NASA JOHNSON SPACE CENTER ORAL HISTORY PROJECT
EDITED ORAL HISTORY TRANSCRIPT

THOMAS L. MOSER
INTERVIEWED BY JENNIFER ROSS-NAZZAL
HOUSTON, TEXAS – 27 MAY 2010

ROSS-NAZZAL: Today is May 27th, 2010. This oral history interview with Tom Moser is being conducted in Houston, Texas for the NASA Johnson Space Center Oral History Project. The interviewer is Jennifer Ross-Nazzal, assisted by Rebecca Wright. Thanks again for taking time out of your schedule today to meet with us.

MOSER: My pleasure.

ROSS-NAZZAL: We certainly appreciate it. Last time you spent some time talking about the thermal protection system for the Space Shuttle. I just had a couple more nontechnical questions, but important questions. Would you tell us about the difficulties you faced attaching the tiles to *Columbia*?

MOSER: Sure. Back up just a bit—the thermal protection system was unique in the fact that it had to be designed for reuse for 100 missions. We knew we'd have a lot of repairs, so we focused on lightweight material that had the thermal performance that was necessary and enough durability, but at the same time protect the structure—in this case the aluminum structure—to a temperature less than 350 degrees and the outer surface in the neighborhood of about 2,500 degrees Fahrenheit [on the tiles]. So it had to be an insulator and perform for multiple missions.

We knew that the attachment of the tiles to the Orbiter was going to be a problem, because aluminum being the primary structure, it expands and contracts a lot. The tiles essentially had no expansion and contraction in a relative sense. We put something between them called the strain isolation pad, or the SIP. The way it was attached, there was a layer of adhesive put on the vehicle, and the tile had the SIP bonded to it with the same type of adhesive, and then we would bond the tile to the structure. That was it. It was not complicated, and it worked beautifully for expansion and contraction.

The strain isolation pad was just a loosely woven felt material. Believe it or not, the same felt that Stetson hats [were] made of. This loosely woven felt did [the job] beautifully. To keep the felt together, [i.e.] give it some integrity, every [few inches] a stitch put through [the felt. This was so] it would not come unraveled. Well, when you attach a tile to the SIP, which is attached to the structure, and something tends to pull the tile away from the structure—like aerodynamic loads or vibration—all these little individual stitches acted as a stiff spot.

When you think about pulling up on a tile as you try to pull it off of the structure, like the aerodynamic loads would do, then these little stiff spots would cause a stress concentration, or it would cause the bond to fail right there. When that happened, being a very [brittle and] fragile material that the silica fiber is, then [the failure] would propagate. So once you started a failure—it's like a crack in the windshield of your car. Once those suckers start, they just go. That's the way these little cracks would [propagate], and all of a sudden you'd lose the bond integrity.

We said, "Oh my goodness!" The way we found it, believe it or not, we were doing some aerodynamic tests with the tiles on a structure at different airloads. We bonded some tiles to the speed brake of a T-38 aircraft. The objective was to deploy the speed brake so that the tiles got a very large aerodynamic load. We calculated [the loads] we wanted [to simulate], and lo and behold, [some] tiles came off. When something comes off of an aircraft, that's a major deal because now you're dealing with the FAA [Federal Aviation Administration] and everyone else, any time something comes loose from an aircraft. Us grunt engineers were trying to say, "We think we need more tests, because some of these conditions we haven't tested." The focus [had been] on the thermal performance, "Yes, we hear you strength integrity guys, but we'll deal with that at some point." This failure on the T-38 caused a major management focus because they had to sign off on this FAA stuff that [documented] we had an object come off an airplane.

That let us highlight the characteristics of this bond [attachment of the tiles to the orbiter]. Then we started with the solution process. "What do we do to dissipate this peak in load underneath the tile?" One way to do it is you could put a very hard plate [on the underside of the tile]. You [could] put a piece of aluminum, or piece of graphite epoxy, to dissipate [the] force that was [concentrated]. That would have been a lot of weight to add to the vehicle, I mean a lot of weight. So we tried to do different things.

An engineer by the name of Glenn [M.] Ecord in the materials group one weekend came up with the solution. This falls under the title of "necessity is the mother of invention." We had to find a solution. Glenn took real real fine silica powder, like talcum powder fineness, and put it in distilled water, nothing more than that, and then [brushed] this colloidal solution of silica powder on the bottom of a tile. Little grains of silica would just embed themselves amongst all the fibers in the tile, and when they dried it was like putting a little barrier of real densified silica right there. [The powdered silica] adhered to the silica fibers, and that provided the strength that we needed on the bottom of the tile. It literally doubled or tripled the effective strength of the tile by dissipating that concentrated load into the rest of the tile. We had to take the tiles off the vehicle and apply] this [process]. That was a good [solution to a major problem]. Necessity is the mother of invention, and [there are] a bunch of cases in the Shuttle where that is [proven].

The next thing in the tiles—I think I may have mentioned this before. John [F.] Yardley was the Associate Administrator all through Shuttle [development]. John Yardley started his career as a stress engineer at McDonnell Douglas. He was a very very good engineer. He was probably one of the best managers I've ever worked with in my life. John says, "Okay, you smart guys, now you got the tiles bonded, how do you know that they're bonded good enough?" That was the next step. He said, "It's a very people-dependent thing, because it's a function of mixing up the adhesive, applying the adhesive properly, bonding it properly. It's a people [driven] process. If not done properly, you lose the tile, lose the tile in the wrong place, you lose the vehicle."

So we developed a scheme [with] which [to verify a good bond]. We attached a suction cup to the tiles and pulled on each tile. His next question to us was, "How do you know you didn't do more damage pulling on it," [that is], decrease the integrity of the bond of the tile? What we did was we put microphones [on] tiles in the test lab. We pulled on them, [recorded the] noise. We gathered enough data to know if it [withstood the load and] only made so much noise, it had the necessary integrity.

Those are the kinds of things that finally got us over the hurdle. Now we've got 25,000 tiles on the vehicle. Let's show that we have the required structural integrity on all 25,000 tiles to say that we're ready to fly the first mission. We went through a complicated [logic] matrix. I think I left a copy of that with you. We have a process to certify every tile that it had sufficient strength margin to fly. Some of which we did by analysis, some we pulled to show that we had enough strength. Others we couldn't get [access] to but we showed we had really big [strength] margins. Others we said, "We think we got enough margin, but if it fails it's not going to be a catastrophic failure." We went through all 25,000 tiles, late in the program, "Yea verily," at the flight readiness review [we were able to say], "we're ready to fly."

That was the character of NASA program management then. You had to be willing to convince the people you were talking to, the decision makers, that you knew what you were doing, and you were right. The way you would convince them, or the way they would convince themselves that you were okay, they just kept probing and probing and probing and probing. You had to be able to explain yourself in a simple way, but with enough data and enough confidence that you could convince them you were right. We put together a pretty comprehensive story on all 25,000 tiles, and it withstood a lot of scrutiny. We said, "Yea verily, we're ready to fly."

First flight came. We lost seven tiles, but they were in a region that was not very high-temperature. We didn't do any damage to the vehicle at all when we lost them, but it gained a lot of national publicity when those tiles came off.

That was it, [the story of the tiles]. We had our back against the wall. We were the pacing item on the first launch. Everybody else was ready to go, and assuring those tiles were attached was the thing that was pacing [the program].

ROSS-NAZZAL: How much time did you spend out in [Palmdale] California and then Florida [NASA Kennedy Space Center] as they were putting the tiles on and taking them off and putting them back on again?

MOSER: There's not a simple answer to that, but let me tell you what we did every single day. Every morning at 7:30 we had a meeting. We understood exactly who was doing what, what progress they'd made and what problems they had, both in California and in Florida and in Houston [at JSC]. It was primarily in Florida, because that's where the final [manufacturing and assembly] of the vehicle occurred. We felt it wasn't being done as good in Palmdale as it could have been in Florida, so we moved all the operations there. A person by the name of Kenny [Kenneth S.] Kleinknecht was the JSC resident guy at the Cape [Canaveral, Florida]. It was a small group, but every morning at 7:30 Chris [Christopher C.] Kraft, Aaron Cohen, myself, Kenny Kleinknecht, and maybe two or three others depending what the issues were and what [was planned from] the previous day [met to determine the status, resolve issues, and determine what was to be accomplished that day]. Every morning we met at 7:30 until that vehicle flew.

ROSS-NAZZAL: I understand that they were working long hours, long days. Can you tell us, did people from California move out to Florida at that time period?

MOSER: I'm probably not the right person to answer that because I don't know about those problems. It doesn't surprise me that they had problems doing that, but I'm not aware of the difficulty there. We had one other little thing. As we went through all this couple years of these issues and problem solving that I just told you about, we had some outside experts "helping" us.

ROSS-NAZZAL: I was going to ask you about that.

MOSER: These outside experts weren't people involved in the actual program at JSC. We had some people on there from [NASA] Langley Research Center [Hampton, Virginia], [and a] big group of people from academia. I don't remember how large it was. It [the TPS group] was one of the groups under Walt Williams [NASA chief engineer] looking at the entire vehicle before first flight. We spent a lot of time, in addition to solving our problems, educating that outside group and convincing them. This wasn't a matter of weeks, this was a matter of months that we worked with all these people.

We would go back and forth between here and the West Coast and Langley Research Center. We finally got everybody to feel comfortable with it. Some of the guys at Langley Research Center thought it would be best to do a wind tunnel test of tiles around the forward attachment of the Orbiter to the external tank. It was a fairly complicated aerodynamic region, and they wanted to do some testing in that area. We at JSC, the guys that were responsible, didn't think it was really necessary to do [the test]. We thought, "No, we think we've got this covered. We understand it well enough, we understand all the loads on it, and we've got enough margin." But they kept insisting and throwing up red flags, so we said, "Okay we'll do the test."

When I say okay we'll do the test, our project manager had to agree with it, Aaron Cohen—and Chris Kraft even agreed with it. We did it to "satisfy the concern." We didn't probably tell John Yardley about it though. We didn't hide it from him, we just were doing our job. Well, John heard about it, and we were all down at the Cape and he said, "I want to meet with you guys at 7:30 tomorrow morning at breakfast." "You guys" were Chris Kraft, Aaron Cohen and myself. We met with him at breakfast, and he was livid because this was a matter of a couple weeks before the first flight.

As any good engineer or engineering manager would think, if something goes wrong you're going to shut this whole thing down. Boy, he [Yardley] went up one side of us and down the other. He just ate us alive, which he could do. Aaron and I sat there, and we didn't say anything because we didn't want to do the test. But Chris Kraft agreed with the Center Director of Langley to do it. Chris said, "They didn't want to do it; I agreed to do it." We hadn't run the test [at that time]. We said, "John, it's okay." So we had to convince him that what we had done [was okay]. He would probe and probe and probe, like all NASA managers would do. They'd probe and probe and probe and probe based on their experience, and if you didn't have the right answer every time, then you probably weren't going to get across the goal line. Well, we got across the goal line. Long story short, the [test was successful and the] vehicle flew.

Almost two or three days before the first flight, Chris Kraft called Don [Donald P.] Hearth, who was the Center Director at Langley, and said, "Don, is there anybody at Langley Research Center that has any issue or any concerns about this flight and about the thermal protection system?" Don Hearth said, "Let me go check. I'll go run the trapline and I'll call you back." He called back and says, "No, we're good to go."

The day before the flight a person comes out of the woodwork, says it's going to fail. "Tiles are going to come off, you're going to lose the whole vehicle, and here's how it's going to happen."

ROSS-NAZZAL: Is this Holt Ashley?

MOSER: No, it was John Houbolt.

It was frustrating because Chris [Kraft] took us up there, [and] we would work, work, work, work, work, and then Chris, being from that area, we'd all go to dinner. We grew to know one another. It was a lot of respect for one another and a lot of technical camaraderie. We thought we had it pretty well covered.

ROSS-NAZZAL: I was going through some TPS [thermal protection system] documents and in one of the memos Holt Ashley suggested that you had to search for a SIP replacement. Do you recall that?

MOSER: Never did. Not so, no. Probably Holt was talking about, "What can we do to eliminate the stiff spot in the SIP? Is there another way to dissipate that stress concentration?" Holt was a good guy. He was a good ally on a lot of technical issues like this. That's probably what Holt was talking about. I'm sure it was. Probably looked at some other SIPs but I don't remember specifically what it was. You can see the problem there; now you had a whole series of tons of thermal performance tests and everything else that had that SIP in it. If we'd changed the SIP, we'd have had to change processes, we'd have had to change recertification. What Glenn Ecord did, he found this magic solution that saved the bacon.

ROSS-NAZZAL: How did the tiles perform on the next few orbital test flights?

MOSER: They performed great. Not perfect, [but] they performed great. I'd have to go back and look at the history. We lost a few tiles, none of any consequence. On the chine of the Orbiter we lost a tile. It got hot enough to cause a little bit of deformation in the structure, but it was repaired. It was not permanent. We never did anything that permanent[ly] damage[d] the vehicle. There were a few places where we lost some tiles, but of no consequence. Today I don't think there's any [tiles lost].

We knew that the glass coating, borosilica I think is what it is, on the tiles was paper-thin and more fragile than an eggshell. We thought that we'd probably have to replace about 10 percent of the tiles on the vehicle every flight just because of handling damage, but that was never the case. People learned how to work around them and be careful. I don't know how many are replaced today but probably not too many. I think at one time some were taken off every flight just to get some flight data on them. How good are they, go pull them until they fail, inspect them. I think there's a lot of confidence [that's] been gained in the tiles. Today there's probably ways to make a tile more [damage] tolerant.

Let me back up and say another thing about tiles, and maybe I said this before. The tiles were designed for a lot of severe environments. Remind me to send you that technical paper on the tiles, [AIAA-81-2469 Strength Integrity of the Space Shuttle Orbiter Tiles] it's pretty good. It shows all of the wind loads, the vibration loads, the deformation of the structure. If the structure deflects underneath the tile 90/1,000 of an inch, the tile will fail. It has a lot of various things that have to be considered.

It was designed for all those environments, but was never ever designed for any debris. To this day it's not designed for debris. It's not certified for debris. After the *Columbia* accident [STS-107]—one of the guys responsible for the tiles and I communicated a lot during that time. He said that there was some push to say that debris impact was okay. And I said, "No, you can't say that. There's three choices. Number one, you can redesign so that it is good for that. Or you can recertify. Or the program direct manager can make a decision that it's acceptable risk. The first two you can do. The third one you can't, that's their [the managers'] decision. For you to recertify for that environment is huge."

That was a major issue. Today I think the program management has better criteria on what kind of debris impact they can take, [i.e.] knowing that there will be some damage. So they're able to fly the vehicle, but it was not designed and certified for any debris, period.

ROSS-NAZZAL: Were you involved at all in the discussions about repairing the thermal protection system in space?

MOSER: A little bit, but not intimately involved in it, no. That was more [about] different materials to apply. After the first few flights we did some stuff on repair techniques, but we dropped it just because it didn't look like anything was panning out. [There were] places on the vehicle you couldn't get to—we even looked at a little flyaround vehicle to inspect, and even have some capability to do repairs. But we were getting more flights underneath our belt, and we thought we're not going to ever go there [with a capability to repair the TPS]. I didn't get involved in any of the details after *Columbia* on tile repair.

ROSS-NAZZAL: Were you in the Mission Control Center when they found out that they were missing some tiles? Was that a major issue for your group that you remember?

MOSER: I was at the Cape on STS-1. When we got the word [from the crew] that we lost some tiles, I was told to go get on a Learjet and get back to Houston and figure out what the problem was and what we were going to do. So that's what I did, came right back to Houston and we convinced ourselves everything was okay, and why we were okay. And that was it.

ROSS-NAZZAL: Not a big deal?

MOSER: It wasn't really a big deal. We knew where it was, but we did our engineering pretty thoroughly for about a day or day and a half, something like that, and said, "We're okay," and come on back in. Then we had a press conference. I think it was Gene [Eugene F.] Kranz and myself and Don [Donald R.] Puddy as I recall. The media was firing a lot of questions.

ROSS-NAZZAL: What were they asking?

MOSER: They wanted to be convinced why it was okay. The media is interesting in those days, and I think probably today. They had really done their homework on all this stuff. They knew about all the problems we'd been through, so they asked some penetrating questions. Had to convince them too, or you'd get bad press. Bob [Robert F.] Thompson used to always say, "The best interview is one which you never read about in the paper." If it doesn't get written, that's a fantastic interview. Any time he gave interviews and he wasn't quoted, he felt he was successful.

ROSS-NAZZAL: Tell us about moving over to the Orbiter Project Office. What changed? You were in engineering management, and then you became project management.

MOSER: Started on the Shuttle in ’69 so was there, as I said [in the first interview], “sketch pad to launch pad.” After the first few flights I was the section head in Structures and Mechanics Division. Then I was asked to be Chris Kraft’s “horse holder” [technical assistant]. Didn’t know what that job entailed. I called somebody that had done it before and said, “I just got this call.” He said, “You were asked to do it?” I said, “Yes, I’m trying to decide if I want to.” He said, “You do want to. You want to do that.” That was a fantastic experience. Chris had this program where your job was to observe. You didn’t really produce too much. He just selected some people, and he just wanted them to be around him and see—from that level and from that vantage point—how the Center worked.

Then I was asked to be the deputy Orbiter project manager when Aaron was the project manager. I served in that capacity. What we were doing then—the vehicle was essentially developed. We were just in the early operations phases, so I was there just making sure that the vehicle was ready, all the flight readiness preparation was in place. We had the right flight rules—one of the things that was important about the early flights [was to make sure that the vehicle flew within the capabilities].

From an Orbiter perspective, [the project] started with a lot of really large, complex test vehicles. There was a vehicle or [thermal vacuum] test article planned for the forward-fuselage of the Orbiter—everything from the payload bay forward, including the cabin, all the forward-fuselage, and all the systems in it. And it was going to be [tested] in the thermal vacuum chamber at JSC. Everything aft of the payload bay, with all the propulsion systems and everything else in there, was going to be a test article. These were just dedicated test articles.

There were to be two Orbiter airframes, that’s [a complete] structure. One [test article] to show that you could take the maximum load expected and then increase that by 40 percent to 140 percent of maximum load before it would fail. The other one was a fatigue test [article]. These structural tests were just characteristic of the aircraft manufacturers; they have static test article and fatigue test article.

Because of reductions in budget, we had to be creative, like Ecord was with the silica and densifying the tiles. We had to figure out a way to not compromise the safety or the integrity of the vehicle but convince ourselves without some of these expensive test articles we could [test and then] fly them. So we said, "Okay, we think on the thermal performance we can start off a little bit more benign the way we [design the mission and] fly it. We will "barbecue" [rotate] the vehicle in space to make sure that it [keeps a] more uniform temperature. We will try and be as lightly loaded thermally as we possibly can, and we'll gradually increase the envelope to more severe and severe and severe conditions." The Orbiter Project, we had to make sure that the flight profile was doing exactly that, we were sneaking up on it slowly.

The same thing with the structural tests; we eliminated both of the structural test articles. *Challenger* vehicle is what we [structurally] tested. I may be repeating some stuff from the previous interview. When we decided to do that it wasn't good enough just to say we're good to go, and it wasn't good enough to just convince John Yardley, we had to convince an outside group made up of aircraft manufacturing, people who made the [Boeing] 747, the [McDonnell Douglas] DC-10, the [Lockheed] L-1011, those class [of aircraft]. They brought a group of their structural experts in and we had to convince them what we were planning to do was okay.

What we planned to do was to load the vehicle slowly up to 120 percent of the maximum mechanical load or airload, if you will, and inertia load. A strain gauge measures the strain in the vehicle [structure]. If I put one on the table right here it would read zero. If I start bending the table, the amount of bending that I put in is how much strain that gauge is going to measure.

We had to prepredict, I think it was like 3,000 strain gauges, what they were going to do as we loaded this vehicle in a lot of different ways. If we could do that, then we could say, "Well, we can extrapolate to 140 percent." We did that—prepredicted, everything was cool, we extrapolated [to show the structure could withstand the ultimate load].

[The static structural test article flew as the] *Challenger* vehicle. We saved $100 million one year by eliminating that [dedicated] test article. But again we had to fly the vehicle [in the] early flights, make sure we were sneaking up on those [design] loads. We didn't get any surprise, and it all worked. The early flight phases, when I was the deputy project manager, that was our focus. Then I stayed in that position for a couple years, then I became director of engineering.

ROSS-NAZZAL: As they were integrating the vehicle[s] in California—we had *Challenger* [OV-099], *Discovery* [OV-103], *Atlantis* [OV-104]—what was your role as they were producing them, manufacturing them, and then sending them over to the Cape?

MOSER: That's where the contractor has all the capability and expertise that the NASA guys don't have. They have the capability to do the detailed design and manufacturing that NASA doesn't have, nor should they have. We would just work with them when problems and issues came up. A lot of times during that phase of a program there are "make work" changes being made. We didn't change anything [in the basic design]. That was the thing that the Orbiter Project never allowed, and that was to Aaron's credit. He could say "no" more firmly than anybody in the entire world. It was no, no, no [to changes with the design]. So we weren't spending a lot of our time with [North American] Rockwell [Corporation] implementing changes, it was just if problems would occur or something like that. We didn't get too much involved in the actual day-to-day stuff. Didn't want to, didn't need to, and we were off working other things.

ROSS-NAZZAL: There's no difference between any of the Orbiters in the fleet?

MOSER: Yes, there are. We had to take some weight out of the vehicle; there were changes made as it progressed. But relative to the early development they were minuscule, and they were very gradual and very slow evolution. Each one of them is a little bit different, but not significantly. There were some process problems. The payload bay doors, for instance. I think that they were changed into a more efficient manufacturing way, since it was all graphite epoxy. That was not a macro change, I take that as a detail change.

I don't remember any other significant change. The reason I said Aaron kept saying "no, no, no" is once we froze the design in '72 and says that's it, then if we had a problem it was a make-work change. Little bit thicker material here, something of that sort. People were constantly proposing changes to make the vehicle better. The RCS [reaction control system] jets, a group of people wanted to move those out to the tips of the wings. So now you can see, [if] you got a little bit of thrust out there, you can move the whole vehicle real easy as opposed to back where they're located up close to or on the fuselage now. But the answer was no.

Somebody else wanted to put canards—that's a little wing on the front of the vehicle [to] give it more aerodynamic stability—the answer was "no—not going to do it." The only real change that we made was we added a head-up display so the astronauts, as they looked out the windshield, could see the critical elements that they need to in flight for their control systems. That was key. "No, no, no, no, no, not going to make any change."

ROSS-NAZZAL: What other activities occupied your time in that position?

MOSER: As the deputy that was it primarily. It was in supporting flight operations and making sure it was compatible between the vehicle design capability and the way the vehicle was going to be flown.

ROSS-NAZZAL: Tell us about moving over to Engineering.

MOSER: The Engineering Directorate was a totally different thing. There you're in line management, you've got all the engineering disciplines involved. In any development program that's the key element to making a system work. You have to work with the ops [operations] guys to make sure the operations plans are compatible with the design and the right balance.

Going into that large a spectrum of engineering was a big change, because I had "grown up in the structures and materials area" and now I had guidance, navigation and control, environmental control, communications. It was a matter of, like any person at that level, you have to make sure the people have the resources and the right guidance on where to go, and get out of their way.

You have to support them, and at the same time you have to then be responsible from the top down. Every year when a budget comes about, if you took everybody's wish it doesn't fit. You have to be the bad guy, you have to weigh what's more important relative to where the organization is going and where you want the Engineering Directorate to go. Totally different thing, you're not in the day-to-day projects. I always sat in all the flight readiness reviews representing all the disciplines in that respect. There was another thing too as the director of Engineering. I was talking to some of the guys this morning as part of the Space Systems Engineering Development Program, and the title of this thing was dealing with change and all the change that they're going through now.

Space Station hadn't been approved. We were wrestling with, as the Director of Engineering representing all of those various disciplines, "What is this Space Station going to be?" I spent a lot of time on the requirements for Space Station. We needed to understand requirements—how are we going to manage it, what is the organization going to be, what is each Center's responsibility going to be. I spent a lot of time with that, but that program wasn't approved.

In the meantime, we've got 650 engineers in the Engineering Directorate, and not doing a lot of developing. So Chris Kraft, the Center Director, says, "Okay, what we're going to do, we're going to move a lot of the Engineering Directorate guys over to ops, because that's where the focus is." There was ranting and raving and kicking and screaming. People don't like to change. He knew that was the right thing to do, so he moved a good number of them over there. We needed to keep our tools honed and in good shape in all the structural disciplines so we started looking for flight projects. The vehicle was flying so Aaron and I became the "chief salesmen" for Johnson Space Center [engineers] on flight projects. We went around knocking on doors of anybody at NASA that had any money and we said, "What help do you need?"

Somebody asked us one day—I think it was the Associate Administrator for Space Sciences. He said, "Well, what are you guys good at?" We [Aaron and I] looked at one another and we said, "Everything," because we had the full spectrum [of engineering disciplines]. We weren't aerodynamicists particularly, we weren't heat transfer guys, we were good at all those things. Because we hadn't thought about, we didn't have a brochure that says, "Here we are." We weren't good at marketing.

We got small projects. We got a project that we designed and built in house, an orbital fuel transfer system. General [James A.] Abrahamson was the Associate Administrator [of Space Flight] at the time. He wanted to show you could take hydrazine and move it from one tank to another [while] in space. It involved the crew, so we designed and built this experiment to put in the payload bay of the Orbiter. Those are the kinds of things we designed and built in house.

What I did to fill this void between Shuttle and Space Station, I formed a Flight Projects Office. It was a project office for a bunch of little projects. That group in the Engineering Directorate then had all the other divisions working with [them] to do things, like this experiment that I just told you. Then we integrated some synthetic aperture radars in the vehicle, which required a lot of engineering.

We were looking for work. Marshall [Space Flight Center, Huntsville, Alabama] was doing the same thing. They worked on railroads, and they worked on trusses and trestles and minimizing earthquake damage to buildings. NASA was running around looking for stuff to do during this hiatus between Shuttle and Space Station.

ROSS-NAZZAL: On your vita you mentioned two specific missions that stood out, one of which was the Solar Max satellite, STS-41C, and the other was STS-51A—you had shown Rebecca a photo.

MOSER: Yes, that was Joe [Joseph P.] Allen. That was the satellite recovery of WESTAR and PALAPA satellites. I was director of Engineering at that time. That was another thing that we did in house. We designed and built the tools with which to go out and capture the satellite. I think what I mentioned was when I was sitting in Mission Control looking at this process going on, it was like this guy going out with a harpoon getting ready to stick it into this satellite.

I said, "That's a modern-day whaling scene." It's a guy going with a harpoon in a harsh environment trying to capture an unwilling creature. So I had some of the guys over in the graphics [department] superimpose a modern-day whaling scene with Joe Allen with the harpoon on an old-day whaling scene, the guy with the boat with the harpoon. Here it is, all integrated into one picture. I think Joe Allen has got a copy of it, and I've got a copy of it. I don't know if anybody else does or not, but that was one of the things in the Engineering Directorate. That was another one of the projects. As other problems came up on the Orbiter like that or another mission, we did that.

I was director of Engineering during Solar Max repair. I think I was Chris's horse holder when that idea came up. Maybe it came up there, but then I was director during the implementation of it.

ROSS-NAZZAL: Did you ever do anything when the crew was in space, and they needed something, like an Apollo 13 event? I'm thinking of the Flyswatter event for instance [STS 51-D].

MOSER: Yes, there were a few things like that but to tell you the truth I don't remember the specifics of them. There's always something like that. There's always real-time things that you have to put your engineering hat on and go solve or say it's not a problem. We had ice form on the part of the cooling system and had to get rid of that and cap it off. But I didn't see those as big challenges.

ROSS-NAZZAL: What do you think were some of the milestones of the program until the *Challenger* accident [STS 51-L]?

MOSER: I don't think there was a major milestone. I think it was a slowly evolving program to establish the capabilities of the vehicle. The vehicle was designed for four people for seven days. So 28 person-days in orbit is what the vehicle was designed for. The first vehicle had a couple of ejection seats in it, crew of two. We started with that and gradually evolved into determining the capability of the vehicle. We've flown seven people. The maximum that we've flown just in the Orbiter itself had been seven people for two weeks or something like that. That's 98 people-days, when it was designed for 28.

What we did is just kept expanding the knowledge of the capabilities of the vehicle and doing that. The other thing we did is found out how to better accommodate payloads. NASA had a terrible image with the payload community early on about it was a privilege to get to fly in this vehicle. We worked very hard at trying to simplify the way we integrated payloads, both in an active sense—in active systems, cooling and power—but also in just structural accommodations. That took a lot of our time. To my way of thinking, there weren't major milestones. It was just a gradual increase in all the capabilities was accomplished during that [time frame].

ROSS-NAZZAL: You mentioned to Rebecca and Sandra [Johnson during the first interview] that you were in the Mission Control Center for the last flight of *Challenger*. Would you share with us your recollections of that day?

MOSER: Yes, that was not a good day. As a matter of fact I was not on the floor in mission control. I was up in the VIP area, as was Chris Kraft on my left and Aaron Cohen on my right. We were sitting there and it was getting to be "Okay, we got this thing by the seat of the pants." We weren't complacent; we'd gone through every check on every flight. And we saw what happened. As soon as we saw the vehicle encounter that—not explosion, but it was like an explosion—all three of us thought it was probably the main engines because that was always the thing we worried about most, the high-pressure high-speed turbopumps and everything else in those engines. We thought that that was it.

We went over and looked at films that we got very early on. Within a few hours we knew what it was. We knew it came from the solid rocket motors. Then I led an internal group of failure investigation. We started that process, and within a matter of a few days we had it nailed. We knew exactly what it was.

The only fortunate thing in any of that, was we could clearly define what the failure was; therefore, we knew what to fix. Had that failure been in the main engines, it may have canceled the program because we may not have ever found out exactly what it was. We didn't have that much instrumentation, [and] that much [detailed information].

We had some fixes that we think would have worked, and we could have been flying again very quickly, like after the Apollo [1] fire. I think it was what, eight months from the time of that and a lot of redesign on the Command Module, I mean a lot of redesign, and we were flying again. It took us two years [after *Challenger* before we flew again]. Bureaucracy took over, and it's just too bad.

Extrapolating on that, Apollo Program was eight plus years from go [ahead] to fly. Shuttle Program, '72 to '81, nine years from start of development to flight. We're 23 years in the Space Station, and it's just now being completed. Let's take out four years for *Columbia* and *Challenger*, because two years down in both of those programs—that's still 19 years.

Bureaucracy is catching up. I have this theory called the "conservation of complexity." The conservation of complexity is when you take the technical issues and the political issues and you put them together, that forms a complexity unit. Apollo [had] huge challenges technically. I mean huge, beyond belief. We didn't even know what we didn't know. I mean period we didn't know what we didn't know. But the political environment was very simple. President was for it, the Congress was for it, there wasn't a lot of bureaucracy and we moved on and we did it.

Fast-forward now to Shuttle. Shuttle came along. Shuttle had some technical issues—thermal protection system, the main propulsion system and the avionics—three major state of the art advancements. Simpler technically, but more complex politically. I'm still maintaining my [conservation of] complexity.

Space Station comes along. Developmentwise, technically, there's nothing to Space Station. Yes, there's a lot of operations that have to be planned and details, and it's dangerous, and it's complicated—but nothing to develop, everything existed. But the political environment is just horrendously terrible. Again, make my case of "conservation of complexity." You just plot this graph which I have, and it shows we're falling right in line.

Then Constellation comes along, and [it is more complex technically and politically]. If you do Constellation the way the Constellation Program is defined, yes, there's some technical challenges on how people live and work effectively on the lunar surface, but there are no major technologies as far as propulsion or anything like that. It's trying to use "off-the-shelf" stuff there, but the political thing is very complicated. What we have today is all of a sudden this Constellation thing has just exploded [politically]. We don't know what it is or where it's going to go. It may condense back down to Constellation. I don't believe that'll happen, but there's some good parts of that too.

When we were talking about John Yardley made the decisions and Chris Kraft and Aaron Cohen—all these guys had full confidence in themselves because they'd been there and done that on a lot of things. I had the good fortune of getting to do a lot of things where we designed, built stuff, and blew things up. You learned by doing those things. What's being proposed is a group of technology initiatives. [They] are not going to just be in the laboratory, [experiment] and analysis. [The engineers have] to design, build, and test things. That can be very good for the thing [because] NASA has gotten away from learning [by doing].

I think that some of the deficiencies in some of the decision making from what I can see at NASA today, is people are having a hard time making decisions. It could be, too, because they're living in the post-*Columbia*-*Challenger* environment where they're careful, they're more afraid to make decisions than probably they could be, should be. So with these other small [technology institutes]—we call them small, they're going to be pretty large—they're going to be things where you design and build things and go fly them. That's going to be very good if that comes about.

[End of interview]