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ORAL HISTORY 2 TRANSCRIPT

ROBERT J. WREN
INTERVIEWED BY JENNIFER ROSS-NAZZAL
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ROSS-NAZZAL: Today is October 23rd, 2007. This oral history with Bob Wren is being conducted for the Johnson Space Center Oral History Project in Houston, Texas. Jennifer Ross-Nazzal is the interviewer, and she is assisted by Rebecca Wright. Thanks again for coming for a second session. Really appreciate it.

WREN: Glad to be here. Thank you.

ROSS-NAZZAL: I wanted to start out today by asking you about some awards and commendations that I saw on your biographical datasheet, which you so kindly provided us. You were the nominee for the Texas Society of Professional Engineers Junior Engineer of the Year Award. Can you tell us about that award and who nominated you?

WREN: It was Joe [Joseph N.] Kotanchik, the Division Chief of the Structures and Mechanics Division. Joe nominated me, and I didn't win it, but I was the nominee from MSC [Manned Spacecraft Center] from NASA, Houston. And that was about it.

ROSS-NAZZAL: Were you nominated based on the work that you had done for the Vibration and Acoustic Test Facility [VATF], or what was the nomination based upon?

WREN: I think it was based upon when I was trying to figure out how to make those simulations I was talking about last time. We were working with Ken [Kenneth McK.] Eldred and so forth at Wyle and trying to come up with a unique way to do this. Nobody had done it and I think it was probably for that.

ROSS-NAZZAL: I also saw that you received a group award for the Lunar Module Test Article-3. Can you tell us about that award and the test as well?

WREN: When we started it in VATF, and I didn't mention -- I left out a few things last time. Arnie [Arnold N.] Levine led the vibration group, and when we first got out to Building 49 I was leading the acoustic group, but I knew how to do the vibration, but you only knew so much, and Arnie was great. He led the LTA-3 vibration test but I helped him a lot because I had done a lot of that sort of thing in the past.

LTA means Lunar Test Article. North American used the term BP boilerplate and Grumman used the term LTA Lunar Test Article, same thing. Depending upon what the test would be that they're intended for, there'd be anywhere from just plain structure with lump masses representing the subsystems and components to perhaps partial systems. Usually not complete flight systems. And of course there's exceptions. Because like we said last time 2TV-1 for Block II thermovacuum number 1 was actually a test article, but it was a complete system. It could have flown. Lunar Module 2 is the same thing. But the LTA-3 was a lump mass structure. We had some boilerplate command modules that we also tested the same way. I can't recall the nomenclature and the names on it. It was the same idea that you had lump mass representation.

What are you trying to do? Well, what you're trying to do is I guess a couple things. One is to investigate the structural response behavior, dynamic structural response behavior, of the structure, and framework and so forth. Find the vibration, what we call the vibration modes: first mode, second mode, third mode and so forth. What that means is that you get resonances at certain frequencies, and you like to know that because that's where you get the highest stresses is when you're in a resonance mode and you're stressing it real high, and it's the most severe test of the primary structure and secondary structure and bracketry and so forth. The second thing is almost always what you usually do is come up with structural models so that the analysis can go forward when you're designing these vehicles. You'd like to validate your structural model and show that you've got a good model, and you did your modeling correctly.

So by instrumenting a lump mass vehicle like that and shaking it and pushing it and testing it and so forth, either statically or vibration-wise or acoustic-wise, you excite the responses in the structure. Then you can compare that with the model you've been using and say, ah, I had a good model. So therefore my analysis is probably pretty close to being accurate, right on the button. Or, hey, way off. So you got to go tweak the model or something.

ROSS-NAZZAL: Do you recall any instances where changes had to be made as a result of your testing?

WREN: Yes. I don't remember any specific ones. I know that almost always you find some things that need to be tweaked. You find areas where you need to strengthen perhaps some secondary structures, some gussets and brackets and that sort of thing. But what you try to do when you design these things is the same classic tradeoff. You want to make it real strong but

the stronger you make it the heavier it's going to be. The heavier it is, the bigger problem you got because we have what we call throw-weight and you're limited with your throw-weight, which means the amount of mass you can take to orbit by the amount of thrust that you have available in your different stage vehicles. You have that constant tradeoff. If you make it too light of course then it'll fail. You don't want that. Of course the same sort of thing is going to apply in some of the other systems.

But in the structures world what we try to do is envelope. Take all the loads that we think a vehicle will see when it's put to use and envelope that. So in other words we create some diagrams of stress and strain and frequency and so forth, that it will never see any loading that's above that envelope top, and then we call that limit load. Then we take that and we'll design the vehicle say with a 1.1, 1.2 yield on that limit load. Yield is when the structure actually deforms. But it deforms to the point where it won't go back to its original shape. That's called yield point. Then we also design it for ultimate where it will break. On top of the limit load we'll put like 1.4 or 2.0. Usually classically we put 1.4 if we test it. In those cases where we don't test it because of schedule or funding or perhaps we want to fly the article, then we usually put a 2.0 factor on the limit load, which we call the design ultimate of 2.0. Then not test it but make measurements and so forth.

By the way, just to complete that, at the end then when you actually construct the vehicle and pick out all the parts -- and parts come in standard gauges and so forth. So what you do is you analyze, but then when you actually pick out the part, suppose it's, oh, a quarter of an inch instead of five-eighths of an inch or something. So you go back and then back-calculate and see, well, what kind of stresses did you really have based upon the materials you actually used. Then that comes out of a formula as what we call margins of safety. So when you hear the folks talk

about, are your margins positive or negative or what, that's what they're talking about. You've got your margins on your finally as-constructed vehicle. The ideal that you want to get is a margin of zero. What that means is you've got a perfect design, you're right there, you haven't wasted any weight, and you're the most efficient from a thrust and throw-weight point of view to get the payload. Any time we have anything on top of a booster we call it a payload. And so to get your payload in orbit or wherever it needs to go. So that's kind of what we did on LTA-3.

ROSS-NAZZAL: And did you hit that ideal?

WREN: Yes I think we came pretty close to that. What you do is if you're way far off, you're going to get it close, because you'll make some modifications. You'll either carve some weight out somewhere, lighten it, drill some holes in low-stress locations and so forth, or you'll beef it up and strengthen it and that sort of thing.

ROSS-NAZZAL: Did the test require you at all to go to Grumman up in New York?

WREN: No. I did not go to Grumman on that. We had Grumman folks down. Came down from Bethpage [New York].

ROSS-NAZZAL: You had mentioned there were a few things you hadn't mentioned last time. Are there some things that you wanted to talk about?

WREN: I wanted to be sure that I mentioned on the acoustic part. I had forgotten Omega D Squared. That's Wade D. Dorland. I called him Omega D Squared. When I was working with Ken Eldred at Wyle, we were fishing around for acoustic experts around the country. Ken said, "Hey, you got one right there at NASA. He's up at Marshall [Space Flight Center] at Huntsville working on the Saturn."

So I went up and paid Wade Dorland a visit. Boy he was good. He was a good person in structural dynamics with acoustics. Acoustician. So I tried to talk him into coming down to Houston. He didn't want to leave Huntsville. I think he was from Nebraska or Kansas, and he liked it up there. He didn't want to go to the subtropics down there in Houston. The British embassy was on subtropical duty pay when we arrived in Houston. I don't know if you knew that or not.

ROSS-NAZZAL: I can see why. All those mosquitoes.

WREN: Anyway I finally managed to talk Wade and his wife Corinne into coming down to Houston and joining us, and that was wonderful because he was a big help. Later on when I got pulled away from VATF and Building 49 to go do 2TV-1 and LM [Lunar Module]-2 and the project stuff I talked about last time, Wade took over for me in the VATF. By that time Arnie Levine had left and gone on to Building 13 to do other things. When I went back to do LM-2 which we'll talk about later, why, Wade was right there to help with that, because we were doing it in VATF. So I wanted to be sure that Wade Dorland got mentioned. We had a good group of people out there. I can't remember all the names. But I tell you one thing. When I had the section there we had an Experimental Dynamics Section. Gosh, I can't remember all the names.

They may be in my notes. But oh, in addition to Wade, Steve [Stephen] Huzar, I can't remember all. But I do remember that Estella [Hernandez] Gillette was my secretary.

ROSS-NAZZAL: Was she?

WREN: And then later on, why, she became equal opportunity officer person at the Center. She married Pete [Peter] Gillette. Pete was a member of the instrumentation group that we had out there. The electronics group for measurement of instrumentation and so forth and recording and that. Bob [Robert P.] Bolte and all those guys. Pete was part of that group. And Don [K.] McCutchen, oh, Eddie [J.] Jung, I can't remember all the names. But we could find them in the notes.

ROSS-NAZZAL: Oh, absolutely we can add those.

WREN: And let's see if there was something else that I inadvertently -- oh did I tell you about when we did 2TV-1 about David Llorente? Ben Boykin and David Llorente were the engineers that came from Downey [California] on that. John Stungis had all the technicians. Turns out that David Llorente, boy, he was a character. David Llorente flew airplanes and he flew for Hollywood [California]. As a matter of fact he flew the biplane Gypsy Moth in the movie *Gypsy Moth* for Hollywood. So we rib him about all that. So he worked in the movies.

The other thing I wanted to be sure to mention is Doug [Douglas] Ward from PAO, Public Affairs Office. When I had to do all those press conferences and so forth, Doug Ward, he was the jewel, he ran front for me and made all arrangements for the press and for the interviews

and so forth. Heck of a nice guy. I was fortunate to be acquainted with him for a number of years from then on. Thought highly of Doug. He did a lot of commentary for the missions also. He was a good troop. And let's see if there was anything else.

I think I mentioned that my most prized letter of commendation was -- well I got a couple of them from George [M.] Low, but the first one for 2TV-1 meant a whole lot to me. He also sent one for LM-2.

I noticed somewhere that it was stated, I think in the material you had, and I had forgotten all about that logo, that symbol thing with the roadrunner and the proud bird with the heavy tail. I had forgotten. That was a riot. That was so funny. But I noticed in the little write-up you said that 2TV-1 was a constraint on Apollo 7 and I don't remember that. I know it was a constraint on Apollo 8. But it might have been on 7 also. Seven was an Earth orbital flight just before eight and there were a lot of things about the Command/Service Module that answers would help with Apollo 7. But I don't recall it was an official constraint but it might have been an unofficial one.

I guess the other thing I wanted to mention. Oh with Rolf [W.] Lanzkron I think I mentioned that I had standup meetings with Rolf every morning during 2TV-1. I remember the very first time that we met one another. I have to back up. Although he was very very good and very capable and very much admired, he could be a holy terror. He made people shake in their boots. Just his mannerism and his demanding style. And we needed that at the time. But it made a lot of people kind of nervous. So the first time I met him he started to tear into me. I said, “Ooh wait a minute, uh-uh. We're not going to conduct business this way, we're going to keep it civil, and if we can't keep it civil and professional then you can get somebody else and

I'm going to go do some other job." He looked at me and his eyes got real big. I don't think anybody had ever talked to him like that.

I think he respected that, and he got a big smile on his face, and from that point on we worked together just fantastically. People kept saying, you're working with Rolf and you're not having any trouble? Said, no he's great. We're doing good. So we're good to go. So I wanted to mention that. Rolf was a great guy.

ROSS-NAZZAL: And did he work for Engineering Directorate?

WREN: No. He was in ASPO. He was in the program office, Apollo Spacecraft Program Office. He was head of the Command/Service Module. He was manager with Command/Service Module in ASPO. Let's see. Oh, there was a couple more funnies. You want some more funnies?

ROSS-NAZZAL: Absolutely, yes please.

WREN: When I was out at Ken's house. Ken Eldred out in El Segundo [California]. Actually he and his wife lived up in Santa Monica [California]. We went up there one night. I was invited for dinner and went up there and I was amazed, because here I was a neophyte, I didn't know anything, and his backyard why had limes growing, lemons, avocados. Wow! It's a hilly area. So we're having dinner and all of a sudden, why, this guy comes in through the front door, a neighbor from across the street.

He came in and turned out it was Frank Gorshin. You may not know but at the time one of the funny people in entertainment at the time; what reminded me was that the movie *Where the Boys Are* was filmed in Fort Lauderdale [Florida] at the Elbow Room, and there's a whole story about how that movie with Connie Francis -- well I just picked up the DVD [Digital Video Disc] because my middle son is in the FBI [Federal Bureau of Investigation]. Lives in Fort Lauderdale. He's in the Miami [Florida] office. FBI office. And so the guys stop and hang out at the Elbow Room. It's still there. In the afternoon after work. They filmed the movie *Where the Boys Are* there. It had Frank Gorshin in it. Well I went and found a DVD. They finally put the movie on a DVD.

So I got it the other day at Barnes & Noble and I'm going to play it when Pat comes in. We'll have a lot of fun with it. But I noticed on there that Frank Gorshin was in that movie. I thought, oh that's that funny guy that wandered into Ken's house that night. You never know what will happen in this world, but he was a great guy too, [Frank] Gorshin, funny, oh he was funny.

Another thing I guess I wanted to mention, kind of funny, is we had two guys in materials. If I recall I think they also came down from General Dynamics. R. L. Johnston and R. E. Johnson. They're both Bobs. Bob Johnston. See, and R. E., Bob Johnson. Okay, but one had a T in his name and one didn't. Now the only way I could ever keep it straight -- and I love both these guys, they're a riot. But is the taller one had the T in his name. So Bob Johnston, R. L. Johnston, that meant he was taller. R. E. Johnson, he was a little bit shorter. Anyway they're both great guys. And Sam Glorioso (phonetic) and all that bunch, yeah. I guess that's probably enough of all that. I just wanted to be sure. Oh, I know. A couple more things.

The sign of the times, we talked about everybody wore narrow black ties, white shirts and crew cuts and flattops. We also had to wear coat and tie. We were very professional and that came from the top down. You had to have your coat and tie on, and that's why in a lot of the old pictures you'll see everybody's wearing coat and ties. When you finally maybe get on the consoles or something, why, you'll take your jacket off. But you had to wear coats and ties. You had to be professional. I thought that was interesting.

Then the other thing about badge control. This is just a minor thing. But it's interesting. Is that you were not allowed to wear your badge off-site. Why in the world, is that? Well, the reason was that you're working with classified information. It just helped the situation if you didn't advertise when you're off-base or off-site where you worked. In case the Russians or some bad people might come and try to compromise your situation and gain information and whatever. So if anybody was caught wearing a badge outside the plant, off-site, that was bad. There was disciplinary action. Then we came to NASA. Of course a lot of us did that, every time we went across the street to the post office or went off-site for anything, why, you took your badge off and stuck it in the pocket so it wasn't exposed. It's funny, through the years, all that just drifted away. You see folks everywhere. They don't pay any attention to it because it's not important anymore. Anyway that's where it had its roots.

ROSS-NAZZAL: That's interesting, because I think a couple of times people have told me you need to take your badge off here, you're not on site. You get used to wearing it. So you don't really think too much about it.

WREN: That's where it had its roots, why it happened. So that was the things I wanted to be sure to pick up that I omitted last time.

ROSS-NAZZAL: Let me ask you a couple questions based on that information you shared with us. Were there any other women who were working in your group besides Estella Gillette? Any other female engineers? Or was that primarily men who worked in that branch or section?

WREN: No, I had a woman boss when I was with the Bureau of Reclamation. There were some ladies that worked with me at the bomber plant at General Dynamics. But when I was out in VATF I don't recall any lady engineers at that time. Now, we were adding lady engineers. [Later on I had at least two crackerjack female engineers on my Engineering Directorate Support Teams, Nancy E. Tengler from Structures, Coupled Loads Analysis and A.R. Shamala from Materials, Fracture Mechanics Analysis and Control. And Karen S. Edlestein and Lynda R. Estes both from Structures, Glass Window Analysis. Also, the Orbiter payload customers, the ISS Work package contractors and the ISS international partners including the Russians had many female engineers.]

But no, I don't recall any at that time. But like I said, I had certainly had a very excellent -- June Brooks [phonetic] was her name in Austin [Texas] at the Area Planning Office of the US Bureau of Reclamation. When I worked there part-time going to school, and then later I worked there full-time when I was in grad school. We all worked for Melvin Schwab [phonetic] and Harry Burleigh [phonetic]. But yes, June Brooks. So no, I don't think so. As long as I'm looking here, I might as well see if I left anybody out in Building 49.

Estella was our secretary. I had J. D. [James] Johnston. Oh yes. Steve Huzar. Wade Dorland. Bill Boyd. Billy [M.] Adams. Randy Dickson. I forgot Randy. Some of these folks are still around. Don McCutchen. Art [Arthur] Chapman was the -- now Art Chapman was the technician. He wasn't an engineer. But boy he was great and he coordinated with all of the technicians that we had on contract with Brown and Root-Northrop. So he was that interface. [Also Bud Murray and Billy Nelson.] He did a fantastic job and he made great coffee in the morning, real strong. No, that's it, I think, on that. I guess some of the folks I worked with out when we were doing all those vibration and acoustic tests.

Milt [Milton A.] Silveira. I didn't mention Milt the other day. Uncle Milty. These are NASA folks. Dick [Richard A.] Colonna. Dan Newbrough was with GE [General Electric] and he was Dick's sidekick. Ben Holder. Tom Modlin. On and on. Some of the Rockwell people out at Downey were Lou Walkover, headed up the design group. And Bob Westrup, the structures group. And oh and John Heldenfelds. Structural dynamicist. Was excellent. And Joey Yahata. I guess I forgot to mention the instrumentation people. I'm jumping around here but --

ROSS-NAZZAL: That's okay, this is great information.

WREN: The instrumentation and data group out in VATF. John Lowry. Remember Johnny. Married a girl that came from Alaska. And Bob Bolte. Pete Gillette. Al [Allan D.] Gist. See, I forgot some of these. Billy [B.] Nelson and Eddie [J.] Jung. All fine folks. And I think that's probably it. [Charlie D. Stamps, Austin W. Frost and others provided great NASA QC—Quality Control—inspection and sign-off support. QC stamps were very important on our TPS's, etc.]

ROSS-NAZZAL: That's quite a crew there.

WREN: Yes and then -- oh and I didn't mention all the folks when I did 2TV-1 who were associated on the NASA side with the SESL, the Space Environment Simulation Lab. I think I probably mentioned Jim [James C.] McLane. But I didn't mention Jim [James S.] Moore, Rich [J.] Piotrowski, Rudy Williams, Don [Donald C.] Cole, [M. Gene Goodhart, William W. "Bill" Killingsworth, Marion M. Lusk, Albert L. "Al" Branscomb, James "Pete" Vincent] and then Bill [William W.] Petynia did the Lunar Module chamber test of Chamber B. Very capable. I think he came down from the original Space Task Group, Bill Petynia. Of course I mentioned John Stungis. His crew from Downey and Ben Boykin and David Llorente. I just like for the folks to get credit. Those that I can remember. I apologize for the ones I can't remember.

ROSS-NAZZAL: Well this is good detail. A lot of people mine those oral histories for information about who worked there and what various people did. So it's fantastic.

WREN: I can remember some of the names of the subsystem managers at the time, but I can't remember all of them, like the ECLSS [Environmental Control and Life Support System] guy, oh he's so smart and so good. Frank [H.] Samonski [Jr.]. Jim [R.] Jaax worked with him, who later came, rose up in the Center management, and Hank [Henry A.] Rotter [and John E. Whalen], who's still around, by the way, today [and Richard J. "Dick" Gillen and Wilbert E. "Will" Ellis]. And then the passive thermal, we had [R. Bryan Erb, David H. Greenshields,] Jim [James A.] Smith and Bob [Robert G.] Brown. Oh boy, so good. And Jim Janney, [Robert A. "Bob" Vogt,

John Strouhal, Ed Chimenti, Donald M. "Don" Curry, Robert L. "Bob" Dotts, Ray Serna, Bob Ried, Winston D. Goodrich, Carl D. Scott, Tommy [J.] Taylor, Carlisle D. Campbell.] And oh so many -- and power, Tom [Thomas L.] Davies and Shelby [L.] Owens. And so on and so forth, [James Barry Trout], Bob [J.] Bragg, [and John Casey] in batteries. But I think that's about it on the folks I wanted to be sure got mentioned somewhere. And then we'll have some more when we talk about LM-2. So think that's about it. [Also, we worked with Charles A. "Chuck" Berry and Willard R. "Royce" Hawkins, M.D.'s, for crew support. Also Warren J. North, Scotty H. Simpkinson, Martin L. "Marty" Raines, Joseph H. "Joe" Levine, Richard S. "Dick" Johnston, Robert E. "Ed" Smylie, Bob Gardner, Paul Vavra, John D. Overton, Ralph S. Sawyer and others.]

ROSS-NAZZAL: You mentioned Doug Ward and Public Affairs interviews. Can you tell us about those press conferences and how frequently you had them while you were working?

WREN: One of the most terrible times in my life. [Laughs] No. No, I finally got used to them. But for an engineer to have to do that sort of -- and it was required. It was needed. It was necessary and it was good. But it's an uncomfortable thing for most of the technical folks to try to do that. Doug understood all that. He paved the way, settled you down, and he'd get you positioned in the chair right. Get your tie right and your jacket and all that sort of thing. That was very helpful. Doug was real good at that. I did another thing one time.

I wanted to know about this Space Act of '58 because we came down here for the Mars mission. I think I mentioned that, not for the Apollo. We came for Apollo, but we really came because we were going to go to Mars. Somewhere along there later on, why, we drifted away

from that. Well I asked Doug to go see if he could dig out a copy of the Space Act of '58, and he did it, and he came back with it within hours. Of course in there it said that the agency was created to do exploration and then generate the capability and hardware and methodology and control and operations and so forth to be able to do that. But the main purpose was non-DOD [Department of Defense], nonmilitary, nondefense exploration. Later on we'll come to find out that we drifted away from exploration and more into just Earth orbital stuff and so forth. We'll talk more about that perhaps later. But Doug Ward, he went and got that copy of the Space Act of '58, and I read through the whole thing. But I appreciate that he went and found it and brought it to me.

But the press conferences, I guess the one thing -- and I got used to it, and bless their hearts, is that you'd have some people in the press who were science people or engineering technical people, like [Mark] Carreau with *Houston Chronicle* is very good. But of course he wasn't there at the time because this is a long time ago, but folks like that. But then you'd have some others that would come in and bless their hearts just didn't have a clue about the technical aspects. When you're in a rush rush rush round the clock going fast, and this is a failing I guess on the part of us that were working, you didn't have a whole lot of patience for silly questions where there wasn't any understanding of what was going on. That's a failing on our part, because you should just stop, take a breath and say now wait a minute, not everybody is core-drilling and in-depth in this technical sort of thing.

That was what was good about Ken Eldred I mentioned. He could actually work his equations and all this sort of thing, but then he could talk about it and explain it where people like me could understand it. Anyway I learned that you needed to have more patience and

understanding when you're working with the press, with the media. At that time we called them the press.

ROSS-NAZZAL: Did Doug Ward give you any instructions or training before your first press conference?

WREN: Oh yes. Yes. Yes.

ROSS-NAZZAL: What did he tell you?

WREN: He'd tell me how to sit, how to patiently take the question and try to work with it as best you can. Be patient. If you keep repeating the same question, why, then just how to move on to something else. Little suave things to do. Doug was great.

ROSS-NAZZAL: Were you the only member there who was describing what was going on or were there other people?

WREN: Usually I was it.

ROSS-NAZZAL: You had to bear the brunt of it.

WREN: Right.

ROSS-NAZZAL: How frequent[ly] did you have these press conferences?

WREN: Well, I can't recall. Maybe weekly. Of course during the course of the test we probably had -- when we actually put the crew in the chamber for example in 2TV-1, put them in the vehicle, I can't recall, but we probably had a press conference every day there for that seven, eight days. We probably had them weekly maybe leading up to it and monthly even before that. After it was over and everything was okay, why, then we didn't have them anymore.

ROSS-NAZZAL: Did the media ever come out and shoot footage while the test was going on itself?

WREN: Yes, I think they did. Yes, they were around, and shooting motion as well as still photos. Trying to do a little bit of interviewing. But that was difficult because everybody was working hard. I think they were allowed in there as I recall. I'm a little fuzzy on that, though. Don't remember.

ROSS-NAZZAL: Did you carry over these press conferences when you started working on LM-2?

WREN: Yes, yes, not as many because we didn't have crew involvement. The crew involvement made a big difference in the interest of the media, the press. Which is natural. I don't know if I mentioned another thing.

When you work with these space vehicles there's a big difference as to whether it's man-rated or not. Of course when you work in airplanes, why, they're all man-rated. But when you

work with rockets and launch vehicles and satellites and things so many of them are not man-rated. They're not carrying men. Carrying satellites, communication, so forth, or missiles, whatever the purpose is. What's the difference? Well the difference is that first of all like you can have a higher G load for liftoff on your rocket because you don't have people in it. People have limitations on G levels. Can only take so many Gs. If you don't have any people on board, why, then you can just go for it and have all your components and subsystems and of course structure designed where they'll take a high G load, high thrust level, a high stress. And of course you can get higher performance because you go like crazy.

But when you get people involved you've got to back off of that. That's why we throttle down, by the way, today when we have the launch of the Shuttle. You'll notice that they'll be talking about throttling down at a certain point of the engines. That's the reason, because you're trying to keep your G level. In the case of the Shuttle we try to keep it at three Gs. Generally speaking about five or six Gs is pretty much the limit for folks. Now in special training for high-performance aircraft we have some of the crews that are used to it, to be able to take eight to ten Gs. But that's pretty high-performance. Then we have G suits that the guys wear. That's another thing.

On for example the performers like the Air Force Thunderbirds and the Navy Blue Angels, especially the Blues, they don't like to wear G suits when they fly. Of course they're pulling maneuvers that are very high G level. Because the suit gets in the way of the stick and it's very sensitive how you're controlling your stick for your motions and maneuvers. And so what do they do? Well, what they do is they've developed procedures, which they practice in centrifuges, to constrain the abdomen and so forth, and the throat. And grimace like this [demonstrates] to keep the blood flowing to the brain -- what you want to do is to avoid blackout

and do this on their own without the advantage of having assistance from a G suit. A G suit applies pressure. The whole idea is to keep the oxygen to the brain so you don't black out. But anyway the difference between man-rated and nonman-rated if you hear those terms, that's what that's all about. Is for the crew as well as for the systems.

Of course everything we've been doing here naturally at Manned Spacecraft Center is man-rated. We have margins probably that we put on there for crew -- we think a lot about crew safety. In fact that is probably uppermost when we design vehicles. First of all what is it you want to do? What do you want to accomplish on your mission? Do you want to go to the Moon? You want to go here? What do you want to do? Okay, now how are we going to do it? What kind of equipment would it take to do it? And so forth.

You go through that scenario and you end up developing some hardware and some subsystems and so forth to accomplish the task. But if you got a crew involved then it's got to be operable, they have to be able to fly it, they have to be able to withstand the loads and the environments, you got to have the right atmosphere, oxygen and so forth and so on. So there's a lot of considerations when you have people involved in what you're doing, and that's what we mean by man-rated. So those are considerations that you didn't have to deal with when you're working just with say like we put a TDRS satellite, Tracking and Data Relay Satellite, in orbit for communication purposes, etc. You don't have to be concerned about being man-rated.

But crew is always uppermost in everything we do. The crew has to be able to survive, they have to be safe, they can't be hurt in any way. That's the goal. They have to be able to perform what it is you're asking them to perform function-wise. Then whatever kind of equipment that you have, it has to be able to be operated by the ground controllers, mission ops

[operations] and mission control. So there's a lot of considerations when you do manned activities.

ROSS-NAZZAL: You mentioned that there was great interest by the media in the crew itself. When the crew was finally released, did they take part in one of the press conferences that you participated in?

WREN: I don't recall but I would be very surprised if they did not. I'm sure they must have, yes, yes, yes, and I don't recall whether we had one where they joined me, or whether they had their separate one.

At the time the schedules were hectic. And that's part of the reason why for example each three-person crew -- in Apollo we had three sets of three crew people assigned to each vehicle, the primary crew, the backup crew, and an assist crew. Each one of those, especially the prime crew, had a nonastronaut helper, like I mentioned Joe [Joseph A.] Gagliano. The point is that the crews were extremely busy, because not only were they flying but they were going to design reviews, testing, involved in testing, witnessing, helping, doing this and that. They're all over the place. They could be at the Cape [Canaveral, Florida], they could be in Downey, or they could be at Bethpage. In Gemini they could be at the Cape or they could be in St. Louis [Missouri]. Everywhere. Somebody has to orchestrate all this. So their time is very valuable. So it could well be that they had separate press conferences as they could work it in. So I don't remember.

ROSS-NAZZAL: One of the things that we did not talk about last time was the Apollo 1 fire. And I was curious what impact that had on your duties and assignments in the building that you were working in.

WREN: Well, first of all I've been through three of these, Apollo 1 and of course the *Challenger* and *Columbia*. It's no fun. I also went through some of these at the bomber plant when we lost some B-58s and lost a crew and had to go out and recover things in the bush out there. It's not fun. But there's risk. You can't fly with zero risk. It's impossible. So the question is how much risk do you assume.

Now the case of Apollo 1, everybody thought at the time that things were moving pretty well. So complicated. So many problems to solve. And as I recall Apollo 1, it was a test down at the Cape and we had it on the stack. I believe it was on an S-IB stack as I recall. It was going to be an Earth orbital flight. They were doing a preflight checkout, like you go through these rehearsals if you like. Put the crew in and there was a fire and couldn't get them out. So it was as bad day. Everybody was all down in the dumps. It was bad. So you had an emotional thing on the part naturally of all the workers. People had been working so hard solving problems, seeing successes. Two steps forward, one step back. Then all of a sudden the whole thing just fell apart.

Of course the press at the time said, oh boy, better cancel the whole program. We can't do Apollo. We can't go to the Moon. NASA doesn't know what they're doing. All those negative things. Of course you felt bad for the crew because you knew the crew and in some cases the families. I don't know how to describe it other than it's a bad day, just a bad day.

You know it can happen but you hope it doesn't. Now as far as what caused it, we think we know what caused it. Probably to this day we don't know exactly what the trigger point was. But probably what caused it was first of all we had a pure oxygen environment inside the Command Module. Had talked about earlier on trying to go to a two-gas system where we'd have oxygen and nitrogen. For weight-saving purposes and other reasons, why, we didn't. We had pure oxygen, 100%, which is highly flammable. Probably what happened is we had a spark in the wiring. Might have been in ECLSS, not quite sure. But then it ignited and of course it just flamed and got high temperatures. I believe that the crew very quickly ran out of oxygen. I think the reports would show, if I remember correctly, it was anoxia, they were suffocated. Not so much just burned up. Of course they'd have burns. But they just asphyxiated, ran out of oxygen and had toxic gases from things that were burning and so forth. But what did we do then as we tried to recover?

We went back and again think brought up going back to two-gas system. It was late to do that because of where would you put the parts, the components, and of course weight and so forth. So what was decided on that front as I recall is that we would start out with two-gas on the pad and then as we launched we would bleed down the nitrogen until we finally achieved 100% O2 for the rest of the flight. On the pad before that, why, by the way it was overpressurized with 100% O2. So instead of 14.7 PSI [Pounds Per Square Inch] I don't recall, it was probably a couple PSI over, 16 something perhaps. So we did go to a two-gas environment on the pad.

What else did we do? We had a massive reassessment of the flammability characteristics. R. L. Johnston and R. E. Johnson [and Lubert J. Leger, Mike Pedley, James D. "Don" Medlock, Dwight Janoff, Mike Steinthal, Calvin Schomburg, Glenn M. Ecord, Bud Castner, Samuel V. "Sam" Glorioso, Royce G. Forman, Dave Moore, John H. "Howard"

Kimzey, Steve Jacobs, James E. "Jim" Pavlosky, Paul Ledoux, etc.] and all those smart materials people did exhaustive work on that, as well as support from Downey. What we did is we eliminated as much as possible all flammable materials. What do I mean by that? Well first of all the metallic materials in a lot of cases where we could, we changed the tubing from titanium as I recall to stainless steel, which had better flammability resistance characteristics. We changed to brazing and we changed quite a few things with the hard goods, if you like, with the metallics. On the nonmetallics we tried to go away from flammable materials as much as possible. I don't recall if we achieved it 100%.

What did we use? We used a lot of beta cloth and Nomex and things like that trying to get away from nylon and flammable things. So we had the materials change. What else did we do? We created very stringent requirements for inventory of what the materials in every single Command Module. And same thing applied, we did the same thing to the Lunar Module also by the way ascent stage compartment. So that there was very tight control on the materials.

We also introduced another thing, which is a break in the propagation paths was very important. So if something was flaming, why, it couldn't spread very rapidly. There would be a break in the path. Some folks out in California right now wish they had that with the fires in their Malibu homes. But tried to create breaks in the propagation paths. We instituted flammability assessments where the contractor as well as the civil service folks had to follow very stringent flammability requirement -- created some flammability assessment booklets and directions and so forth, requirements. Everything had to have a flammability assessment analysis backed up by test. So we went to a lot of configuration control measures to keep a good handle on flammability and materials in the cabin.

Then the other thing we did is that they had trouble trying to get the crew out. And the crew was trying to open the hatch and couldn't get it open in time. So there was some major changes in the hatch. We ended up with something called a unified hatch. This unified hatch could be opened from the outside or from the inside very quickly with an arrangement of some over-center cams and some different latching and so forth. So it was quick opening. It was one hatch. Before there was a hatch and then there was another kind of a hatch thing that was on a cover that we were flying that went away with the launch escape tower. The cover was over the top of the vehicle to keep soil and debris and so forth off the windows and off the main Command Module structure. That protective cover had an opening. Ended up with one unified hatch, quick opening. I guess that's probably -- as I recall what we did.

Now later on of course when we got to the Shuttle and then all the studies we did for Space Station and Space Bases, we went to two-gas system with an Earth-like environment, 14.7 or slightly over pressure. But always with the standard makeup of nitrogen and oxygen 80-20. So we don't do pure oxygen anymore.

ROSS-NAZZAL: You mentioned that it was a difficult time because you knew the families. You knew the crew. How closely had you worked with the astronauts prior to this time when you came on board at MSC?

WREN: Well, I hadn't worked with any of them before I came on board in MSC. I didn't know any of the crews. No astronauts came from the bomber plant. So I didn't know any of them. I got to know them when I got here to Houston. We used to hang out at the Outpost, which is still here by the way, several other hangout places are not here anymore. Singing Wheel, and Guy

Francis's old Flintlock Inn, and so on and so forth. But you got to know them. Working with them as well as after-hours. I was acquainted with all three. I was not personal friends with any of the three in the fire. Of course when you went down to the Cape, why, you'd usually find some of the guys hanging out after work. I don't remember the names of all the places where you'd go by and have a little food.

When you're in that business of a flight crew and high performance and especially the test pilots, it's so stressful that you got to have some way of relief. Humor and comic relief and so forth. Kidding, that sort of thing, you just have to have that. And of course it's highly competitive. So you always have competitions. For example, when you land the Shuttle -- I don't know if you know this or not -- but the guys always have a competition going to see who can get right on the centerline of the runway when you stop. Wheel stop. And so oh yes, yes, well you did it better, Navy guys fly better than Air Force -- you have all that banter that goes on. That's good.

ROSS-NAZZAL: How about we talk about the LM-2 test that you were working on? How did you get involved in that?

WREN: Okay, well when 2TV-1 was over, and I thought well maybe I'll be going back to Structures Division and perhaps back to VATF, although by that time, why, Wade Dorland was doing a great job out there, and I was losing my depth capability, more broad and all that. Well anyway I didn't have to think about it much because I got grabbed by the Program Office. And said hey wait a minute, we got LM-2 coming up and we want you to do that job. So there was announcements and I got appointed to do that. Same thing, it was a project sort of job. Of lesser

magnitude people-wise because we didn't have a crew in it. [I was to report to Owen G. Morris, Manager of the Lunar Module in the Program Office.]

But what was it that was needed to be done? The Lunar Module needed to have a demonstration of its survivability on landing on the Moon. There had been some series of structural tests earlier on in the development of the Lunar Module. I was not involved in a lot of those. Some of those were done up in Bethpage and I think maybe some were done at Langley [Research Center, Hampton, Virginia]. I don't recall. But anyway we're getting right down to the wire now. We're getting close. We're talking about we only got a couple, three more flights, and we're going to go land. George Low and the guys were really pushing it. We really need to have a demonstration of an all-up Lunar Module and it will survive.

So okay, and what we had is the LM-2, Lunar Module 2, had been used for some earlier tests and I don't recall what they were. But it was a fully flyable Lunar Module. What that means is it had all the systems on it. Was ready to go, was all operating, just like the 2TV-1 was for the Command/Service Module. We did not have a crew in it because we didn't need to. What we were trying to do was show the survivability of not only the structure -- because a lot of that had been proven earlier -- but all the systems.

So when we did the simulated landings, the protocol was that we would fire up all the systems, power up everything. Of course that entails then just like on the 2TV-1 that you've got all of your Apollo support equipment, checkout equipment and so forth, all there and hooked up so that you're operating the systems and you're monitoring their behavior and so forth. So you want to know that the systems are operating before you land, that they're operating and there's no transient glitches during the impact of landing, and that they're still operating satisfactorily after

the landing, or after the impact. So that's what we had to do, and we hooked up all the support equipment. Had all the systems running. Then we would drop it for the conditions.

As I recall you always want to check envelopes. Different conditions and limits and so forth. So I think we tried dropping at different heights, at different angles. And I think that was probably the test control conditions. The Lunar Module for shock absorbers it had crushable honeycomb built into the legs and also into the footpads. That was supposed to take the shock. So we wanted to again see that all that worked. Although it'd been demonstrated earlier on. But that's what we did. We dropped it -- powered up all the systems and kept them on and then made the drop and checked it to be sure it was still operating after the drop.

ROSS-NAZZAL: What kind of surface were you landing the LM-2 on? Was it a surface that was ideally similar to the Moon? Or was it just a concrete surface?

WREN: No. Just a concrete -- or some kind of hard surface. It was not necessary to have representation of the pockets and holes and so forth of the lunar surface. We didn't need to do that. We just needed to impact impact loads on the vehicle. Like I said the main thing was that all these systems -- although all the systems had already been through component tests, subassembly tests for vibration and acoustic, lots of different things. But when you put it all together you want to be sure it all works, the total end vehicle package works.

Give you an example. I'll back up a square. When we were doing vibration and acoustic tests in VATF earlier on with the Command Module and with the LM, we did some tests on the instrument unit, which was the interface between the SLA [Spacecraft Lunar Module Adapter] and the S-IVB. The instrument unit served two purposes. One, it was interstage, structural

interstage. The other thing was it had a lot of components on it. Instrumentation, avionics and so forth. So we did a vibration test on this, and it had been tested a lot at Marshall and other places. And so just as a final quality check, why, we were going to set it on some things and vibrate it and see if anything happens. We fired that thing up and parts started falling all over the floor. [Laughs]

ROSS-NAZZAL: That's not what you want to see.

WREN: So there was major scramble to go back and beef up a few things. So my point being is that that's why you want to do things like the LM-2 test where you have all the systems there and hooked up the way you're going to do it on the flight vehicle, per all the configuration control drawings, all that, inspections and QC and all that. Now let's see if it really holds together and does what it's supposed to do, and doesn't do what it's not supposed to do. That's what we did. I recall the end result of the LM-2 test is that it performed beautifully; I can't recall any glitches. It was very successful.

Also by the way we had a full load of propellant for propellant weight in the ascent stage naturally and a partial in the descent stage, because when you come into the lunar surface you've used up part of your propellant in the descent stage of course. The descent stage had a throttlable engine so you could hover and the crew could find the good landing spot. But the ascent stage -- and these were hypergols as I remember. Hypergol is propellant and a fuel and oxidizer where when they meet one another they immediately ignite. That's what a hypergol is. And we used hypergol on those engines. It just went like a skyrocket. It was not throttlable. It just went. We didn't need to hover. We're going to go get back up to lunar orbit. But anyway so we had a

partial load in the descent stage and a full load to represent the mass and slosh and all that sort of thing in the ascent stage.

ROSS-NAZZAL: What did you learn from working on the 2TV-1 test that you applied to this test?

WREN: Oh, again how to orchestrate a sizable group of manpower and resources. A typical project engineering function, management function with all the different systems, subsystems, components, all the different people, subsystem managers. And the tests, all the different test crews, all the different instrumentation crews, so on and so forth.

ROSS-NAZZAL: You had mentioned last time when you were working on the 2TV-1 test that it took a while to get to the testing stage. Was it the same case for the LM-2 test?

WREN: Oh yes, yes. Yes, same idea. You create test plans of exactly what you're going to do, and you follow those very precisely. Complete with, in both cases, test readiness reviews, just like you'd have a flight readiness review, where you have a review board that reviews everything. It's set up with the management and the Program Office. And that everything's good to go and we're ready. All carefully controlled, everything is precisely written down and controlled. Nothing just off the cuff. It's all done in a very measured meticulous fashion, very rigorous.

ROSS-NAZZAL: Was the lunar landing then dependent upon the success of this?

WREN: Absolutely. LM-2, like 2TV-1 was a direct constraint on Apollo 8, LM-2 was a direct constraint on Apollo 11. If we did not complete the LM-2 all-ups, systems drop test successfully, we could not go to the Moon with Apollo 11. Or could not do a landing. Now we went to the Moon in Apollo 10, where we did a circumlunar and we went around, but did not land. We couldn't land, which is what we did on 11, without successfully finishing LM-2. So yes it was a direct constraint on Apollo 11.

ROSS-NAZZAL: And did I see correctly from your notes that you watched the Apollo 11 launch? Is that correct?

WREN: Yes.

ROSS-NAZZAL: Do you want to take a break for a second?

WREN: That's all right. I just needed to wet my whistle with a good coffee. Everything's helter-skelter 24/7 round the clock going crazy, got to beat those Russians. Finished LM-2. I don't remember what we were doing just prior to July 20th, but I know that we were working on -- you had to do the test report and a lot of paperwork after the test, report it, get it down quickly and all that while everybody's remembering, and wrap it up if you like. We were probably doing that. And it came time for the Apollo. Of course you had Apollo 10. Then it came time for the Apollo 11 launch and we said, "Hey, we need to go see that." So we couldn't get any commercial flights. Oh my gosh, how are we going to get down to the Cape?

So several of us rented a Cessna Skywagon and took off out of [William P.] Hobby [Airport]. That time I guess it was still just the airport, Houston Airport. We were going to fly down there. We had a mechanical [problem] as soon as we took off. We went back and had to change out a component and wait while the techs [technicians] at the airport changed the component. Finally got that fixed, took off. Running late, we got to get down to see the launch. We had to go around the thunderstorm. That took up more time. And oh God, we got to hurry. Finally we got down somewhere. I don't know whether it was Tallahassee [Florida] or Jacksonville [Florida]. Before we got there we lost all power. Electrical power. Magneto or something went out. So we're flying along with a flashlight on the controls and on the dials. [Laughs] We pass by the tower with this darkened bird a couple of times trying to wake them up. Finally got their attention and they realized, ooh, those folks have got a problem.

So we landed, because we couldn't talk to them, we had no coms [communications], so we couldn't even get clearance. So we just finally landed. And of course that [led to a] mandatory investigation later by the FAA [Federal Aviation Administration] on all that. But meantime we designated one person to stay with the aircraft. We went and rented a car real quick, van or something, and we piled in that thing and drove like crazy the rest of the way across Florida to get down to the Cape to see the launch of Apollo 11. That was the first full Saturn V launch that I had ever seen. And oh my goodness, we barely got there in time. We saw the launch and it was something to behold.

Shuttle launches are great, but that Saturn V, my goodness. Like I said the other day, the frequency, the rumble and roar that comes from it, is just amazing because of the size of the engine bells. It just would shake your whole cavity, chest cavity. Even though we were miles away from it. The other thing is that it seemed like it was in slow motion. It took forever and a

day for the Saturn V to lift off the pad, where the Shuttle goes a lot faster. And of course unmanned ones, they go zip. But that Saturn V, it just lumbered up, you think, oh my God is it ever going to clear the tower. Week later maybe it clears the tower. But oh what a sight, what a sight, to see a 36-story building in effect lifting off the pad, just amazing, just amazing. Never forget it, never forget it.

ROSS-NAZZAL: Did you feel a sense of pride that day knowing that you had participated in this event?

WREN: Absolutely, absolutely, absolutely. And it was wonderful. We made our way back of course so we could see the landing on the lunar surface, but oh yes, this really felt like all the hard work and the effort and all the round the clock sort of thing was well worth it.

ROSS-NAZZAL: And where were you when they finally did land on the Moon?

WREN: I was at home in the middle of the night watching it on TV. I wasn't even in the control center, no. Black-and-white TV. Yes that's where I was.

ROSS-NAZZAL: Had you seen other Saturn launches? You mentioned that that was the first --

WREN: No, I don't believe I had. I had seen a lot of Titan launches and Atlas launches and Delta launches and so forth on different occasions. But no, that was the first Saturn launch. I didn't see an earlier Saturn with the S-I, II, whatever it was. No. But I saw the big one. Saturn V.

ROSS-NAZZAL: That's pretty impressive. What a great story to have taken all your friends.

WREN: Right. And by the way we went back -- and later on the guy that we left there to talk to the FAA and get the plane fixed and fly it back, why, he finally got back, we managed to grab commercials and get back in time to see the landing. Of course in those days, we [were] a lot younger and we had a lot of vim and vigor and vitality. So, moved pretty quick.

ROSS-NAZZAL: What are your recollections of Apollo 13?

WREN: By that time I was not on Apollo anymore. I was off on Space Station, Space Base studies. So I was not directly involved. But it was a harrowing experience, but I was not directly involved. So I was more on the periphery.

ROSS-NAZZAL: Well let's talk about your Space Station, Space Base studies that you were working on. How did you get involved in those studies initially?

WREN: Can I mention a few things about some of the LM-2 people? Or is this appropriate?

ROSS-NAZZAL: Absolutely yes.

WREN: Some of the folks where I forgot them before.

ROSS-NAZZAL: Absolutely please do so.

WREN: I wanted to be sure that I mentioned Moe Roth. And I may have mentioned him the other day. Was from Grumman. He brought down a whole team of technicians and engineers. I can't remember all the folks' names and I apologize for that. There was a structural dynamicist in particular. I talked to Owen the other day. Owen Morris. He can't remember his name. We both envision him. I can't recall the name and I apologize. But he was so sharp. Then in my little group, my little office, Lillian [M.] Hudson was my secretary. I had Tom [Thomas L.] Moser who later went on up in the management ranks. Tom was a great guy. I had done a lot of structural work with Tom and knew his wife real well, Nelwin. Ken [Kenneth L.] Suit, Bill [William T.] Mulcahey. We had a small little group. Then of course we were supported again by all the subsystem managers. About the same as what I mentioned the other day I guess.

One little funny thing is that Tom and them came up with a wooden plaque that they gave to me. I still have it somewhere in a box. On the plaque it says he hung in there. It was a safety pin kind of a drawing thing on this wooden plaque. He hung in there. With a safety pin. Anyway that was cool. I guess that's probably about it. I mentioned Don Teegarden was the spacecraft manager on 2TV-1.

I want to be sure to mention the spacecraft manager on LM-2 was John, John [G.] Presnell. And he worked and was in Carl [B.] Peterson's office. All of those folks were in Owen Morris's shop. Owen Morris was like Rolf Lanzkron, he was in ASPO and he was the manager for the Lunar Module at the time, Lunar Module manager in ASPO. Again on the LM-2 again Milt Silveira, Dick Colonna, Dan Newbrough, Tom Modlin, Ben Holder and so forth. And then this dynamicist and his team that I can't remember the name from Grumman. So I just wanted to

be sure that I mentioned the names. That's all. [Also, from Grumman, Jack Buxton and Jim Reinhartsen.]

ROSS-NAZZAL: Yes, that's a nice touch because you did work with a large team.

WREN: Oh yes, they're all fine folks. Really proud to have been able to work with all those fine folks. Anyway so then LM-2 was over and now we're getting excited too because hey remember we came, a lot of us, for the Mars mission. So what do we follow the Apollo with? Of course we still had a lot of Apollo flights to go, and some Apollo Applications and AEXs and so forth, and later on the ASTP [Apollo-Soyuz Test Project]. But what are we going to do beyond Apollo? Okay, well, we got to go to Mars.

So what's the first steps? The first step is the Space Station in Earth orbit. Then something bigger in Earth orbit like a Space Base. Then we'll probably need to go establish a Lunar Base and then a Mars mission. So that was the thinking. So Rene [A.] Berglund headed up a study office in the Program Office for Space Station, Space Base studies. And the way it was generated, or created, was that MSC -- I don't remember, we might have been JSC by then, I don't remember when the name changed. Would head one study. Marshall up at Huntsville would head the other study. They'd be parallel studies with parallel support contractors.

In the case of the one at MSC it was North American. I don't recall when the name changed to North American Rockwell and all that or North American Aviation. Later on it just became Rockwell. I think I mentioned the other day too that when I talked about STL [Space Technology Laboratories], and I did all that studying back at the bomber plant, that's part of

Thompson Ramo Woolridge, which is TRW. That's what Space Technology Laboratories. Anyway so we had North American. And up at Huntsville they had McDonnell.

We did these parallel studies and what was it we were supposed to do? We were supposed to proceed with definition studies. When you do that sort of thing you put it into a phase nomenclature. So A, B, C, D. Phase A is requirements definition. Phase B would be preliminary design. Phase C would be final detailed design and manufacture. Well, D would be manufacturing and operation and so forth. So what we set out to do was to do Phase A and B studies on the Station and Base and so forth.

So what we ended up doing is we did a Phase A and B on a 12-man Space Station, Saturn-lifted, with Saturn rocket technology. We also then did a Phase A on a 200-man Space Base, Saturn-lifted. All these are Saturn-lifted. We did a Phase A on a lunar base and a Phase A on a Mars mission. These were like as I recall the studies lasted about a year or two. Then later on when it was all over with we had a comparability assessment between the two studies, Marshall and JSC did. When we got all through -- and I can go back and talk about some things, but we got all through, then we put it on the shelf. They asked us to go back now because I guess it was becoming apparent that we were not going to be able to continue to fly the Saturn Vs. And we had Shuttle development starting. So said okay ,what would it take to do the same thing, put up a Station, but do it modular in little chunks using a Shuttle. So we went back and did a complete Phase A and B study on a Shuttle-lifted modular Space Station so we did that. Now back up and say, okay what did we do.

Well, on the Space Station, like I said, you create the requirements definition, what is it you're trying to do and how would you go about it and so forth. I don't remember all the details now. I remember that on the Space Base we used a Tinkertoy or stair-step approach where we

took some of the Station developed modules. For Skylab we used the upper stage in effect as the vehicle, on orbit vehicle, and we may have done the same thing on the Station. We had a 12-man station. We came to the Base, then we took several of those and put them together [for a 180 to 200-man Space Base]. We had several questions that we kept asking the medics to provide answers for that would become design drivers for the vehicles. We were having trouble getting answers. What were the questions?

Well, some of the questions were can the crew survive extended zero G or not. We didn't know at the time. Can the crew survive radiation from solar radiation or maybe cosmic radiation? So nobody really knew. There's a lot of work on the part of the life science folks to try to find answers to that, but we didn't really know. So we said well okay in the meantime then we'll design the preliminary design, the vehicles, like we need all that stuff. We need the protection.

So on the Space Base where you're going to be up there for extended period of time -- and the same thing for a Mars mission for say a two-year mission -- we'll create for example artificial gravity. So in the case of a Space Base as well as Mars train, we came up with -- of course you come up with a lot of different ideas. Most of them are no good and you throw them out. Some of them maybe they survive. But one of them was a spoke. We had a rotating spoke thing. And so it had a rotating hub and then it came out with arms and these spokes. Then we put the living and working modules and so forth at the end of the spokes. So then when you rotated this you ended up with artificial G out at the end. The further out you were the higher G. And rig it where you had 1.0 G out at the very end, see, and then lesser as you came in. So we got artificial G. The medics came back and said, well that's okay, except that now when you're rotating you get something called a Coriolis effect and that could make the crew dizzy. Said well

okay, but maybe it's more important to have some G and get over the dizziness. They agreed with that. So that's some of the things we did.

We came up with different ways of power on the Space Base. I think on the Station we just used solar arrays as I recall. But on the Space Base we did some investigation into -- I think we had three different power arrangements, potential arrangements. One was a solar array. One was radioisotope thermal generators, RTGs. The other one was a regular nuclear reactor sort of thing. So we had two based upon nuclear approaches, different approaches, Rankin cycle and the Brayton cycle. Then we had the solar arrays. We never got to the point of choosing one over the other because we just did Phase A on the base and Mars train. But that's the sort of thing we did.

What did we do for protection from the radiation? What we tried to do was keep the crew when there was a solar flare alert or something or somehow they would know there's cosmic radiation coming more than normal, we'd put the crew in the center so that there'd be equipment around the periphery and the equipment racks and so forth would serve as protection against the radiation. My pet idea, especially here later, and somebody asked me for new activities that we're doing these days to go back to the Moon and perhaps finally go to Mars -- because I've asked them again, I says, “Hey did you guys ever really solve those two problems?”

“Well, we think zero G is OK now. We've demonstrated that long-term up to a year and probably more. But we still don't know about the radiation.”

I said, “Well look we generate all kinds of water up there with our fuel cells and so forth. And we got the consumables to put together to make power and the byproduct's water. So hey why don't we put water tanks all around the outside?” Because the smart people use water as a radiation barrier for a nuclear power plant on the ground. So why can't we use water up there

and surround the crew with water? I hope that they're going to take advantage of that and do it. Later on we came up with inflatable structures. That's another whole story but it would be easy to come up with water containment capabilities, but anyway. So but at the time back in those studies, why, we just got them inside a lot of equipment for protection. That's what we did in those studies.

ROSS-NAZZAL: When you were working those Phase A type studies are you working within the constraints of a budget or are you just simply coming up with ideas to present to the folks at [NASA] Headquarters [Washington, DC]?

WREN: No. You have constraints of cost as well as the schedules and of course obviously capability, performance, and crew considerations as always. So no you have cost considerations too. Although in Apollo I had mentioned that we didn't have any funding problems, that's not to say there wasn't funding problems. We didn't see them in the trenches where we were working. Now Webb, Jim [James E.] Webb, and [Robert C.] Seamans [Jr.] and the top management practically lived in Congress working the budgets and so forth. Jim Webb, he was a perfect I think NASA Administrator, especially at the time, because he knew how to work with Congress. And so we were sheltered from those kind of funding problems. He worked all the budgets, those fellows at the top. But we didn't see the funding. In classical project management, the cost is part of it as well as schedule and performance yes.

ROSS-NAZZAL: Do you recall what the costs were at that point for the Space Station?

WREN: No. No. No. I just flat do not remember the dollar figures. If I happened to say something it would be wrong, and I wouldn't want to do that, no, I can't -- don't know.

ROSS-NAZZAL: What impact do you think that these studies had on the follow-on program to Apollo? The Skylab Project.

WREN: The Skylab as I recall, it was a combination of what do we do with Apollo hardware -- we had some hardware. Remember, I talked about the Command/Service Module Block I and Block II. Well the Block I was meant to operate in Earth orbit and Block II to work with the Lunar Module and go to the Moon. So for example the Block II, while it had in addition to side hatch, it had a hatch up the top so you could go into the Lunar Module, Block I did not have that. But it was easy to add that. Block I vehicle. And then be able to dock with something like a Skylab.

We used the fourth stage, S-IVB, as I recall, for the Skylab. But the Skylab did a whole lot of good things. It made use of some existing Apollo hardware, the S-IVB tank and the Command/Service Module. It allowed us to explore the capability of staying on orbit for a period of time in a Station. Or in something like that. So we would be learning a lot in designing the Space Stations and Space Bases and these other studies we were doing. So it helped a lot in that. Plus it put more people on orbit in Skylab. Did that. It also allowed us to explore more some scientific returns.

When we did the Space Station and Space Base studies, we created a whole great big huge book called the blue book of scientific requirements. What would be the science requirements to do those missions? We got all the smart science people, a myriad and numerous

studies and meetings and so on and so forth, to create this big old blue book. What did we do with that? Well we took the blue book then and said, "Okay that's what the science guys want. Now that becomes a forcing function on the design of our hardware. And so we'll design our Station and our Base and Lunar Base and Mars train and all that to satisfy and accommodate the scientific requirements, in addition to just exploration and crew requirements and operability and mission ops and so forth." So we used that as a forcing function for design.

A lot of the experiments then that we demonstrated and tried out on Skylab were along the same vein. What is it that the scientists, smart people, would like to see us do? Quite a bit of it was life sciences. How does a crew function for extended periods of time in zero G? The mobility considerations. All kinds of things, life support. Even to food and so forth.

Now we didn't get to do a whole lot of science things on Apollo. On 11 for example it almost was like that the science requirements, they were asked, the smart scientist community was asked, but then it became so apparent that we were having trouble even getting the confounded hardware to work and accomplish the mission and land before the end of the decade and before the Russians, that the scientist people almost got in the way. "Hey, sorry guys, yes we thought we could accommodate you but we're having trouble even flying this thing and getting the crew there and back," so the scientist community was put on the back burner.

Now we flew some science experiments on the first one. We had a skinnied down list of things that were very important. The most important things, scientist guys, pick out your top ones of all the things you want to do, say what's your four, five, six most important. Those were developed but off line if you like so it wouldn't conflict with Apollo hardware development. I don't remember the names of all those things. But they were like the ALSEP [Apollo Lunar Surface Experiments] Package and so on and so forth. We managed to find places to carry them,

the weight, and where do you put them. We left them on the Moon. And I think there was a reflector we left up there for the laser to measure the distance between the Moon and the Earth and that sort of thing and seismometers and so on and so forth. But it's very minimal.

Now later on as Apollo went along, why, we managed to get more and more science things. And of course on the very final mission, Apollo 17, why, we actually got a scientist person as a crew. Harrison [H.] Schmitt was a geologist and actually flew, and he could go out and poke around on the rocks and so forth and actually do his geological work. But my point is even though [science] progressed in Apollo, it still was minimal. So we wanted that to not happen when we did Station and Base Studies. That's why we created this big blue book so that we could be sure that the science requirements were right there and visible and in the front. They became design drivers on all the hardware. Of course we wouldn't be able to accommodate all, but at least you had a sizable shopping list and you could end up with a sizable list of things that you really could fly that the scientist people wanted to fly. Everything from materials experimentation in zero G and new processes and so forth to life science kind of things. As well as some astronomy things and ground observations and so on and so forth. So that was a driver on the Station and Base Studies big time.

ROSS-NAZZAL: Who was working with you on the Space Station, Space Base studies?

WREN: Let me be sure I don't leave out some names that I remember. Sorry about this, but, of course it was Rene [A.] Berglund's office in the Program Office. Leonard [S.] Nicholson worked with him. I believe he was a technical assistant. Sam [Samuel H.] Nassiff was there in that office, interfaced with him. In the Engineering Directorate, why, I worked with Don [Donald C.]

Wade. By this time I guess I was back from SESL and from VATF now and I was back in the Structures Division and I was working with Don Wade, who was the deputy SMD [Structures and Mechanics Division] manager. Don started out -- because I wasn't there, they started this two, three months before I got back, as the manager for Space Station for the Structures and Mechanics Division. I became his assistant. Then later on I took over and Don vacated that position and I just did it. I worked directly with Don and then later I guess I was put into what we had called a little project office in the division that worked all kinds of projects, various projects. Bill [William G.] McMullen, [P. Paul] Don [Donald] Smith, [W.R. Downs], Les St. Leger, oh and Andy Meyer, who came over, joined us from Gemini Program. I think he had come from Langley originally, Space Task Group. I don't recall all the names of the folks at Rockwell and so forth. I don't remember.

I think I put in the notes, and I probably don't need to reiterate them here, but when you're doing those kinds of studies now you really have to know your systems engineering, and all the different systems have to play together. In addition to those for which the Structures and Mechanics Division was responsible, all the disciplines of structures and materials and thermal and so on and so forth, mechanical systems, you had to be conversant with all the other systems, because they interplayed with one another, all the avionics systems, guidance and nav [navigation] and communication and so on and so forth. So you had to know enough about that to be sure everything hummed and worked together and nothing would interfere with one another, or at least minimize that effect.

Oh Tony [E.] Redding. I can't remember all the names,[*] I name one and forget [one], but I remember Tony Redding was a power expert and a lot of fun to work with. Another guy that worked with out of the guys out of the engineering directorate at the time was John [B.] Lee, which I still see John all the time. John flew P-51s in World War II and he was with the old Space Task Group. Another was Jack [C.] Heberlig. I think he went back to Virginia. I haven't seen him in a long time. And Jack Eggleston was Max's technical assistant. These are all fine people. And so that's the people I remember and unfortunately like I said a lot of them I don't remember.

ROSS-NAZZAL: What was the reaction at JSC when folks found out that well we can only do the Space Shuttle, we can't do the Space Station, we're going to scrap the Mars Program, all these ideas that you'd been working on? What was your reaction and the team that you were working with?

WREN: Well we were crestfallen, because it was exciting to get the accomplishment of landing on the Moon in a decade and beat the Russians. That was great. But remember, we wanted to go to Mars. So when Apollo was cut short, and we had extra flights that we could have flown and we didn't -- of course they ended up as good exhibits, but we couldn't fly them. Golly, we've got

[*] Others: Thomas L. "Tom" Davies, Shelby L. Owens, Roly Rice, Howard Wagner, Joseph G. "Guy" Thibodaux, Chester "Chet" Vaughan, Norman H. Chaffee, Henry O. Pohl, Ralph J. Taeuber, Richard B. "Dick" Ferguson, Witalij "Walt" Karakulko, John W. Kiker, James K. "Kirby" Hinson, William C. "Bill" Schneider, Arthur R. "Art" Amuedo, Caldwell C. Johnson, Allen J. "Al" Louviere, Walter W. "Walt" Guy, Harold E. Benson, Robert B. "Bob" West, Owen E. Maynard, Robert D. "Bob" Langley, Bob White, Clarke Covington, Lyle M. Jenkins, Hubert J. "Hugh" Brasseaux, Warren L. Brasher, Jerry E. McCullough, Doug Cooke, William E. "Bill" Milligan, J. Thomas "Tom" Milton, Leo G. Monford, Nick Jevas, Bill Heffstetler, and many others.

-- now the scientists, we can even get more science and send some more geologists up there and get some more rewards.

Well, Congress's mood I guess was well you've been there, done that. We've got Vietnam and got other problems in the country, so on and so forth. So we felt like that they said, "Okay, well, the space program's over."

"But hey, we wanted to go to Mars and establish base on the Moon."

"Well, no there's no money for that."

So we took those studies for example and put them up on the shelf and they started gathering dust. Said, well okay, well let's come up with an Earth orbit capability. So we started in the Shuttle where it was an airplane that could fly up and fly back. It was a challenge to fly an airplane up to orbit and back, there's no doubt about it. But it's not the same as exploring the universe. It was just different.

Another beautiful thing about Apollo -- and I think I mentioned it somewhere in the notes -- one of the reasons why we were so successful in Apollo was because we had a singular clear goal, very crisp and clear, very defined. Land men on the Moon before the decade is out, period. So everything truncated into that. Everything we did, if it didn't go to that end result, it didn't get done, it was set aside. Like Apollo Applications. Well yes we thought about that, but do that some other time. Right now we got this singular goal. Okay well, what happened?

Then after Apollo we didn't have a singular goal. We had one to fly this airplane up there and bring it back, but it was Earth orbital. Well, we had accommodations like a truck to take up a bunch of payloads for different things. Maybe there were upper stages that would go on up in the geosynch, or maybe go on some other place, or maybe they'd just stay in low Earth orbit. But it was a truck, and you'd fly up and fly back. And so you think, well okay, if we're not

going to do that, we'll develop the capability again. NASA Space Act of '58. And then why don't we just turn it over to a contractor, commercial outfit, to operate it? Then we'll go on and continue to explore. Well that never happened. It never happened. So in that sense I think there was a little bit of disillusionment. You just kept on solving problems and working technical things.

But it didn't have the same aura and the same excitement. Yes there was some excitement when we did the -- and I'll get into it later perhaps about the first drop test we did of the Orbiter and so forth, and some excitement when we flew the first launches and all that. Still it wasn't the same. Somehow it wasn't the same.

I mentioned like on the Apollo we have splashdown parties. And we'd all gather, and the contractors would have these big humongous parties, and nobody worried about that the contractor was paying for civil service to be there, you know, this conflict of interest. They didn't worry about all that. And they'd have these big ice sculptures there and everybody's having a good time, lots of hors d'oeuvres. It was a happy time. It was a happy time. Everybody was prideful of what had been accomplished. By all the people: civil service, contractors, everybody. And a lot of that excitement has gone away.

To this day we don't have that, I don't think. The folks and all the young people over here working, we got some really sharp folks. Thank goodness, we still have sharp people working. But there's no singular goal. Now maybe this new program will satisfy that, establish a lunar base, and later on a Mars mission. I hope so. Because you need an air of excitement other than just technical challenges. You need to have a purpose. Why are we doing this? I have trouble describing what I mean there. So yes it's like we're doing a good job, but we're just going up to Earth orbit and going around and round and round. There's a lot of little goals, get

this payload or this satellite up and that's fine. But there's no singular goal. And sometimes when you're doing different satellites and different programs, why, they might conflict with one another too, and your manpower and resources.

I guess the Catholic church is unique in the fact that it's like the military, you got one person at the top that is in charge of everything, the Pope. Or the general or somebody. Well that's the way we were in Apollo. We had one goal. A real 91 approach.

ROSS-NAZZAL: I think this might be a good place for us to stop and then pick up with your Space Shuttle work next time.

WREN: Well I hope it's helpful.

ROSS-NAZZAL: It is. It is.

[End of interview]