NASA STS RECORDATION ORAL HISTORY PROJECT
EDITED ORAL HISTORY TRANSCRIPT

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INTERVIEWED BY REBECCA WRIGHT
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WRIGHT: Today is July 20th, 2010, and this interview is being conducted with Jim Odom in Huntsville, Alabama as a part of the NASA STS [Space Transportation System] Recordation Oral History Project. The interviewer is Rebecca Wright.

I know you've been part of aerospace history for 50 years, but we want to concentrate today on the contributions you made to the stack, including the STS design, development and evolution. If you could start today by sharing with us your experiences when you were part of the studies of the differences of the orbiter, the Phase A and the Phase B studies, and then those decisions that were made that produced the results of what we have today.

ODOM: I'll be glad to. I joined the studies toward the end of the Phase A period, and all through the Phase B. Coming out of our original studies was our most desired concept, which was the orbiter with the flyback booster. We liked that one a lot because it was the most economical [to operate]; it didn't throw anything away. It was certainly the most desired by our team. When that went to [NASA] Headquarters [Washington, DC] and then to the [Capitol] Hill, it had a development DDT&E [Design, Development, Test and Evaluation] cost of $10 billion. After the deliberations with the Hill, we were told that we needed to cut that in half to a DDT&E of roughly $5 billion.

From that we set aside the flyback booster and came up with the concept of the tank, the solids and the orbiter. The orbiter didn't change that much. It changed some, but that's when we ended up with the same engines that the orbiter has today, and obviously with the reusable motors and the throwaway tank.

During that period also we were dealing with the cross-range requirement from the Air Force. Not many people realize the impact that the Air Force requirements had on Shuttle. The 1,500-mile cross-range was something that they really wanted for the orbiter coming back in. They also wanted a larger payload bay, and some of the payload requirements were driven by them. I won't say they were the outside of the requirements, but [they were] driven by them. The cross-range had a lot of impact on the configuration of the orbiter. Max [Maxime A.] Faget wanted the fixed wing, and that was looked at a lot, and because of the cross-range it felt like the delta wing—the configuration that's been flying—was better suited for that.

Coming from that, we still wanted to get the per launch cost down. So when we went to the configuration we have today, which is the more expensive, we raised the launch rate up to a very high number. I think we finally ended up at 60 a year, and we had to plan for that. We were very disappointed that we couldn't have the flyback booster because it would have been more economical, we believed, than the configuration we have. But you've got to live with what Congress tells you to live with, so we did.

WRIGHT: You were on the Source Evaluation Board [SEB], and then served as project manager for the external tank. You knew of the constraints or requirements when you developed that production program. Share with us how you were able to determine what elements now became priority, how you were able to take such a limited budget—since I know you had mentioned that you didn't want to invest into high risk technology with that tank because it was expendable.

ODOM: While I may sound critical of the results of the configuration that we ended up with, [I am not]. There were a lot of things done in the program from a management standpoint, [and] a technical standpoint, that in my judgment was outstanding. One, that you just alluded to, is coming out of the Phase B studies a lot of us that were doing those studies were the ones that ended up managing the elements of the program once it was implemented. My boss was Bob [Robert E.] Lindstrom. Bob headed up the Shuttle Office at Marshall [Space Flight Center, Huntsville], J. R. [James R.] Thompson was the project manager for the engine, George [B.] Hardy was the project manager for the solids, and I was given the project manager position for the external tank.

One of the things that Bob Lindstrom did which I think was absolutely very smart is when we went out with the RFP, request for proposal, for the tank [he] had already picked me to be the project manager. When we staffed the Source Selection Board [Source Evaluation Board] for the external tank, he and I cochaired the Source Selection Board, which to me was [very] smart, because it gave me the insight from the [beginning] of the RFP [process]. A fellow by the name of Lowell [K.] Zoller was my deputy, and he wrote probably 80 percent of that RFP. He was a great engineer, he was a very good writer. He and I and the people that we had in the project office, having gone through the Phase B, we pretty well knew what the program needed, what the tank needed.

To me, having a project manager on the Source Selection Board, cochairing it, is the right thing to do, is a very smart thing that NASA ought to do in the future. It lets you be a part of seeing all these designs that come in, it makes you a part of the selection—you're not the voting, selecting official and that's good—but you're a part of the process, and once your contractor is on board you're extremely familiar with that contractor, with what it has bid. So it makes starting up a project significantly easier and more productive if the project manager has [gone through] the Source Selection Board [process]. That's one thing that I think was done right.

Also, I served on the Source Selection Board for the orbiter, which also gave me a lot of insight into the orbiter and what it was going to look like because the tank obviously interfaces significantly with the orbiter, putting it mildly. Those were two things that I didn't do myself but management saw the value of it. Afterwards I too saw a lot of value, and I think the agency should really consider doing that more in the future.

WRIGHT: We can talk about your steps in becoming program manager for the tank, and taking your knowledge that you had learned from the SEB into starting to design how to make that a reality.

ODOM: There were a lot of changes. The original tank that we went out and procured was fairly heavy, for the right reasons. One of the things in the design of the tank [is] it's pretty big, and it's got a lot of metal in it, but you want that metal to be very thin. What a lot of people don't realize, a lot of the skin that's on the tank that's been flying now for 30-odd years is like an eighth of an inch thick.

The tank takes a lot of asymmetrical loads, which really affects the structural design and capability of the tank. If you visualize—the tank is stuck between the two solid rocket motors. The thrust from the solid rocket motor is taken out up at the intertank at the front end of the motors. The weight [and thrust] of the orbiter is [carried] at the back end of the tank. So you've got the roughly 250,000-pound orbiter hanging on the back end of the tank when all the

[SRB]thrust after liftoff goes principally in at the front end. The orbiter thrust also goes in at the back end.

It makes the tank a very asymmetrical vehicle. It looks nice and round and smooth but the load paths are very complex, because you've got the heavy weight of the LOX [liquid oxygen tanks] on the front end, you got a long lighter weight hydrogen tank [at the back end], but yet the orbiter thrust goes in at the back end of the hydrogen tank. It makes the load paths very complicated, which makes it structurally a lot more complex than it looks on the surface.

When we went out with the RFP the weight requirements on the tank were a lot more lenient than it came to be later. When we went out with the RFP, we picked Martin Marietta [Corporation] as the prime contractor. They were based in Denver [Colorado]. We moved a number of the people from the Titan [rocket] program, that had grown up designing Titan, to [NASA] Michoud [Assembly Facility] to head up the program.

The Michoud plant that's in New Orleans [Louisiana] had been used for building the first stage of the Saturn IB and the Saturn V [rockets], and it had been virtually shut down after the Apollo program. We had a gap in there from the early '70s until we started building tanks, we literally had to revitalize the plant. The security and the facility contractors had been kept in place so the place was ready to move into, it'd been taken good care of, but we had to then lay it out for the production of the tank.

The plant is basically 42 acres under one roof; it's air conditioned. It was ideal for building a 25-foot diameter tank. We had to build some additional high bays and checkout cells, but the basic factory floor space was already available to us. We had to lay it out initially to build 60 a year. We never really thought we would do that but that was the requirement. To get the per launch cost down you had to get the rate up, which was an interesting maneuver.

We laid out the tooling such that all we'd have to do is add additional tooling. We spread the production out pretty much over the 42 acres, but we started off with initial capability of building up to between 10 and 15 a year. That was the minimum. Our initial investment in the tooling was about $900 million, which made us have to really think hard about the design of the tank because we wanted to build that tooling [only] one time. As the rate went up all we wanted to do was add additional, like tooling. So the buying and the designing of the tooling was extremely crucial to the success of the program.

We wanted to automate the welding process. Welding was the big thing, and we were using state-of-the-art welding then. That's been [upgraded] a couple times in the course of the program. The other thing that we wanted to do, that to me was very critical to the tank, was in the structural test program we wanted to really understand the capability of literally every square foot on the tank. So when we designed our structural qualification program we put extensive strain gauges on each article to make sure that we understood the capability and how the load paths were getting from the solids and the orbiter into the tank and how they would be accommodated.

We did, in my judgment, a very very thorough structural qualification program early on because we knew that the tank that we were flying early on was heavy. We wanted to make sure it was safe, and safe until we had flown it a few times and knew exactly what the loads were, how they were dissipated out into the structure.

We instrumented the early flight tanks. I think it was the first four or six, we put quite a number of strain gauges on the whole vehicle to understand the loads and understand the aerodynamics of the whole vehicle. We took a lot of heat in the project for the cost of the structural test program and the cost of the instrumentation. In my judgment it was probably [some of] the smartest money that we spent.

WRIGHT: How did the results of your tests meet with your analysis and expectation?

ODOM: Beautifully. What it gave us [was] a map of all of the loads, how they got dissipated into the tank. Having known that, then you could look at the capability of the metal. We looked at the qualification program [and how] we loaded the structure. Not only did it verify the design, but it verified how the structure reacted to the loads. With that information it made it possible to go through two lightweight [redesigns]. This was after I left the program. I was in the program from day one and up through the first six launches and then I went on, did something else. But it was to me one of the smartest things we did.

A lot of that I give credit to guys like Larry [Lawrence B.] Mulloy, who was my chief engineer, and a good structures man. The bulk of the complexity of the tank is in the metal and in the thermal protection system. The initial design of the tank, the only requirement for the TPS [thermal protection system] was to maintain the quality of the propellants and to accommodate the aerodynamic heating up on the front end, because the tank is the "[tip] of the spear" for the vehicle, so it gets the highest aerodynamic loading and heating during the atmospheric flight.

Consequently, the LOX tank that's on the front end has to protect against the high heat from the ascent as well as maintain the quality of the propellant. You got to protect the metal and you got to protect the quality of the liquid oxygen. When we talk about TPS, what most people don't realize is you've got a third of an acre of tank that you have to insulate. We had roughly only requirement in the early design was, like I say, just to protect the quality of the propellant, not get too much heat into it to cause it to boil off too fast, and to protect the metal.

After we got into the design for a couple [of] years, the orbiter tile issue came on and we had to start protecting the acreage against ice formation. Not only did you have to protect the metal and the propellants, but then you had to keep that third of an acre above 32 degrees [Fahrenheit] when it's -424 just an inch away. That really added to the complexity of the tank. Then after that we had to go in and put insulation on all of the lines and brackets on the outside of the tank.

That really complicated [the TPS application] because all of that had to be done by hand. We developed the automated spray for the big acreage on the tank, and that was relatively easy to do because [it was automated]. Where it really started causing us a lot of labor was going in and having to hand-insulate all the lines and brackets that's on the outside, to avoid chunks of ice coming off and hitting the orbiter. Of all the changes other than the weight reduction, the changes to the TPS was probably the most difficult and probably cost us the most money.

The other thing that happened during the course of the project was [the fact] it is "bucket chemistry." It's a whole bunch of chemicals you put together and you make a foam. That's an oversimplification but it's true. About the time we started this was when we had the Love Canal problem [Niagra Falls, New York, toxic waste dump]. Then, all of the attention to [chemicals] and waste that go into streams and go into the environment got to be [a major problem]. All of these foams are made up of six to eight major constituents and you mix them in the right proportion and you get foam. A lot of these chemicals were made by small companies, and as the environmental issues came on, it drove a lot of these small companies out of business.

So the last time I heard, we had reconstituted and requalified the foam [about] six times just because of the chemicals that they're made of and the companies going out of business, and every time you change a component in a foam like that you have to requalify. We spent a lot of time and effort over the last 30 years requalifying that foam, because not only did it have to accommodate the aerodynamic abrasions, it had to accommodate the thermal, and it had to structurally stay on and yet be sprayable. So the TPS is a lot more complicated than on the surface that it looks like.

WRIGHT: During the time that you were trying to determine what you were doing, were there other products or were there other vendors trying to come to you and say, "Use our TPS system?"

ODOM: No, it was fairly narrow. There were a few that would come, but this was a new industry at this point. There were a lot of foams on the market that were built for just Earth use, and those didn't require the structural capability to withstand the high temperature and the aerodynamics of flight. Those were the things that really drove the foam, and we were the only users for that so there weren't a lot of people standing in line wanting to sell to us.

WRIGHT: Did you have highly specialized technicians that had to hand-paint or hand-apply those?

ODOM: [Yes and that was] very critical. One of the things I really give Martin credit for is they put in place good training programs for their people. There was another thing that Martin did and they did this with my [support and] encouragement, it wasn't my idea—I wish it had been. We picked about 35 of our most crucial vendors. Most of our vendors were small businesses. We had Reynolds [Metals Company] and these kinds of companies that were supplying the aluminum to us, but a lot of our fabricators and our part vendors were really small vendors.

They set up a program that before they signed a contract with a subcontractor—and we picked 35 of the top most crucial—the Martin manager, myself, and the head of Martin's procurement would go sit down with the owner of that company and understand why they wanted the business, understand why they thought they could do it. And we would get comfortable with them almost on a first name basis before we signed a contract. What's interesting is a number of those people have been there for 30 years along with Martin. The contract was never recompeted. They were a good company.

There was one thing that you might find interesting we did. A number of us on the project had come through the Apollo program. A number of us had worked on the Saturn V vehicle. I had spent a number of years working on the second stage, which was 33 feet in diameter, and not quite as long but almost as big, as the tank. So we had a pretty good feel for large structures and building them. When we picked Martin, the biggest thing they had built was the Titan [rocket], which was 10 to 12 feet in diameter. As we started into the design, as we started laying out the plant [and] designing the tooling, I sensed that a number of the people didn't really have a good feel for how big this thing really was.

So one of the smartest things that I think we did, and I highly recommend it for a new contractor, is we went to the local artists' guild in New Orleans and we got this guy that had been building the props for Mardi Gras parties, and [we] had him paint on canvas a full-scale tank. It was really interesting, I watched him some. He would get up on a ladder and his paintbrush would be on a long handle, and he would paint this thing in one dimension to look like it's three-dimensional, to where you could not only visualize the size, you could visualize the curvature of it.

We built this thing, and we didn't tell the workforce that we were doing it. Martin management was in it with me. He painted this canvas, put it all together, and over one weekend we hung it up on one of the walls in the plant. On Monday morning I deliberately picked some of the structural designers that I had [observed]—they were good but they just hadn't done anything this large. I walked out there with them to look at that for the first time. They would look at it and say, "Oh my goodness, I didn't know it was that big."

The thing is I think we paid $7,000 for that. I took a lot of heat for having spent that, but to me it was probably one of the best investments [we made] because the people not only designing the tank, but the people designing the tools and laying out the plant, it just made [the size] become real for them. I didn't have any problem with them picking up the concept and accommodating the size of it in the future.

That thing stayed on the wall until just a couple years ago, I think they had to do some modifications to the wall and [had to take] it down. But there were a lot of things like that that we did across the program. There were a lot of things that were done to help people understand the complexity of [the Shuttle] vehicle. It's a very complex vehicle. It looks so simple when it lifts off, but it's really not.

WRIGHT: You already mentioned that people think the tank is the most simple, but it's very complex on its own. When you set up the facility, from what I understand the tooling and the processes that were put in place pretty much have stayed in place all of the years.

ODOM: The [basic] layout didn't change. They have upgraded some of the tools or upgraded some of the [tools and] processes, but the basic tooling is what we put in there at day one.

WRIGHT: That is an amazing achievement itself. Also the years of ensuring that every tank was the same as the tank that came before.

ODOM: Very critical. A lot of effort went into that, and a lot of effort went into the non-destructive testing of each tank. In other words we do everything you can do to one and not destroy it, but still have it qualified to fly, to give you assurance that the structure is good, and it's proved to be good.

WRIGHT: Can you share that whole process of moving it from one set of series of tests to the other set? Also, if you don't mind, including the help of your own knowledge because you worked on the orbiter SEB, you understood how the orbiter was going to work and how that helped you understand the tank.

ODOM: You just made a good point. There are a lot of things that were done right in this program. One of them was each of us helping each other on SEBs and these kinds of things, which was very good. Also I credit Bob Thompson. There was a lot of angst in the system relative to Lead Center. This was one of the first real major tests of a program not managed out of Headquarters but managed out of a Center. A lot of people were worried about it.

Those of us in the program really didn't worry about it that much, the reason being [men] like Bob Thompson who was the program manager and Owen [G.] Morris who was the systems engineering lead—those two people and those two organizations [deserve the credit for the success]. The three of us that had the projects here, and our boss Bob Lindstrom—were a very cohesive team. Had that not been the case, life would have been miserable for all of us. But it wasn't. The fact that Bob Thompson was located at [NASA] Johnson [Space Center, Houston, Texas] and part of the Johnson Center in my judgment was not an issue, but because of his characteristics.

He was very fair. He was a good manager, and the same with Owen Morris. A lot of us interfaced with Owen in the systems engineering. What that helped us do at the project level was understand [the other projects]. In the case of the tank where we're in the middle of everybody, being involved with the systems engineering—which was basically the overall vehicle engineering—and the working groups helped us understand our element and how it interfaced with all the others.

The way that management structure was set up with the working groups and the program manager Bob—he treated all the projects very fairly. That was what everybody worried about, was that Aaron [Cohen] and the orbiter would get all of the attention and we wouldn't. That was not the case.

To me, that's up to an individual, and I give Bob Thompson credit for doing that extremely well. The same way with Owen, who basically led the systems engineering, which was so critical for this vehicle. As complex as it is, if you don't do the systems engineering right then you can have a lot of trouble.

WRIGHT: You did this during a time when we didn't have Internet service and video camera access. You really had to find good ways to communicate.

ODOM: We had an airplane that went back and forth to Houston almost every day. We didn't have video conferencing then, but we traveled a lot back and forth to Houston, we traveled to our vendors, and we traveled to, of course, our primes [prime contractors]. In my case my prime was at New Orleans. I had the tank from the beginning through the sixth launch, which was 11 years, and I went to visit my plant almost every week. Back then we had our own NASA aircraft here at the Center. Occasionally we'd have to go commercial but most of the time we had a little King Air or Queen Air that we could run down to New Orleans and it was about an hour and a half flight, you could get a full day in very easy. I went down there almost every week for the 11 years. I got to know New Orleans real well.

WRIGHT: Tell me about the first time you saw that first tank come off your process. All of your work had come together, your assembly building, your people were in place. Now you had one. Tell me what that must have felt like.

ODOM: It was a big day. We had spent a lot of time rebuilding a good relationship between NASA, the Michoud facility, the local government, the state government, as well as their congressional delegates. Every time we'd have a major event we would invite them to come in. They responded very nicely. When we had the rollout the week before last of the last tank, I was reflecting back on the first tank. We had a big event. We had a lot of dignitaries there. They had just elected a new mayor, and he came out. It was quite rewarding to see that thing ready to go. We had already built some test articles ahead of that, but to have the first one going to the Cape [Canaveral, Florida was a major event].

Just shipping the tank and moving it on the ground [required] very special transporters. We modified some of the existing barges that NASA had moved the Saturn stages on [and] we had to redo the dock facility, reset up all the logistics for the tugs and the barge traffic to the Cape. We spent a lot of time working with the Cape on how to process the tank. The early tanks we shipped with a lot of open work, which [we did] not like, but to meet the schedule. [It was necessary.]

Early on we moved a good bit of work to the Cape, which was true for all the elements. I had worked with the Cape people since the late ’50s. I had worked with them down there through Redstone launches and Jupiter launches before we even became NASA. So the launch activity was understood. Of course we had already gone all the way through the Apollo, so we understood launching big stuff, which was of real benefit for us.

WRIGHT: You mentioned about testing, once the tank was ready to be integrated. Can you give us the evolution of how those tests progressed?

ODOM: This was something that I think current programs and new programs need to go to school on. We did a very thorough structural qualification test program. We would test the liquid oxygen tank, we would test the liquid hydrogen tank. Many of them we would take to destruction deliberately, some of them would go to destruction when we didn’t intend for them to, but we understood the structural capability of the tank extremely well. That’s just from a structural standpoint.

The other function of the tank besides being the backbone, is it's the big propellant tank for the orbiter engines. So one of the major test programs was taking a tank over to [NASA] Stennis [Space Center, Mississippi] and testing it with the engines. There's where we really learned the performance of the tank from a propulsion standpoint. So far as loading the tank, so far as protecting the quality of the propellants, delivering the propellants, verifying the pressurization system—which was really an orbiter system and an engine-supplied system—but the tank was the user of the pressurants. As you ascend and as you deplete the propellants, you have to keep the tank pressurized. It's a very integral part to the whole propulsion system. That we verified very thoroughly in the testing at Stennis. To me, that was probably one of the most critical of the large system tests that we did.

The second, next most critical, was the ground vibration test. That's where we put the tank in the vibration test tower out here at Marshall, and we put it in concert with a dummy orbiter and dummy motors and shake it to [simulate] the in-flight frequencies to make sure we understand the frequency and the mode shapes of the frequencies extremely well.

We had one surprise. When we put the tank in the tower, we were loading it with water to simulate the liquid oxygen up in the liquid oxygen tank. I had been in and out each day as we assembled the vehicle, but over the weekend we were putting the water in the tank, getting it ready for the dynamic testing. What we didn't realize was that as you load the water in and you get the bulkhead at the bottom end of the LOX [liquid oxygen] tank full of water, there was no pressurization system and it wasn't cold. What it did, it just collapsed the big ogive panels on the front end of the LOX tank.

Dr. [William R.] Lucas was the Center Director, and he was out here that weekend when they were loading the tank and I was at home. Of course I didn't think anything about it because it's a lot more complicated to put LOX in it than water I thought. It turned out that the tank started just collapsing on itself, and Dr. Lucas called me and he said, "Jim, your tank just caved in." I decided I needed to come out pretty quickly. But we learned from that and [how to] solve the problem. What we did was [keep] pressure on the tank when we load oxygen at the Cape. We could have gone in and put additional metal, but that would have just detracted from the payload. It was a loading condition that we just missed when we did the structural analysis.

WRIGHT: I guess it proved that testing [was important and required].

ODOM: It's one of those things—it's the serendipitous, or the things that you don't [expect], that quite often are the [most significant] things that come out of a test program.

WRIGHT: Were there changes in the requirement while the other components were being made that impacted the tank?

ODOM: Not so much. The load profile, the aerodynamic size, the aerodynamic loads—those were things that matured that had some impact, but not much. We did enough Phase B to really pretty well understand the vehicle. It was more the subtle things like the additional requirements for the ice protection. There were a few things in the pressurization systems and depleting the fuel out of the bottom of the tank that we learned as we went along, but they were pretty easy things to fix or to accommodate.

There weren't any major things that we had to do to change the shape of it or to change the size, because it was pretty well fixed when we started. It was the attention to detail in the manufacturing, automating the welding, [and] automating the TPS application. Those were things that were normal business, but they were significant because they affected the quality of the tank as well as the productivity of the tank.

WRIGHT: You mentioned some about the TPS but we haven't talked too much about the welding.

ODOM: The welding was something that we worried a lot about. Michoud had built the S-IC, the first stage of the Saturn V vehicle, so there were some people in the area—not many—that had welding experience. We learned a lot about welding aluminum on Redstones and Jupiters and the Saturn series, as well as the Saturn V. To me one of the most significant organizations that helped with this [was] our Materials Lab here at the Center, as well as our Structures and Propulsion Labs, because those people had grown up—all of us had worked together for many many years, even leading up to this. We had really cut our teeth on welding in the Saturn vehicle stages.

That was something, that the Titan work that Martin had done helped their people understand the sensitivity [also]. A lot of people don't realize that literally every inch of weld, and there are thousands, [must be quality checked before shipping]. Because if you really look, at the end of the day when we started looking at what we were going to need to fly to [International Space] Station, almost half of the [added] capability to orbit came out of the tank. So you can see why it was important.

One of the things from a flight standpoint we had to do [was] a lot of work with [US] State Department as to where we could enter the tank into the ocean. For the various azimuths that you'd launch on or the various inclination orbits, you have to pick where you want the tank to go in. Part of where you pick to put the orbiter in orbit has to be consistent with where you can drop the tank. We wanted to put most of them in the Indian Ocean, because that was the least ocean traffic there.

One of the things that you wanted the tank to do is obviously withstand all the loads and the heat of ascent, but you also wanted it to start breaking up as fast as you could, and break up into as many small pieces as you could. The reentry was extremely crucial to us as to the breakup mechanisms, the dispersion of the parts, and more importantly the size of the parts that actually hit the ocean. Most of the skin burns up, but the heavy structure comes in that's on the back end and up in the intertank area. So just because you got it to orbit, that wasn't the end of our problems.

WRIGHT: Were the studies extensive and did you monitor where the debris comes down the first six flights?

ODOM: Oh, yes. Matter of fact, we had a lot of help from DoD [Department of Defense] in tracking the pieces.

WRIGHT: Did you recover any pieces to study those, or you did it all through analysis?

ODOM: No, all analysis. We did not recover any.

WRIGHT: You were having to have the tank protected from the heat but also ice. Then when the orbiter finalized its decision for the tiles, I think there was some thinking that maybe it was going to be the tank that was going to possibly hold up the first launch. It ended up being those tiles. Were you able to share expertise from your TPS research?

ODOM: Yes. Aaron and I spent a lot of time together. It's too bad that you don't get to interview him. He was a very capable guy. I enjoyed working with him a lot. We spent a lot of time together, and when we would have program reviews we would look at all of the elements together in these reviews. One of the things that we did here at the Center—and this started way back even before Apollo—is we had program reviews with our Center Director, where the project manager would come in and present the project to the Center Director and all of his lab directors as well as the contractor would present. We would do that quarterly. It not only kept management apprised, it kept us on our toes, and it kept an involvement of all of the technical organizations very in real time with the project. I think that was extremely valuable. I saw it all the way through the Apollo program, and we continued it here through the elements at Marshall. I think it's a very good way to keep Center management involved with the project.

WRIGHT: I guess it also gave you a forum of helping to make the decisions on what component was going to be impacted.

ODOM: Yes, absolutely.

WRIGHT: Seemed like any time that you had to save weight the external tank was the first place [you looked].

ODOM: It was the first place because the other propulsion units [did not have] much margin. We deliberately put margin in the tank, because until we flew it a few times you're not really sure exactly what all those loads would be—and the loads are very complex, because it's such an asymmetrical vehicle. It's not like a nice vertical stack like we had on Saturn.

One thing that's unique, and I'm not sure the public ever really understood, was if you visualize the tank sitting on the pad, it's bolted down by the two solid rocket motors. You've got the tank in the middle, then you've got the orbiter hanging off to the side. So here you got 250,000 pounds hanging on the side of this fairly rigid tank and solid [rocket motors]. When you light the orbiter engines first, it actually pushes the tank over, it bends it about three or four feet. The top of the tank actually goes off vertical about three or four feet, then you light the solids. Once they pressurize, it wants to pop it back straight, and you time all of that such that it lifts off when it's [again] vertical. I still [enjoy] just watching, but for the casual observer you would never notice that detail.

WRIGHT: That's very interesting.

ODOM: My point is all of that is systems engineering and integration between engines and tanks and solids and orbiters. All of that has to be orchestrated down to milliseconds of timing relative to launch. But look how many times it's worked.

WRIGHT: Thank goodness. Speaking of which, I know that you were off on other projects when [Space Shuttle] *Challenger* [STS 51-L accident] happened. Were you pulled back in to help with anything?

ODOM: No. And that was deliberate, because I had been a part of the project. When that happened, I was the director of engineering here at the Center. I'd already moved off of hardware management, and they asked me to serve as the head of engineering. I basically took care of the engineering of all the other programs, but I was enjoined from working on the *Challenger* accident, which is right.

WRIGHT: So you got to watch the external tank still do its job.

ODOM: Oh, yes.

WRIGHT: You were also involved in the Hubble [Space Telescope], the program itself and how the Shuttle had to integrate with it as well.

ODOM: Yes, that was a very challenging program that I thoroughly enjoyed. I was the project manager for Hubble for three years, the last three years of the development, right up to the flight. We were going to launch the Shuttle in [August 1985], and then the accident happened in January. We had it all ready, and I'd served my commitment to that so I moved off after the accident. But I thoroughly enjoyed Hubble.

One thing that helped me in managing the Hubble was I knew the Shuttle very well. The Shuttle and the Hubble could not have been integrated better in my judgment. The thing that surprised me the most was how the crews—especially on this last repair—developed the capability to do those repairs. We had designed the Hubble to be repaired, but we didn't design it for them to take 110 #6 screws out. That just still blows my mind how they could do that with all the heavy gloves, but they did. I went to the Shuttle launch, I went to two of the repair launches, and I went to the last one, which I thoroughly enjoyed.

WRIGHT: How is the tank impacted depending on the payloads?

ODOM: Not at all. You build the tank for a payload capability that covers all the eventual things that the orbiter can do. The only real impact was making the tank lighter to make room for more payload. Because the tank virtually goes to orbit, it goes just a few hundred feet per second short of the orbital velocity that the orbiter needs. That says the tank is the one to go after weight, because it's basically pound for pound. You take a pound out of the tank, you get almost a pound of payload.

WRIGHT: When you stopped painting you saved thousands of pounds.

ODOM: Oh, yes. That's an interesting [experience]. We painted the first three tanks because we didn't know how long it was going to be on the pad, and that foam is very susceptible to ultraviolet light so the longer it's on the pad, the foam will start to deteriorate, and little minute surface [particles] will start to shed off. To avoid that, we painted the first [three] white. It was like 1,500 pounds of paint we put on it, basically a flat latex paint. You wouldn't believe the ugly letters I [received] when we took the paint off. "That old ugly colored tank." Most of them were from ladies that just thought it really looked good before.

WRIGHT: Just wasn't pretty anymore.

ODOM: Wasn't pretty anymore. I wouldn't have thought the public would have paid [that] much attention to it.

WRIGHT: Did you do tests for the elements of nature, how long the tank could be exposed on the Cape? Or was that mostly done with analysis?

ODOM: Analysis. We did a tremendous amount of testing of the TPS, and we did a lot of it right out here at the Center. Every time we'd have to change the chemistry of it, we would go all the way back through these tests and expose them to arc jets, we would expose them to structural tests, we would expose them to environmental testing. I'm sure we went through that probably six or eight times in the life of the program. TPS quality and qualification testing was a big component of the program, and it was right up to the end.

WRIGHT: You had a range safety system. How were you involved with that? Tell us about the importance of why, then of course if you were part of that when it stopped.

ODOM: Fortunately we ended up not having to do too much of it, because we had to have a linear shaped charge that you could cut the tank [with]. Basically in our case, if you had to abort a flight, we had a linear shaped charge that would cut a big gash in the LOX tank and a big gash in the hydrogen tank. Once you destroyed the integrity of the pressure vessel then it crumbled very quickly so it wasn't that hard to accommodate. It was a critical system, but it was pretty benign. It just went along for the ride, but it had to work. We knew that from the beginning, so that wasn't anything that surprised us because we'd [worked] that on Apollo.

WRIGHT: Were there discussions about including it, or was it always part of the plan?

ODOM: We'd have liked to not include it, but it really wasn't a choice.

WRIGHT: Were there other safety measures that you had put in with the tank? I know we talked about the debris and making sure it was in the ocean.

ODOM: The most critical to a pressure vessel is the factor of safety. That's how much capability the structure has over and above the maximum anticipated load. We typically liked to have a 1.4 factor of safety for structural components. In the tank because we understood the capability, we understood the loads—it was I think one of the first where we ever took the factor of safety down to one and a quarter. Leaving you only 25 percent margin is getting pretty precise for a vehicle as complex as this. But we did that because we had enough testing to really understand the loads and how they dissipated through the structure.

WRIGHT: It seems like it was a system that one piece impacted the next piece.

ODOM: Oh yes, absolutely.

WRIGHT: Do you believe that the TPS was the most critical system, or is it hard to consider one?

ODOM: It was probably the most demanding because it had so many different requirements on it. It had to adhere to the tank, it had to withstand the cryogenic temperatures at the surface, it had to withstand the [aerodynamic] loads on it, and it had to keep the surface above 32 degrees. That's tough—and it had to be light. So I would say from a complexity of requirements, the TPS is probably the number one from a tank standpoint. And the structures would obviously be second.

WRIGHT: You stated a couple times about working with the vendors and getting to know them so well. This was somewhat of a change from what you had done in Apollo because so much had been done here.

ODOM: The reason being, the tank was the first [real] production program NASA had ever done. We got a lot of special attention with the tank because NASA had [typically] built maybe a dozen articles, like Apollo we did 15, [only required] one or two or three of a kind. NASA really had never done a production program [as large as required by Shuttle], and still hasn't. The tank is still the biggest production program as far as quantity. The solids are obviously close to that. The engines are close to that because we built a lot of engines and we built a lot of motors, but those [were reused]. So far as a throwaway, the tank is the largest production program that the agency has ever done. Consequently, it was unique in that that was not characteristic of NASA programs.

WRIGHT: And the longest running. It's been going on for years till just, as you mentioned, recently the last one. A lot of tanks came out of that facility, haven't they?

ODOM: Sure have, [and it required] a lot of metal.

WRIGHT: How many people did you have working for you when it was at the peak during those first flights?

ODOM: In the project office I had probably 25 or 30 people. I had probably another 200 or 300 here at the Center, not full-time but almost full-time, in all the engineering disciplines. You'd need to get from Martin, how many. We probably had I would guess 1,000, 1,200 people by the time we got into production at Michoud.

WRIGHT: It's easy now to look back on the decision of putting so much money into low development cost compared to operational cost. Can you talk about how much time you did or didn't spend on looking at the overall operational cost compared to trying to move into development at a lower cost?

ODOM: Because the tank was a high production thing, we spent a lot of time—and we should, because like I say, early on we put almost $1 billion just in the tooling. The other key thing that I wanted and the project wanted was to build all of the test articles on exactly the same tooling that we built the flight articles, because [we] wanted to know that I was testing exactly what [we were] flying. That is so critical. If you don't do that, if you don't know what you're testing, then you don't know that your test program is qualifying your flight hardware. That's why we put so much money at the front end of the tooling. DoD would not spend as much money on tooling on the early development articles, and then once they had flown a few, they would go into a production contract.

What we did differently [was starting] our production contract at day one. And that was gutty. That was out of the government's experience. It was another thing that was quite unique for NASA, to basically start a production program at day one. What [we] wanted to do was make sure that we were testing what we were going to fly, and use the same welding techniques, the same TPS, all of that the same that you would have on the first flight.

WRIGHT: You had a pretty daunting 20 a year, 400 in that facility.

ODOM: That was big then.

WRIGHT: It's big now.

ODOM: While it's not germane to the building of the tanks, there was one thing that NASA did that to me was very smart. When we were getting ready for the first tanking test and the first launch, all of the management in the program had to divide up our time and meet with the press at the Cape or wherever they showed up. I don't know whose idea it was, but the agency hired two men that had been writers for [Walter] Cronkite [broadcast journalist], and they'd worked for almost all of the networks writing news stories. They contracted with these two guys to come around to the Centers, and those of us that were selected to have to interface with the press, they would train us how to do that.

When I first heard that I was going to go—I think it was a three-day class—I first thought well gee, I'd worked with the press some but not a lot back in Apollo. The press was different in Shuttle than it was in Apollo. What they taught us is something I still use today. They taught us to take a negative question and give a positive answer to it. That's the most disarming thing you can do to an adversarial press person. To me, it was probably the most valuable training that I've ever had. I wish I knew who to give credit for it. It was sure worthwhile, and it paid off dividends.

When we were doing the first tanking test on the pad a few months before the launch we were all down there, and I had drawn the straw for one particular day—we had to just mill around the press site and be available to answer questions. I saw this one cameraman giving the Cape guys just fits. They had this great big, basically a big revetment where they put all the TV cameras. It was a good shot, but he wanted his around on the other side and they kept explaining to him, "Look, we put this safe place where you can get to it." He wanted to go on the other side. They called me in to help them argue with the guy. We kept asking, "Why do you want to be on the other side?"

He finally said, "I'm not here to film a success, I'm here to film this tank when it blows up. That's all I'm interested in." They didn't prepare me for that. That's the closest I've ever come to hitting a press [person]—I really wanted to but I didn't. My point is another integral part of any manager's role in NASA needs to understand how to deal with the press. That's probably even more critical now than it was then. But it was a very good thing. There are a lot of things that were done right in the Shuttle program that records will probably never hear of.

WRIGHT: Well, I'm glad we've gone over that. Is there some more that you can think of or some other aspects?

ODOM: I think a strong systems engineering and integration organization is an absolute must. A must is involvement of the Centers and their [engineering] laboratory capability. To me that's been one of the strong assets of NASA. We certainly saw a lot of that here at Marshall because that's where [we] grew up. You've got to have the confidence and the trust of management at the Headquarters level, at the program level, and the project and below. Without that, life can be [very difficult].

[End of interview]