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J.R. THOMPSON
INTERVIEWED BY JENNIFER ROSS-NAZZAL
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ROSS-NAZZAL: Today is May 13, 2011. This interview is being conducted with J.R. Thompson in Huntsville, Alabama, as part of the NASA STS Recordation Oral History Project. The interviewer is Jennifer Ross-Nazzal, assisted by Rebecca Wright.

Thanks again for taking time to meet with us today.

THOMPSON: You're welcome.

ROSS-NAZZAL: We know you're certainly busy, and we appreciate you giving some time here in Huntsville. I'd like for you to set the ground for us. When you became manager of the Space Shuttle Main Engine Project in 1974, at what stage was the main engine at that point?

THOMPSON: I believe it was around May of '74 when I came aboard, and the Shuttle engine at that time was about—they were several years into the development, "they" being Rocketdyne. Then, of course, Marshall [Space Flight Center, Huntsville, Alabama] in the laboratories out there were heavily involved as well.

We were on the cusp of starting to embark on the subsystem or component testing, a lot of it planned at Santa Susana in California, right outside of Los Angeles. It started out somewhat slow, primarily because the work was behind schedule on the facilities up at Santa Susana. They were called COCA [test] stands. COCA-1 was combustion devices, and COCA-2 was turbo

machinery. We struggled through the summer and into the fall on trying to get the facility in shape. They were very massive systems, very complicated. They had controls on them to simulate the component being subjected to the requirements of the Shuttle main engine. To make a long story short, it was very unsatisfactory. We probably didn't get more than a couple of dozen tests off. We had several major problems, some fires with the facilities. For example, in the lock system we had some metallic particles or pins that came loose, and of course that created a fire.

This drug out. We were getting further behind schedule, and it was costing a good bit of money so we looked very hard at leapfrogging all of the subsystem tests and going straight to the engine system. We called it the Integrated [Sub]system Test Bed, ISTB. I believe by the spring of the next year we had assembled our first ISTB test and embarked on that at [NASA] Stennis [Space Center, Mississippi]. It turned out to be a very successful undertaking; it allows us to keep going. Any problems we encountered were real problems because they were conducted on the engine itself, and we had to deal with those.

Several of the more significant ones [involved] what was called a whirl in the high-pressure fuel pump. It was a subsynchronistic orbiting of the turbo pump shaft within the bearings, and it was caused by inadequate cooling of the bearings. They became soft and allowed the rotor to orbit subsynchronously within the bearing cage itself. It slowed us down for about nine months, as I recall, didn't allow us to get much beyond a couple of seconds into the engine test. We ended up solving that problem by putting a little paddle—it wasn't any bigger than your thumbnail. A vortex was being created without that paddle where the coolant flow dumped into the bearings, and the introduction of the paddle disrupted the vortex and allowed the cooling to get there.

That solved that problem and from then on the engine problems that we encountered were somewhat typical of the development of a rocket engine. We had some problems with turbine blades, several lines broke. We had some injector elements burn through, and we had problems with those. You sum all these up, and over the next four or so years prior to the first flight we probably lost about 11 engines through explosions, fires, and working through that development.

But the overall approach of abandoning all of the subsystem testing, going directly to the engine, running head-on with the problems that had to be solved—in retrospect I think was very satisfactory. It was very fruitful, productive, and although the program was very expensive and costly, it turned out to be an excellent product. The Space Shuttle main engine has now flown successfully to orbit probably almost 400 times, and I think this upcoming launch [STS-134] will be over 400 times considering you've got three in every Shuttle. It's been very safe; it's very high-performance. Looking back on it, it was a real marvel.

ROSS-NAZZAL: That's a great summary. Would you tell us what the requirements were for the main engines when you became project manager, in terms of performance?

THOMPSON: The performance on specific impulse was about 450 seconds. That really wasn't a problem, and that's about the way it ended up. I think it started out to be reusable on 55 missions and at a certain thrust level of about 470,000 pounds of thrust or thereabouts. We saw that early on we needed a little bit more payload or performance out of the engine, so we backed off some on the number of flights. I think it was 55 missions and 27,000 seconds, and we reduced that to several dozen flights, but we increased the performance to 109 percent of the 470,000 pounds of the rated thrust, and that met the performance requirements of that time on the Shuttle. It

provided the added performance for the shortfall in payload-carrying capability the Orbiter had. It did reduce the number of times the engine could be used, but I think looking back on it, we found that with all the normal inspections and the refurbishment after several flights that the engines were very robust and could be used a number of times.

ROSS-NAZZAL: Would you tell us how you thought about solutions or suggestions for things like cost overruns, problems with the facilities which you pointed out, budget shortfalls—all of the issues that you would have to deal with as a project manager?

THOMPSON: My counterpart at Rocketdyne was a fellow by the name of Dom Sanchini. He was a very good program manager. Both he and I were focused on the technical challenge, the solutions that we had to come up with, and our job was to motivate and stimulate the team, both at Marshall and at Rocketdyne. Cost was a problem, but schedule and having a technically responsive product was higher at that time. There was a huge amount of money being spent on the total program, so if the Shuttle main engine was late, then that complicated everybody's cost overruns. So although the Shuttle main engine clearly overran its cost objectives that were seen at the outfront, the real challenges during the development program leading up to the first flight in April of 1981 was to be able to produce as good a schedule as we could and had a product that really worked. Particularly the latter was a highlight of the program; it worked very well.

ROSS-NAZZAL: Would you tell us how much time you spent out at Santa Susana trying to come up with solutions to the challenges that you were facing out there at that facility?

THOMPSON: I probably spent at least every other week. Sometimes I was gone for several weeks at a time, but I think over half my time was spent out at the Rocketdyne facility—not necessarily at Santa Susana, that was the test area—but in Canoga Park [California] at the Rocketdyne plant, and then a good bit of time at Stennis. I attended a large number of engine-development tests that were conducted down there.

ROSS-NAZZAL: Tell us about the budget issues that you faced as the project manager at this point, because the budget was much more limited than it was for the Apollo Program where you sort of had a blank check. You had a very small amount of money in comparison.

THOMPSON: Yes, the budget was tight, but the sense I got from the leadership in the program—who, by the way, probably the most focused was John [F.] Yardley—I think the signal that he conveyed to myself and to Sanchini was, "If you guys will solve the technical problems and bring us in as close as you can on schedule, I'll take care of the money." I think he probably moved some money around between projects, probably helped the Shuttle main engine and cut some of the external tank and the solid rocket boosters. That was the sense I had at the time. Everybody spent a lot of time trying to forecast funding requirements and the timing of that, but Yardley probably took it on as a job in [NASA] Headquarters [Washington, DC], if Thompson and Sanchini could stay focused on schedule and the technical product.

ROSS-NAZZAL: You've talked a little bit about testing. Would you tell us how you laid out the testing program for the main engines? How did you come to the idea of the ISTB, and how did you lay out the component testing? Can you give us some idea about that?

THOMPSON: I don't really recall exactly who came up with the idea. I think it ended up being an only option that Sanchini and I focused on and discussed quite a bit because of the situation of the test stands and the cost overruns that we were encountering there. It was looking at all the facts and assessing that we were getting further behind if we didn't get going, and the only way to get going was to jump on the testing of the engine at Stennis. The Stennis facilities were ready, the engine components were well along and could be assembled as an engine, although prematurely. But in the end, as I indicated earlier, it seemed to work out very well.

ROSS-NAZZAL: I had read somewhere that there had been a discussion of whether or not to test the engines at Tullahoma [Tennessee] or in Mississippi. Were you involved in those discussions?

THOMPSON: I recall there were some discussions early on because of the altitude-simulation capability at Tullahoma, and we did have one of the test stands at Mississippi configured with an ejector system to simulate altitude, but it wasn't that much of a trade or an option. It was pretty clear the real focus was going to be Mississippi.

ROSS-NAZZAL: Would you tell us about some of the tests that you witnessed out at Mississippi. Any that stand out in particular?

THOMPSON: Well, the ones that stand out were all the ones that failed, because they were most dramatic. As I recall, a major milestone before the first flight was 65,000 seconds, having

accumulated that much development time. I think we finally exceeded that and got up over 100,000 before the first flight, and a number of tests probably of more than several hundred. But again, the ones that really stand out were the failures, the explosions, the turbine blade failures, for example, that would off-center the rotor and the LOX [Liquid Oxygen] pump would rub, and of course you'd catch fire. These were all big deals. Every time we encountered one of these, we were probably between the corrective action on the test stand and then, bigger than that, the corrective action on the engine that led to the failure. You were usually set back one to two months, and so if you have 11 of those, as we had in the program, that's right there a little bit more of a year of just assessing and redesigning and reconfiguring to react to some kind of a problem. We basically, once we got into testing in Mississippi, went around the clock, several shifts a day, including weekends, to try to come as close as we could to the schedule that we finally ended up at.

ROSS-NAZZAL: When there was a failure on the test stand, tell us what happened from there. Did you take the engine back to California? Did you have to do any work to the test stands themselves?

THOMPSON: Typically after a significant failure we'd convene a failure review board that consisted of engineering at Marshall and at Rocketdyne, and that would be chaired by a senior engineer. They would do whatever analysis they needed to do on a test stand, and then at the appropriate time they would convene either at Marshall or at Canoga Park, and then we'd remove the engine from the test stand. Usually it was a 100 percent loss, although in some cases we did salvage some parts. The test stand itself—I think most of the damage, with a few

exceptions, was pretty cosmetic and could be repaired quickly. The program wasn't slowed down awaiting on the facility to be repaired; it was awaiting the redesign of whatever caused the problem.

ROSS-NAZZAL: You've talked about subsynchronous whirl problems with the turbine blades. What do you think was the biggest challenge that you faced, the biggest technical challenge, as you were working on this development and testing of the main engines?

THOMPSON: Probably solving the subsynchronous whirl problem in the fuel pump. We were very surprised by that. It was tough to figure what was really going on. The bearings were quite worn after just a couple of seconds, so it seemed pretty clear that we weren't getting sufficient cooling to the bearings, but encountering this vortex was something that stymied us for quite a while. It was finally solved by one of our senior engineer's cut and try. I don't think at the time we inserted that little paddle did we think it was going to fix anything, but clearly the vortex was there, and it broke up the vortex and allowed us to get the coolant to the bearing.

That was the most interesting problem, interesting because it had a lot of facets to it. It slowed us down probably the longest, about five or six months as I recall. It was the first big problem we encountered and it caused us some early schedule problems. Everybody at that time was very concerned that we couldn't get the engine to run more than just a couple of seconds. This coming on the heels of the decision to go to the ISTB and avoid all the subsystem tests, started to raise some questions about could we really tackle this thing. After we got through that, other problems were similar to other programs, like the J2 and the F1 [engines], the issues with

turbine blades and injectors and that kind of thing. It was that whirl problem that caused us to pause a long time.

ROSS-NAZZAL: What was the media interest like in the Shuttle main engines as you were facing all of these different challenges? Was there a great deal of interest at that point?

THOMPSON: Yes, certainly they were primarily interested every time we had a major failure. "What does this mean to the schedule?" The first Shuttle was launched in '81, I think it was three or four years late. I think the Shuttle probably paced that schedule as well as the Orbiter. Both of them were struggling with some technical issues. All the systems seemed to really mature, coming together so we could seriously look at a launch about 1980, and from there on we knew sometime in '81 we'd get it off.

ROSS-NAZZAL: How were you able to follow the progress of the project, being as you had work going on in California, work in Mississippi, and at Marshall? How were kept apprised of all the different components and different issues facing the engine? Did you have other management below you keeping track?

THOMPSON: We had other people in the program that were assigned to stay on top of the various subsystems, and we had constant reviews, both at Marshall as well as at the contractor site. Not only within the project, but also within the Center that were Shuttle-focused, not only including the Shuttle main engine, but the solid rocket boosters and the external tank as well. Then we had a number of meetings and reviews with Headquarters, so it was a very review-focused time. You

were almost constantly in some kind of a review or budget cycle or something else. It was a very exciting time, looking back on it. A lot of pain, but exciting nonetheless.

ROSS-NAZZAL: What were your hours like during those years that you were the project manager?

THOMPSON: I'm an early person, so I would usually get to work around 6:30 and then leave in the evening sometime. On TDY [temporary duty], the hours seemed to be a little longer. Down at the test sites, Stennis, there were always things to do and be concerned about.

ROSS-NAZZAL: There was some involvement by the National Research Council with the main engines. Can you talk about their involvement and their suggestions to improve the main engines?

THOMPSON: I think they first got involved back in the days of the subsynchronous whirl. Perhaps the [NASA] Administrator [Robert A. Frosch] or John Yardley asked the National Research Council to take a look at the Shuttle engine because of the criticality, and it was problem plagued at that time. The Research Council appointed Professor Gene [Eugene E.] Covert from MIT [Massachusetts Institute of Technology, Cambridge] to head a team or a panel. They came down to Marshall on several occasions and out to Rocketdyne in Canoga Park, got heavily involved in the program, offered advice, reviewed status and progress, and eventually were satisfied with the outcome. They were very helpful.

ROSS-NAZZAL: You didn't find that particularly challenging, working with another group coming in and having some oversight?

THOMPSON: No. I mean, probably your first reaction is, "Oh no, not another one." But once you get through that, we worked well together. It was not contentious, there was no tension as I recall. It was just a tough problem and we welcomed the help.

ROSS-NAZZAL: Tell us about your relationship with John Yardley, who was AA [associate administrator] for Manned Space Flight at that time, and his impact on the main engines.

THOMPSON: I really liked John. To me, he was the glue that held the Shuttle Program together, and it took a toll on his life too. John was on the road quite a bit. He was very tough, he was very demanding. I mentioned I usually came in early, six-thirty, seven o'clock, but wherever I was, I could expect a call from John at seven o'clock Washington [DC] time. So if you're out in California, that's four o'clock in the morning, and he knew where I was and he stayed in touch. It was tough.

ROSS-NAZZAL: I understand that you tested the engine with a number of flaws to prove its worthiness at some point. Did he approve of those ideas?

THOMPSON: Yes. Probably the best way to say it is he tolerated it. He wasn't particularly enamored with the idea—as you're into the certification program within about a year of the first flight, where there's a lot at stake—of testing the engine with cracked turbine blades. But we

had confidence in what we were doing. For example, on the turbine blades the crack grows at a certain rate. Even after we inspected the blades, we knew that a small crack could develop. If you lost a blade in flight and you imbalanced the rotor, particularly on the LOX pump, it rubbed, you were going to have a major explosion and you'd lose the Shuttle. There was a lot at stake in terms of knowing the rate at which the cracks grew, at which they became critical and broke.

So we felt we had to develop that confidence, or we were just going to be rolling dice. If we could run the tests where we had everything on the table, a lot at stake, and prove that it was safe and there was plenty of margin and the design was robust, then John bought into that. I don't think he ever really felt comfortable with us doing it, because if you had a major failure in late 1980, you would never have launched in '81, and there were a lot of eyes and pressure on the program at that time. But it was a step that a number of us felt that we had to go through if we were really going to stand behind the Shuttle engine.

ROSS-NAZZAL: Tell us about the Management Council and its impact on the Shuttle main engines. Did it have any influence over, say, how much testing you had to do or proving the main engine's worthiness before that first flight?

THOMPSON: Certainly they were heavily involved in that and wanted to know the progress and why the local project managers felt that it was safe enough and the testing was adequate enough to fly safely, and so they monitored that progress pretty well. I would say they were very active as an oversight, and, I might add, tolerant, patient as we worked through some of these problems. I found the NASA management system, and particularly the Marshall management system, people like Bob [Robert E.] Lindstrom, who I worked for, and Bill [William R.] Lucas, who was

the [Marshall] Center Director at that time, to be very supportive, patient, but also very demanding, just like John Yardley was.

ROSS-NAZZAL: Tell us about your relationship with Bob [Robert F.] Thompson at JSC. What was that relationship like?

THOMPSON: It was very good. It was on par, I thought, to the relationship I had with John Yardley. He was a very strong leader, got heavily involved in making sure that he understood what the problem was that you were working, and he was comfortable that we were going about it in the right way. That was a good relationship; it was a good oversight. Headquarters was Level Zero, Yardley was Level One, Thompson was Level Two. The projects, like the Shuttle and the Orbiter and the main engine, were Level Three.

ROSS-NAZZAL: You mentioned the Management Council was particularly patient as you were working through some of these challenges. Did you ever feel any pressure to meet certain schedules or meet certain costs at any point?

THOMPSON: There was a lot of pressure, but you just did the best you could, and if you had a cost problem, you had a cost problem. You couldn't save costs and solve the technical problems at the same time. I could have been fired a number of times. I mean, there was probably a lot of reason to do that, but they were patient and probably in the end had to ask, "Well, if we fire him, who are we going to get?"

ROSS-NAZZAL: Yes, who wants to work those hours? Tell us about the certification of the main engines for that first flight and the flight acceptance test.

THOMPSON: The certification program was probably inspired more by John Yardley. At the time, I think he brought his airplane experience with him. This was much in advance of the certification program. You had to write down what the criteria was, how many engines you were going to use, no failures, how many tests, how long. You couldn't wing it; you couldn't test and then all of a sudden at the very end decide we were ready. You had to write down, and then once you wrote it down he had to approve it, and he usually added something. It was a very strenuous program.

I think before the first flight we completed two ten-test series of engine testing at the normal thrust and then the 109 percent thrust. No failures, no anomalies or you had to start over. That's where we introduced some of the flaw testing that he got quite nervous about, because we were doing that as a part of the formal certification of the engine. You're going to run these tests with flawed parts, and you can't have any problems. You had to be right.

ROSS-NAZZAL: Yes, that's a pretty gutsy move.

THOMPSON: Then the acceptance testing was, as I recall, very successful. All three of the first flight engines were conducted without a hitch, and then, of course, all subsequent flight engines went through an acceptance series. I don't recall any real problems in the acceptance testing after the basic design had been through that torturous certification program.

ROSS-NAZZAL: Talk to us about that first flight readiness review that you participated in for STS-1.

THOMPSON: Well, it was the first one, so there was a lot of attention. It was a very important review. It was very thorough, perhaps somewhat tense. There was no one part of it that stands out. I don't recall any particular focus on the Shuttle engine, other than, "Now you've had eight years of testing of this thing and you've had a lot of problems, have you solved them all?" And, of course, we had the results of the certification program and testing to augment everything we had said at that time. It worked out very well.

ROSS-NAZZAL: Tell us about the minutes before the launch. What was happening at launch control? Were you at one of the consoles monitoring that main engine?

THOMPSON: Yes, I went in that night. It was before midnight, I think, and George [B.] Hardy, who was the project manager of the solid rocket booster, rode in with me. I remember coming over the causeway and looking out at the launch pad and it was all lit up. I mean, the whole sky was lit up, and the realization that "This is it." And we launched later that morning.

ROSS-NAZZAL: Any trepidation as the main engines—?

THOMPSON: Oh, I had plenty. You know, while you're sitting there listening and watching that launch, all your past failures run right through your head. It was a very stressful time, but rewarding as well.

ROSS-NAZZAL: Did you have any sensors on those main engines for that first flight that you were able to get data as they launched?

THOMPSON: Yes, we had a lot of instrumentation, everything we had during acceptance tests, so we knew how they were performing. They performed very well. There were no issues, there was no spurious data that got us all upset during flight. It was very nominal.

ROSS-NAZZAL: Were you at Edwards [Air Force Base, California] or at the Cape [Canaveral, Florida]?

THOMPSON: I was at the Cape for launch and went out to Edwards for touchdown.

ROSS-NAZZAL: Exciting moment.

THOMPSON: Yes.

ROSS-NAZZAL: Were you at the Cape when they pulled out the main engines and looked them over?

THOMPSON: I probably got reports of that, but I wasn't there for any inspections after it got back to the Cape.

ROSS-NAZZAL: Were there any changes made to the main engines following that first flight?

THOMPSON: Sure, there were some. They were normal upgrades or improvements of a valve or of a seal, nothing that was dictated by the last flight. There was no change of that type.

ROSS-NAZZAL: How long did you serve as project manager once the Shuttle started flying?

THOMPSON: For several years, from 1974 to '82. I was a manager of the Shuttle engine for those eight years, and then after that I became the chief engineer at Marshall. So I was still involved in the Shuttle engine, all of the Shuttle elements then for another two years, and then I went to Princeton [University, New Jersey].

ROSS-NAZZAL: Then you came back as the Center Director, I understand. Would you like to talk about your years as Center Director at Marshall?

THOMPSON: I'll just say a little bit. I was up at Princeton during the *Challenger* [STS 51-L] accident, and Dick [Richard H.] Truly, who was the associate administrator at that time, asked me to come back and head up the NASA investigation supporting the Rogers Commission [Presidential Commission on the Space Shuttle *Challenger* Accident]. So I took a leave of absence up at Princeton and was down at the Cape for that early summer after the accident. Then after that was over I returned to Princeton for several months, and then Jim [James C.] Fletcher [NASA Administrator] asked me to come back and be the director of Marshall. I knew

the people, I knew all the elements. I had been removed at the time of the accident, I was up at Princeton, so from that standpoint he was satisfied that I could do it.

It was a very challenging time. The Center was going through a lot of rebuilding. It was very hurtful for a number of people to be involved in something like that, but they settled down and focused on the job that had to be done. We redesigned the solid rocket booster, the capture ring, and the O-ring design. And, as a matter of fact, introduced into the re-certification of the solid rocket boosters the concept of putting the flaws in the [design]; we actually cut the O-rings.

In the design, when the solid rocket motor pressurized, the flange would tend to close and clamp down and squeeze on the O-ring, as opposed to working in the opposite direction. It was that feature that gave us confidence that even if there was a flaw in the O-ring, it would be pinched and would not leak, so we actually introduced the flaws in the re-certification of the joint that failed during the *Challenger*. That was a concept that came out of the engine certification program, and of course you know the results. STS-26 was the first flight after that, it was very successful. There haven't been any problems with the solid rocket booster since then. I was at the Center until '89, and I really enjoyed the years working with people and recovering from that very tragic accident.

ROSS-NAZZAL: There had been a great deal of criticism about NASA's safety culture, and I'm wondering, would you talk to us about how you stressed the importance of safety at Marshall Space Flight Center?

THOMPSON: Well, the Center, going back through Apollo, as well as Shuttle, was very safety-conscious. Probably what I would say is that when you come to this culture thing—people had

seen O-rings before, they hadn't failed catastrophically. From that standpoint, they perhaps became comfortable with an anomaly in proceeding, because it hadn't bitten them. But you can't do that long. You've got to introduce problems. Again I come back to testing with a flaw. You've got to assume that there's some problems with the parts or with the components. They're not perfect, and that even in that condition, your design is such that you've got plenty of margin and robustness to continue.

That was a real lesson that I learned out of the Shuttle main engine and I think carried over in the way I looked at problems as we re-certified the solid rocket booster and as we looked at other problems while I was at the Center and at NASA. An example—I wasn't at NASA at the time, but the foam that came off of the external tank at the time of the [STS-107 *Columbia*] accident, it didn't come off for the first time; it had come off before. That was an area that was at Marshall, but it was [NASA] Johnson [Space Center, Houston, Texas] and Headquarters where they got by with it last time, so "Maybe it's okay." You can't do that.

ROSS-NAZZAL: Communication was also a serious issue that the Rogers Commission examined, and I understand that you really opened up communication at the Center.

THOMPSON: Yes. I worked very well with Bill Lucas, and I never sensed that he stifled communication, but I think probably some did see that. I never felt it, but it was something that I felt when I came back to the Center that we had to address. We tried to emphasize that. Not shoot the messenger, make sure that everybody communicated whatever problems they were aware of or bubbled up. We spent a lot of time—[Thomas] Jack Lee, who was my deputy at the time—we spent a lot of time trying to foster that environment.

ROSS-NAZZAL: I'm going to ask Rebecca if she has any questions for you this morning.

WRIGHT: No.

ROSS-NAZZAL: Is there anything that we haven't talked about, about the main engine in particular, that we may have overlooked that you can think of?

THOMPSON: No, I think we've covered it.

ROSS-NAZZAL: Okay. I thank you very much for your time today, it was wonderful.

THOMPSON: Very good. I enjoyed it and hope it gave you what you needed.

ROSS-NAZZAL: Absolutely it did. Yes, thank you.

[End of interview]