take it for testing.

I had a fairly large construction of facilities budget that I managed for Shuttle facilities as Chief of Engineering Division, in addition to having all the physical plant under the Center Operations Directorate.

Again, a good group of competent mechanical engineers. We did heating, ventilation, air conditioning. We did structural design. We did all of the minor construction projects at the

Center. About 250 civil servants, NASA people, and probably 1,100 contractors. Pan Am [Pan American World Airways, Inc., Aerospace Services Division] was our major base contractor and then we had groundspeople that took care of mowing the grass and painting contractors that took care of painting the facilities. But different, very different from developing fuel cells and cryo tanks.

[While] I was Chief of Laboratory Operations for Aleck Bond, [a need arose to fill the position of] Chief, Engineering Division, so I went to [Sigurd A.] Sig Sjoberg's office—Sig was the Deputy Center Director—and he basically said, "Gene, I would like for you to go take this position as the Engineering Division Chief," and he explained the scope of responsibility [to me].

Well, how do you tell the Deputy Center Director no? You don't really do that. So I said, "Okay. I'll do that."

He said, "Well, now, if it ain't your cup of tea, come back and see me," which I did about three years later. I said, "Sig, it ain't my cup of tea." I think I did a reasonable job of getting the facilities constructed and [managing the division], but it wasn't what I wanted to do.

He said, "Well, I don't have anything right now, but I'll work it." [It] probably was about six months later that he called me up and said, "[Clifford] Cliff Charlesworth [needs] an Assistant Program Manager for the Earth Resources Program. Are you interested?"

I said, "Yes, I'll go talk to him." So, I talked to Cliff.

He said, "Now, I don't want a Deputy Program Manager; I want an Assistant Program Manager. When I'm in a meeting, you're in a meeting. You hear what I hear, then when I'm not around, you'll know what needs to be done and what my thinking is about it, and you can get the job done." So that was the arrangement that I had with Cliff, and it worked very, very well. He had a brusque exterior. He could hand you your head in your hand if he wanted to, but he had a heart of gold. He was a fine gentleman. So I [enjoyed working] with him.

[The Earth Resources Program Office (ERPO) was] doing a Large Area Crop Inventory Experiment [called LACIE]. We were using Landsat [Land Remote Sensing Satellite] data. Started out as ERTS. It was Earth Resources Technology Satellite 1, ERTS-1, and they renamed it. I think they named it Landsat-A. I think that was the series back then. It was Landsat-A, Landsat-B, Landsat-C, which I think they then changed to a Landsat-4, -5, -6, -7, and I think maybe 7's up there now.

…The spacecraft was built under the management of Goddard Space Flight Center [Greenbelt, Maryland]. All of the data from Landsat came through White Sands, through TDRS [Tracking and Data Relay Satellite System] to White Sands, to Goddard for processing. Then they would send it to us every morning, about four o'clock for the day's activity.

We were trying to estimate the wheat production in the Soviet Union, and this was, I guess, in [19]'76 or '77. In order to do that, we had a controlled area, I guess you would call it, in the United States. The U.S. Great Plains grows a lot of wheat, so we used both Landsat data and aircraft data. Probably Ollie [Olav Smistad] told you about the [Lockheed Martin] P-3 [Orion] and the other aircraft, the RB-57s [Martin/General Dynamics RB-57F, Night Intruder] that we flew with Earth-looking sensors to supplement the satellite data and to calibrate and find out how to use the satellite data.

The idea was simple. Wheat is planted in the spring when the field is brown, and it emerges and it turns green and it turns very lush green and then it senesces, or dies, and turns amber-colored. So if you can understand the spectral signature of the wheat crop through this life cycle, then you can tell wheat from other crops, like maybe corn or [barley] or rice. So the idea was to understand the life cycle, and we did that, made estimates for the U.S. Great Plains, which we then checked against the Department of Agriculture's figures for production in the U.S. Then we estimated what the production was going to be in the Soviet Union, and we made that estimate, I believe, in August of that year, and when they released their official production figure the next February, we were within 6 percent of their figure the previous August, so the technology worked.

Now, where did it go? Well, by that time the economic situation had changed, our relationship with Russia was changing, and there was no need to do crop estimation in Russia anymore, so they cancelled the funding for LACIE. We finished that up. About that time Cliff Charlesworth went over to—I want to say SPIDPO, Shuttle Payload Integration [and] Development Program Office. NASA's wonderful for acronyms. [Laughter] Glynn [S.] Lunney had left that position to take on another role, and Cliff went over to take over SPIDPO, and I became Acting Manager of Earth Resources Program for about a year, I think, and then they took the Acting stuff off and I was the Earth Resources Program Manager.

So it was an evolution from [19]'75 to probably '80 sometime, '80, '81, when they did some combining of the Life Sciences Directorate with the Earth Resources Program, so I became Director of Space and Life Sciences. I had five divisions. I had Medical Sciences Division, Planetary and Earth Sciences—I think it was just Planetary Division when I took over, but we also combined it later with Earth Sciences. I had an Earth Resources Research Division, Earth Resources Applications Division, and a Life Sciences Projects Division. Well, [Dr.] Sam [L.] Pool ran the Medical Science Division for me; [Dr. Michael B.] Mike Duke ran Planetary Sciences; [Robert B.] Bob MacDonald was Earth Resources Applications; [R.] Bryan Erb was Research; and a guy named [William H.] Bill Bush was the Life Sciences Projects Division.

Now, to start with the Life Sciences Projects, I guess, because by that time, the Shuttle was about to do STS-1 and we had [responsibility for certain] payloads. We developed [the] OSTA-1 [Office of the Space and Terrestrial Applications] [payload] for the first Shuttle flight. Flew it again as OSTA-3 on STS-3. But the job we had in Life Sciences was to work with the principal investigators, work with the PIs. All of these experiments were selected through a peer-review process at NASA Headquarters, and they would fund the PI to develop his experiment. Well, he didn't know anything about how to integrate into Spacelab, so we served as the intermediary between the PI and the Spacelab Program Office, to basically integrate the scientists' experiments into a payload rack.

The payload racks were pretty much standard. You either had a drawer in a rack or you had a whole rack or you might have a double rack, depending on the magnitude or size of the experiment. But we would help them through the process of designing their experiment, integrating it into a Spacelab rack, doing the testing that they needed to do, getting it to a Center. Usually it was sponsored either by us or by what was then Lewis Research Center, now [NASA] Glenn [Research Center, Cleveland, Ohio], [NASA] Marshall [Space Flight Center, Huntsville, Alabama], [NASA] Ames [Research Center, Moffett Field, California], [NASA] Langley [Research Center, Hampton, Virginia]. It could be anywhere, but they would have to show that they met the safety requirements to put it into Spacelab and to fly it. So that's what Bill Bush and his guys did.

We sort of had our own little mission control for the scientists over in Building 37, I think it was, so that the PIs could come there and they could get their data from the spacecraft. They could talk to the crew, walk them through procedures, if necessary, to conduct experiments. It was interesting. I think we helped—you know [Dr.] Charles Elachi? He's now Center Director of JPL. Well, Charles was the principal investigator on SIR-A, Shuttle Imaging Radar, that we flew on OSTA-1. We flew it again as SIR-B on OSTA-3. But Charles was the PI. A great guy, worked with him during the missions to get their data. I mean, the important thing was figuring out how to get the data. Then they would go analyze the data for the next six months or a year or however long it took, and prepare their reports and publish their results. So, that was Life Sciences Projects.

WRIGHT: Before we move on, once again you found yourself in the position of developing a process for something that hadn't yet been done. There's an unknown spacecraft, unknown conditions. Can you talk to us about how you were able to pull together that process to help the PIs do that when yet it was something that hadn't even been developed before you got there? What were some of the challenges that you had to deal with? How were you able to find the information you needed to do that?

RICE: Well, I guess the way to answer that is that you identify what the need is, what's the demand, what has to be done, and then you figure out what are the ways to do it and you select one. It may not be the right one or the best one, but it's a learning—throughout my career, I felt I was always pushing the frontier back. I was out there kind of pioneering in an area and pushing back, finding out how you do things, and people, the human resources, are the key. Communicating with people what's expected of them, what the goal is, what the objective is. You have to have the vision. You have to have a vision of where you're headed, and you have to communicate that vision to people.

And what I found was that if you can do that, you let them know what's expected, and nine times out of ten, they will exceed your expectations. So, helping people grow and develop these capabilities is one of the rewards of managing. I was a manager of people to get things done; I wasn't hands-on. After I got through with the Lunar Module fuel cell stuff, I was managing people to get things done sort of from that point on in my career. But understanding what you need to get done, whether it was a Headquarters mandate, or Center Director, or whether it was the program manager, you figure out what the need is and then you put a team together to go figure out how to do it.

NASA was sort of termed an "ad hocracy" in those days. [Laughter] A new requirement came along, you put a little task force or a team of people together to figure out how to do it, and many times that would evolve into something you had to institutionalize. ALSEP was that way. It started out a little group of people; "Go figure out what we need to do." We became an organizational entity that had the responsibility to do that. But, yes, NASA was sort of an ad hocracy in those days. More of a bureaucracy today, unfortunately, I hate to say.

But those were some of the challenges. Challenges were to do something that hadn't been done before with people who didn't have the background to know how to do it, but they had the training and the innovation and the creativity and the ideas and an environment that fostered that risk-taking, because if we had failures—and we did—the emphasis was not on who shot John, who caused the failure. The emphasis was on what caused the failure and how do we fix it and get on with the program. So you had the freedom to fail without concern that, "Well, I'm going to be fired because we had a problem."

Now, you look at [Eugene F.] Gene Kranz's book, *Failure Is Not an Option,* well, from that standpoint, he's absolutely right. We couldn't afford to have the failures in space, with manned spacecraft. But we had a lot of failures along the way to get there, and we had the freedom to fail in an environment that was conducive to solving the problem, not fixing the blame. And I credit the people I worked with, the managers I worked with, as mature, adult professionals. I think we had a good team.

WRIGHT: Sounds like it.

RICE: Good team.

WRIGHT: Before we move on to the next one, it's about forty-five minutes.

RICE: Why don't we take a short break. Can we do that?

WRIGHT: Yes.

[pause]

WRIGHT: Is there anything you want to add about the Life Sciences area before you move on to another division? I do have one question. Maybe it's a reflection. The success of the first experiments that were sent up on the Shuttle, can you share with us what that was like, of knowing when it came back and it worked?

RICE: We were given a very short period of time to develop that OSTA-1 payload and get it integrated into the Shuttle and flown. A couple of folks that worked for me spent a lot of time at the Cape, working with the Cape on integrating and what have you. [Richard A.] Dick Moke and [M.] Jay Harnage [Jr.], I think, were the two folks who sort of went through that whole process.

But it was very, very short time. We had some problems with structural integrity of the truss. We found out that some of the landing loads might be a little excessive, so we had to go in and do some beef-up at the last minute to make sure it would survive both launch and landing.

But it was quite an accomplishment, I thought, for us to get it integrated, get it up there, have it work very well, and get it back in one piece so we could fly it again. It was a pretty good job.

WRIGHT: Did the shortened mission have any effect on what your expectations were for the results?

RICE: Well, of course. We didn't get all the data that we wanted to get.

WRIGHT: But it was a beginning, wasn't it.

RICE: It was a beginning, yes.

WRIGHT: What division would you like to talk about now?

RICE: Let's talk about Medical Sciences. We had some, again, medical research going on, looking at studies of bone loss and chemistry changes in the astronauts in space, but when we started flying the Shuttle, and we started having more room for the crew to move around in space once they got there—see, in Apollo and Gemini—even Apollo—there wasn't much room to move about. You could unstrap from the seat, but very small [movement area]. But with the Shuttle, suddenly you had space [to move about], and we encountered something that we really hadn't seen much of before, which was termed space adaptation syndrome. Code word for space motion sickness. Now, couldn't use space motion sickness, because astronauts don't get sick. They have to adapt, and some of them adapted very well, very quickly, and some [took about] four days. Once they had this little syndrome hit them, it might take on the order of four days for them to get over it. Well, there were folks in Headquarters that wanted to do some research on and understand that, what we could do about it. So we spent a lot of time. We brought in "blue ribbon panels" of scientists, doctors, to get ideas and theories about what was going on.

Well, basically, to keep it simple, when you're in a 1-gravity environment like we are here, you have three sources of sensors for orientation. You have the vestibular system, which is the inner ear. You have your visual system; I can see this is up; this is down. And you have what's called propreoceptors in the muscles in your legs that keep you upright. Now, you go into zero gravity or a microgravity environment—no such thing as zero—but you go into a microgravity environment and suddenly the vestibular system is no longer functioning because it works on gravity. The propreoceptors are no longer working because they work and depend on gravity. The only thing you have left is the visual [sensor], which is not affected by gravity.

So the body, the mind, the brain has to adjust, for orientation, to visual only, and, like I said, some people, like John [W.] Young, never experienced a microsecond of space adaptation syndrome. Others, like I said, it might take four days. So you plan not to try to conduct a lot of experiments early in the mission. If you're on a fourteen-day mission, what's the hurry? Kind of get everybody accustomed to the environment and then go into the Space Lab and start to conduct your experiments.

So that was, I guess, the achievement in the medical research area, at least on my watch. I don't say that I did anything to solve the problem other than try to get the experts in and see what they thought we needed to do. We had rotating chairs. We would put the astronauts in the rotating chairs, spin the chair, and have them do head movements to simulate. To some degree that was predictive, but [there was] not 100 percent correlation. Someone could do very well in the chair and still have a problem when they got in space.

The astronauts did not like to talk about it; still don't like to talk about it, I suspect. But we tried patches, we tried the scopolamine patches, like you use when you go out on a boat and you get seasick. Some of those patches work, but for the most part, you just have to deal with it.

But that was interesting. I learned an awful lot during my period as Director of Space Life Sciences about the medical [challenges] that I, again, didn't have any [educational] background in.

[Moving on to the] Lunar and Planetary Sciences Division, they were the curators of the Lunar Curatorial Facility, which housed some 860 pounds of lunar rocks and dust that was brought back during the Apollo Program. We had a very active program of grants, on a global basis. Principal investigators would submit proposals, again, to NASA Headquarters, and they selected the PIs and issued us the money to issue the grants. So we had a fairly large program of shipping samples of lunar material to PIs for them to conduct their research.

We also had some folks that were interested in Martian geology, if I can use *geology* in nonscientific way. So, again, research and very—I guess, probably 75 or 80 percent Ph.D. scientists in that division under Mike Duke. So that was fun and, again, [I] learned a lot. That's been somewhat a hallmark, I guess, of every job I've every had, is I don't know it all, I don't pretend to know it all, I continue to learn every day, and I think that's what keeps me going.

WRIGHT: From the aspects of the rocks, any interesting stories associated with those, of what some of the grants were for? Anything you can recall?

RICE: Not right off the top of my head. They did a lot of chemistry, looking at the chemical makeup of the basically basalt; that was [what] most of the rocks were.

WRIGHT: But the interest continued.

RICE: The interest continued in just understanding the history of a rock, how long it had been there. They were interested in seismic activity on the Moon, stuff like that, and we did get some of that information from ALSEP. Some of the experiments on ALSEP were to detect moonquakes.

WRIGHT: That was interesting that those two pieces of your career kind of tied back in together with the rocks. Any issues of missing rock? There was, not too long ago, an attempt to take some rocks from JSC—

RICE: Oh, is that right?

WRIGHT: —and I was just curious if you ever had any issues of—

RICE: There may have been one or two incidents where someone acquired one the wrong way and offered it for sale or something, but we kept a pretty close eye on the stuff.

WRIGHT: Pretty unique items.

RICE: Yes, yes. When you saw it up, of course, you have some sawdust. The sample gets smaller and smaller as you keep cutting it. But anyway, no, I'd have to think about that one some more.

Earth Resources. The Secretary of Agriculture had, after LACIE, come up with a new initiative, called AgRISTARS [Agriculture & Resources Inventory Surveys Through Aerospace Remote Sensing], that was, again, a cooperative program between NASA, USDA [United States Department of Agriculture], and NOAA [National Oceanic and Atmospheric Administration], primarily, with the State Department—AID [USAID, United States Agency for International Development] was then part of State Department—and Department of Interior. The idea of AgRISTARS was that there were eight crops, I guess, including wheat, but seven other crops of interest on a global basis; barley, rice in Asia. So we undertook to try to develop experiments that would let us identify these other crops besides wheat. That program, I think, ran about three years before it was cancelled. It was, again, using Landsat data, using aircraft, and using ground truth from Agriculture, from USDA, to validate the satellite data.

WRIGHT: How well did it work, combining the talents of NASA, other federal agencies, universities, industry? You had to bring all those together to make this program work.

RICE: That's true. The folks I worked with at Agriculture were very competent, very capable people. [Charles] Caudill was the [person I worked with at] Agriculture. But they had their objectives, we had our objectives, but we had enough of a common goal that, again, you could sort of put agency parochial interests aside and try to work towards achieving the objective. That's sort of been the key to all of these successes; when you can get a team of people that want to work together.

Agriculture is an interesting department. It's an old-line—you know, they've been around since, what, the 1800s?

WRIGHT: I was going to say since dirt, but— [Laughter]

RICE: Yes, that's very good. [Laughter] So they had their own policy, they had their own bureaucracy, and they had their policies, and what you could and couldn't agree to, and this and that and the other, but, generally, each agency funded their activities so there wasn't that much of a funding issue that we fussed about very much. It was generally expanding a program into a new area or something like that. That would take a little while to work through. The folks I worked with at NOAA and at Agriculture were very cooperative and, I thought, had the idea and the goal in mind and worked with us very well.

WRIGHT: We have Bryan Erb's area.

RICE: Yes, that was a research area just looking at advanced techniques for interpreting Landsat data, registering Landsat data. We started looking at advanced sensors like Thematic Mapper. That was coming along. What we used most of the time was called Multispectral Scanner and it sensed in [certain] wavelength bands. Thematic Mapper came along, had much higher resolution, so we were looking at [whether or not] we [can] do better if we use Thematic Mapper. Meanwhile, the French were developing an earth resources satellite called SPOT [Satellite Pour l'Observation de la Terre], to compete with U.S., the Landsat data. So their research was primarily oriented to understanding where we go from here with new sensors, new technology.

The Center had managed Space Sciences and Life Sciences over the years with a combination of engineers, engineering managers, and scientists. Well, neither one had everything it took to make it work, so after our experience with the space adaptation syndrome, [NASA management decided that having an M.D. [Doctor of Medicine] as the head of Space and Life Sciences would be better than having an engineering manager. They selected Dr. Joseph P. "Joe" Kerwin, who had been the NASA representative in Australia for about five years and was coming back to NASA for reassignment.]

Joe came back and took over the docs [doctors] and the space adaptation syndrome problem to solve. So that was my exit from the Space and Life Sciences arena.

[At that point] I moved over to work for [the Director of Engineering and Development,] Aaron Cohen, I think in the spring of [19]'84. About that time, [President Ronald W.] Reagan had announced the International Space Station initiative. [James M.] Jim Beggs had taken a team of people from International Affairs around the world on the [Grumman] Gulfstream [II] to talk to the Europeans, to the Japanese, and the Canadians about participating with [the U.S.] in the program. So [NASA Headquarters] formed an International Cooperation Working Group, and it was [Robert A.] Bob Freitag in the program office, and [Lynette] Lyn Wigbels was trying to pull together a team of people to try and come up with a draft agreement, a memorandum of understanding (MOU).

I was assigned by Aaron Cohen to go work with the Space Station International Cooperation Working Group and figure out how JSC played in that arena. That evolved into the negotiating team for the U.S. under [Margaret G.] Peggy Finarelli’s leadership. Peggy, Lyn Wigbels, Mary Jo Smith, Greg Williams, Bob Lottman, I think, were the primary group that started on this world tour.

We started with what was called Phase B. Basically, Phase A was done; Phase B was the preliminary design phase; Phase C-D is normally the development-production phase, and then there really is no Phase E, but after that, it’s kind of like operations. So we were going to do an initial agreement to cooperate during Phase B to define the design.

Then we did a second round of negotiations for Phase C-D. So we signed the Phase B agreements in, I think, May of [19]’85, and we signed the C-D agreements and the government-to-government agreements—well, that was the government-to-government agreement, and then the MOUs in end of September of ’88.

Now, in between, we spent a lot of time between Washington [D.C.], Tokyo [Japan], Paris [France], Rome [Italy], Ottawa [Ontario, Canada].…

WRIGHT: Tell us about the negotiations. What were some of the major points during those early days that were vital for success?

RICE: A lot of the time was spent on sorting out responsibilities and decision-making processes. These are sovereign nations. They don't want to be told what to do. They want to control their own destiny. So the major sticking points were how do the decisions get made. So we had a management structure that had a multilateral component, where all four parties had to get together and agree. It was called a Multilateral Control Board, MCB, and then under that was the Program Control Boards, PCBs. That was agency-to-agency and bilateral, and then if you had an issue that affected everyone, you took it up to the Multilateral Control Board.

My role on the negotiating team was the technical lead, so it was my responsibility to make sure that whatever arrangements we agreed to in the MOU would work technically and would be, from an operational standpoint, viable options; from a safety standpoint, would work; that all the functionality that we had to have would be there.

The Canadians were going to provide the robotic arm. Well, the robotic arm had to have certain characteristics. It had to have certain reach. It had to be able to be transported along the truss, on a track. The Japanese experiment module was a laboratory, but it had an external facility for conducting experiments outside the pressurized module, and it had its own robotic arm to take things from inside to outside through an airlock. The Europeans basically wanted a laboratory module to conduct experiments. So we had what their interests were to deal with from a technical standpoint, and what we needed as a space station system to get all the things somehow performed that needed to be performed. So that was the technical challenge.

I developed working relationships with the Japanese, with the Canadians, with the Europeans, the ESA group up at Nordvik [Norway]. It wasn't that difficult technically. What was really difficult was sorting out the responsibilities stuff, and that was not my job to do. I gave my inputs and my advice and so forth, and I could talk to my counterparts and reason with them about why a particular thing made sense or didn't make sense. It took a long time, but, yes, we were successful and we had agreements that we signed for both Phase B and for Phase C-D.

WRIGHT: During all those trips, while you were gone, the questions began to arise about the cost and the design of Space Station Freedom. How were those conflicts starting to affect your negotiations and your meetings when you were meeting with the future partners?

RICE: They were concerned. They were putting a lot of money into investments in their hardware. There were issues about the number of flights that it took to get the hardware up there. How many assembly flights, can you do that? We started getting budget restrictions of, say, 1.8 million per year, that's all you can spend, or 2 million a year. So you'd have to go redesign the assembly sequence. Every time you started playing with the assembly sequence, you'd push somebody's launch date further out. That was always of concern to the people we were negotiating with. So, yes, the escalating costs and the congressional caps on the program took a very large toll and exacerbated the problem, if I may say. Anytime you slip the schedule to the right and you have the same workforce and the same burn rate, all you're going to do is increase the total cost of the program, not keep it down.

One of the things I was fairly proud of—and this was after I left NASA, but I went to Grumman and I was Director of System Engineering and Integration for Grumman Aerospace

[Corporation/Northrop Grumman Corporation]. As Director of System Engineering, it was my responsibility to converge the design. I did that and we had a successful CDR [Critical Design Review] in what was June of [19]'93, '92 or '93. That's the design that is flying today.

Now, [Daniel S.] Dan Goldin came in, cancelled the contract, gave it to Boeing [Company], basically gave Boeing the responsibility; did away with the Level Two office in Washington; called it Space Station Alpha, not Space Station Freedom, and this was supposed to save money, save launches. What happened in going to a 57-degree orbit was that you lost 12,000 pounds of payload on every launch. We already had a weight problem just going to a 28.5-degree orbit. So as a result, it takes a lot more launches to get the stuff up there. You had to start taking equipment out and launching that later. But the deal was cut with the Russians after my watch, and I won't say, given what's going on today, where we are totally dependent on the Russians for crew transfer to and from orbit, that it was a bad thing for the program in the long run. But back then, it didn't seem like it made an awful lot of sense.

WRIGHT: Was there ever consideration, when you were doing your worldwide tour, between the U.S. or any of the partners, to invite Russia to be part of the International Space Station?

RICE: There was talk of that, and the Europeans were cooperating with the Russians on some space stuff during that time, so it wasn't like they were the enemy. The cold war was over and we were cooperating, but we had not invited them to participate. I think there was still a concern in this country about technology transfer. Certainly, even with the Europeans and the Japanese and Canadians, there was concern about not making the Space Station Program a shopping spree for U.S. technology. We had a DoD member on our team who was there basically to make sure we didn't sell the farm in the process, so to speak.

WRIGHT: That says a lot.

Our time's starting to get to a close this morning, and I know we could talk so much more about Station in detail, which we can, if that's what you would like to do. One question I was going to ask you, if I can revisit Apollo for just a minute. I learned that you had some involvement regarding the lunar landing sites and lunar mapping. Is that a part of what you did as well?

RICE: No, that was basically another team in Flight Operations that selected landing sites.

WRIGHT: But speaking of lunar landing, so much of what you did your first days provided that success for, of course, the Nation and the world. Can you tell us where you were and what part of the involvement of that time when you saw the Eagle [Lunar Module] land and kind of give us your reflections on your work and watching how all that worked?

RICE: I was watching the landing, just like probably another 100 million people were, on TV. It was about four o'clock in the morning. I had my girls, I got them up out of bed. "You've got to see this." They still complain to this day about how we piled them out of bed in the wee hours of the morning to go watch the lunar landings. But that's part of history and they needed to see that; they needed to be part of that.

How did I feel? Always exhilaration, always relief, when they climbed back in the Lunar Module and they lifted off and they got back and they got home. It's a risky business. You think about it. They were a long way from home. The hardware that we'd built had to work, and the sense of accomplishment was basically, yes, we did it and it worked. It worked reliably.

Except for Apollo 13. Apollo 13, my system, if you want to think of it that way, the fuel cell and reactant storage system is what failed on Apollo 13. The cryo tank pressure increased, popped the relief valve, and started to lose all of the oxygen to the fuel cells. Pressure was dropping. The two tanks were tied together, so although we had two tanks, we lost oxygen from both tanks. Fuel cells were no longer operative.

Well, I was on my way home from work about five-thirty, I think it was, when I heard the news on the radio, and I turned around and went right back to the Center. I went to Building 45, where the Mission Evaluation Room was on the second floor, and [Donald D.] Don Arabian was calling a meeting, so we all went into the conference room and he went to the board and he said, "Here's the situation. Here's where they were when the explosion occurred, or whatever it was when they lost the fuel cells, and they're headed for the Moon, and, gentlemen, our job is to figure out how we're going to get them back."

So I spent the next fifty-four hours at the Johnson Space Center, in the MER [Mission Evaluation Room], figuring out how much power we had on the Lunar Module and so forth. Now, there were a lot of people in mission control, in Flight Operations, contractors at [North American] Rockwell [Corporation], at Grumman. The entire workforce was energized to try to figure out how to do it. So I don't claim a role, but I was there; I was part of that team that had that job to do.

And, of course, we were trying to figure out, "Well, what happened?" We had strip-chart recorders back in those days, little ink pens that squiggled little lines on these strip charts. I'm sure you've seen them, probably in the museum there. [Laughter] But we had continuous data on pressures and temperatures from the cryo tanks and the fuel cells, and we started pouring over the strip charts to see what happened, when did it occur, try to start to come up with some idea of what had happened. So that was, again, a very intense period, high level of activity, concern of whether they would make it or whether they wouldn't. So when I saw those three parachutes coming down, that was one of the happiest days of my life.

Just, I guess, to make this a tie-in to later, when I went to work for Grumman, after I retired from NASA, guess who I went to work for?

WRIGHT: Fred [W.] Haise.

RICE: Fred Haise. Worked for Fred Haise. Senior advisor role for a while, in order to make sure there weren't any ethics problems with my going to work for Grumman on Space Station. But, yes, I worked for Fred Haise.

WRIGHT: I'm sure you enjoyed seeing him behind a desk. [Laughter]

RICE: Yes, I did. Fredo had many, many stories to tell. He really did. He had an interesting career. They had a bunch of rebuilt World War II airplanes down at Galveston [Texas] and he was flying one of those and crashed and was severely burned. But he survived a lot of things in his life. I haven't had any contact with him in a few years. He was up to TRW [Inc.] about, probably, five years ago, gave a speech at a luncheon that they had on Veterans Day or something, and I went out and saw him again. He did his Apollo 13 speech, showed clips from the movie and clips from his camera, his videocamera, that he'd taken. Of course, he was an advisor to them when they made the movie, so you could expect it to be very, very close to reality, other than the fact that, in the movie—and I can understand why they never did it—it was like all mission control did the whole thing. There was no credit given to the contractors. In fact, they made Grumman kind of look silly in the movie, if you remember.

WRIGHT: They did, yes.

RICE: They kind of, like, "Well, it wasn't designed to do that."

WRIGHT: I remember that.

RICE: Remember that?

WRIGHT: Yes. Well, your career with NASA was somewhat diverse and extremely challenging at different points. Is there a time that you would feel is the most significant accomplishment of everything that you've done, something that, when you look back, it's your proudest moment that you were there?

RICE: I have to say the Apollo lunar landing was the highlight. I used to think that everything after that would be anticlimactic in life, but, you know, that's not the case, because I went on to find a lot of other interesting things to do after the Apollo lunar landing. Wouldn't take for the experience. Great experience. I'm just glad that I was a part of it.

Those were the glorious days of NASA. I look back on that time in NASA and the competency of the people, the drive that they had, the sacrifices that they made of personal time. I mean, it was hard. We were working twelve, fourteen hours a day, and sometimes seven days a week to meet schedules, to stay on time. But I wouldn't take for the experience. It was great. It was great being part of the team, it was great working with guys—[Arnold D.] Arnie Aldrich and [Richard H.] Dick Kohrs and George [M.] Low. These were giants in pulling together and managing a team of people to accomplish that.

It wasn't the end. I went on to find a lot of other interesting things, and I'm still finding interesting things to do, even today. I'm working with FAA [Federal Aviation Administration] on air traffic system safety and the challenges, the experience, and know-how has application. And I still feel like, in a way, I'm out there pushing the frontier back in this area with FAA.

WRIGHT: Sounds like you have many more years of exciting times ahead.

RICE: Thank you.

WRIGHT: We thank you for the time this morning.

RICE: Okay.

WRIGHT: Is there anything else that you'd like to add or can think of before we close?

RICE: I don't think so.

WRIGHT: Well, if you do, let us know and we'll pick up where we left off.

RICE: All right.

WRIGHT: Thank you.

[End of interview]