NASA STS Recordation Oral History Project
Edited Oral History Transcript

John W. Thomas
Interviewed by Jennifer Ross-Nazzal
Huntsville, Alabama – 29 June 2010

Ross-Nazzal: Today is June 29th, 2010. This interview is being conducted with John Thomas in Huntsville, Alabama, as part of the STS Recordation Oral History Project. The interviewer is Jennifer Ross-Nazzal, assisted by Rebecca Wright. Thanks again for joining us this morning. We certainly appreciate it.

Thomas: My pleasure.

Ross-Nazzal: I'd like to begin by asking you to briefly describe your career at NASA.

Thomas: I began work at NASA in 1961. I graduated from College in '60, spent one year with the Army Ballistic Missile Agency [Redstone Arsenal, Alabama] locally, and then went to work for Marshall Space Flight Center [Huntsville, Alabama (MSFC)] in their test lab. I was running a static test stand for testing the H-1 Rocket engine for the first stage of the Saturn IB Apollo Rocket. I spent a couple years there and then moved to the Engine Project Office developing the H-1 Engine. I stayed there until 1966 when I went to work on the Apollo Applications Program that was the predecessor to Skylab. I stayed with Skylab until it was completed in'73.

After Skylab I was involved with the international Spacelab Program until 1987. I began as an engineer in the Chief Engineer's Office and then ran a systems engineering division, was chief engineer, deputy program manager, and finally program manager. In addition to the

Spacelab program manager, I had a secondary assignment with Marshall as manager of the Special Projects Office at the time of the [Space Shuttle] *Challenger* accident [STS 51-L]. In that capacity of manager of the Special Projects Office, I had a payload aboard *Challenger*. It was the Inertial Upper Stage [IUS] that was the propulsion element of the Tracking and Data Relay Satellite System [TDRSS] satellite deployment. I was in the operations support center at Marshall monitoring the TDRSS/IUS at the time of the accident.

Immediately after the accident I was assigned to the NASA Accident Analysis Team as deputy to Team Lead J. R. [James R.] Thompson [Jr.] who was also deputy to Admiral [Richard H. "Dick"] Truly, the head of the NASA task force established to support the presidential commission. J. R. spent most of his time at Kennedy [Space Center, Florida (KSC)], as Admiral Truly resided in NASA Headquarters, so I essentially ran the Accident Analysis Panel.

After we submitted the accident analysis report [printed in volume 2 of the *Report of the Presidential Commission on the Space Shuttle Challenger Accident*] in May of '86, I was assigned to lead the NASA solid rocket motor [SRM] design team. Following successful return to flight, I retired from NASA in 1989 and accepted employment as site director for Lockheed Space Operations Company at KSC where I was responsible for prelaunch processing all the Shuttle elements and for all Shuttle launch operations for NASA KSC.

While I was at KSC, NASA had embarked on developing the advanced solid rocket motor [ASRM]. The program had gotten off to a slow start, so NASA urged Lockheed to consider replacing the program manager. They suggested that I would be a candidate for program manager based on my experience with the RSRM [reusable solid rocket motor]. Lockheed acquiesced to NASA's desires, and in mid-1990, I was transferred off the beach in Florida to Iuka, Mississippi to be ASRM vice president and program manager to design, develop, and test the new motor; build the manufacturing facilities; construct a test stand down at [NASA] Stennis Space Center [Mississippi]; and deliver the advanced solid rocket motors. We progressed well, but in 1994 we were just beginning to produce development hardware when the [US] Congress decided to cancel the program. Following ASRM termination and asset liquidation, I returned to work for Lockheed Space Operations Company to become vice president and general manager of Lockheed Stennis Operations, established to provide test and technical services for the Stennis Space Center.

I retired from Lockheed Martin in 1998 with no intention of working anymore, but [Thomas] Jack Lee, former Marshall Space Flight Center Director, formed a small consulting services company known as Lee and Associates. He was supporting a new engine that NASA was developing, designated Fast Track, which was being tested at Stennis, and I was asked as part of his Marshall task to monitor the test program at Stennis. That began my current consulting services which I have practiced since 1998, all with Lee and Associates.

ROSS-NAZZAL: So you've been working over 40 years in the space program, is that correct?

THOMAS: Closer to 50.

ROSS-NAZZAL: That's pretty amazing. What we'd like to focus on today is the redesign of the solid rocket motor. You had mentioned earlier that after the *Challenger* accident you were assigned to the Accident Analysis Team. Would you share some more details with us about that assignment?

THOMAS: The Presidential Commission divided their membership into subpanels, and the one that was overseeing the part that I was involved in was the Accident Analysis Panel. The four Panel members were Neil [A.] Armstrong, Gene [Eugene E.] Covert from MIT [Massachusetts Institute of Technology, Cambridge], Dr. [Richard P.] Feynman from California [Institute of Technology, Pasadena], and Air Force General Don [Donald J.] Kutyna. There were three other panels; production that looked at all the production records, ground operations, and mission operations.

Our role was to support that panel, but we were of course interested in doing everything possible to understand the cause of the accident for NASA. We met at Marshall Space Flight Center, and had all NASA and their contractor resources to do whatever was needed in terms of analysis, test, records research, postulating failures, and building fault trees on the various potential causes of the failure. Using this information and data, the team traced each leg of the fault tree until they either produced the results pointing to the cause of the accident or were cleared as not being causal.

Obviously, in the beginning there was nothing pointing to the cause, so we had to look at every aspect of the hardware design, test, production, and operation of all elements and systems of the shuttle main engines, orbiter, and SRBs [solid rocket boosters] as well as flight down linked instrumentation and ground based photography. The payload was also included because the IUS, a solid rocket motor, was the propulsive element of the TDRSS that was flying in the orbiter payload bay. So we started at the very top and cleared all of those down to the fundamental cause of the accident that we determined to be the aft field joint of the right solid rocket motor.

The team determined that the failure was caused by a faulty design of the field joints on the solid rocket motor that caused the sealing surfaces to open during motor ignition in combination with a cold temperature that did not permit the sealing O-rings to be resilient enough to follow the joint opening rate. A third contributing cause was a breach in the sealing material joining insulation on the mating segments that keeps the several thousand-degree combustion gas temperature from burning through the O-ring seals and the steel case material.

This insulation joint is created when the four-segment motor is assembled at the launch site. A putty material was utilized to seal the insulation joint and it was susceptible to voids and paths going all the way through into the metal and O-ring sealing area of the field joint. Those three contributing factors led to hot gas penetrating the putty, blowing by and eroding the O-ring seals, and eventually melting the steel motor case. That scenario began at liftoff leading to a complete burn-through at 71 seconds into the flight and based on the SRM breach circumferential location, the hot gas plume impinged on the external tank [ET], weakening it to the point of failure after which the Shuttle disintegrated.

ROSS-NAZZAL: Because of your participation you were named to head of the SRB redesign team, is that correct?

THOMAS: Yes.

ROSS-NAZZAL: Would you tell us about that redesign team? How did you decide how you were going to redesign these solid rocket motors?

THOMAS: Knowing the source of the fault going in, our fundamental job was to determine how to redesign the joint to preclude any further hot gas breaching the joint. We began by forming a NASA Design Team composed of members from the various NASA Centers and any contractor support that was deemed necessary. [Morton] Thiokol [Incorporated], now Alliant [Techsystems Inc.] were already looking at different designs. The NASA team developed independent joint designs while Thiokol was maturing their design configurations.

Around the end of 1986, we began bringing those two different team's independent joint concepts together to arrive at one that we wanted to design, manufacture, and incorporate into the flight motors. About that same time I took a few of the NASA design team members and relocated to Thiokol in Promontory, Utah, where we began narrowing the concepts to the one that we eventually proposed as the final design and to continue the development and verification program.

ROSS-NAZZAL: How did you start the process? Would you walk us through some examples of ideas that you had that you didn't end up using?

THOMAS: As you can imagine by listening to what is going on now with the [BP] oil spill in the Gulf [of Mexico], they're getting all kinds of suggestions on what can and should done to stop the leak. We experienced the same thing. I had many people during the accident analysis not only telling me what they thought happened, but also telling me what we should do to fix it, and that continued through the early phases of the design process. The fact that those proposing fixes didn't appreciate is that the solid rocket motor is 12 feet in diameter and weighs over 300,000 pounds; it won't fit into most large conference rooms. Most of the solutions proposed were implausible because of manufacturing complexity and/or handling considerations.

Our fundamental job was to stop the joint from opening when the motor was pressurized at ignition; if it didn't open, then the O-rings would remain in contact with the metal sealing surfaces providing the necessary sealing function. The O-rings then didn't have to be so resilient to prevent hot combustion gas blowing past them. The second and most challenging part of it was to determine how to close the gap between the internal motor insulation at the joint. To prevent the joint metallic parts from opening, we incorporated a capture feature on one side of the joint to prevent it from opening excessively. That was a reasonably straightforward design, but with these O-rings and their ability to be resilient and seal, the joint opening had to be constrained to few 1,000ths of an inch. On a case joint that's 12 feet in diameter, holding that tolerance is a challenge. The challenge was not the design but it was the fabrication of these large metal parts. Thiokol and their vendors rose to the manufacturing challenge and that capture feature was the design finally adopted.

The next challenge was to seal the insulation at the field joints. After evaluating several concepts, we selected one that produced an interference fit between the insulation mating surfaces of the adjoining motor segments. This configuration is what is known as the "J-Seal" and is the first line of defense for hot combustion gases reaching the O-ring seals. With this compression fit, hot gas was not able to penetrate the insulation barrier and reach the metal sealing surfaces.

As an additional sealing enhancement, an adhesive similar to that used on "post-it" note pads was added between the J-Seal mating surfaces. The third part of the failed field joint redesign was to be able to leak-check the O-rings, and in a particular, in the direction which they would be sealing during motor operation. That led to adding another O-ring seal in the metal capture feature for a total of three at each joint. This became known as the leak-check O-ring, and it was the first one that the hot gas would encounter if the insulation J-Seal leaked.

There was one remaining concern expressed by National Research Council group led by [H.] Guy Stever overseeing our design; that was the temperature at the joint. They wanted the temperature to remain relatively constant at the joint so the O-rings would not be subjected to cold temperatures again if the temperature at launch would be below 50-degrees. Their concern was that low temperature would cause the O-rings to lose their resilient properties. Our teams were not particularly concerned with this design feature because tests showed that the O-rings would track joint opening under the specified temperatures at launch; but external heater elements were added to the joints to make the design even more robust.

In summary, the combination of the capture feature, the J-seal insulation, the leak-check methodology and the heaters to maintain the joint temperature, precluded any recurrence of the joint failure mode. Although the focus was on the failed joint, we incorporated changes in other areas of the Motor. Specifically, design improvements were made at the joint that affixes the nozzle to the aft motor segment, at the case factory joints that are assembled before the motor is actually cast with propellant, and the igniter joint.

ROSS-NAZZAL: How did you come to that consensus? You mentioned there were two separate teams working on a design, and then you came together. How did you finally agree on what would be the final design?

THOMAS: When we merged the NASA and Thiokol teams in Utah, both approached the redesign open-mindedly. We evaluated all design solutions, using analyses and testing, to select the best of all approaches. There was not necessarily always consensus, but we moved on as I had the final vote.

ROSS-NAZZAL: How many people originally worked on the design team here at Marshall? Then you mentioned you'd taken some of your team out to Utah—how many people was that?

THOMAS: It varied with time, but the average would be on the order of 120 locally. We were using mostly the engineering subject matter experts in materials, design, analysis, and safety disciplines. We had an integrated, co-located team with few managers and extraordinarily talented engineers. When we merged the teams in Utah we had eight to ten people that established residence there.

ROSS-NAZZAL: How long did you stay in Utah before you came back to Alabama?

THOMAS: Our team relocated there in late '86, early '87, and most returned to Huntsville after the DM [Development Motor]-8 test, which I believe was in August of '87. I had planned to return to MSFC following test, but the MSFC Center Director decided that I should to be at KSC for prelaunch processing of the return to flight hardware. So I went from Utah to Kennedy and remained there until STS-26 was launched in 1988.

ROSS-NAZZAL: What was morale like when you first arrived in Utah at the Thiokol plant?

THOMAS: It was actually very positive; there was no hostility or being protective, resentful, or anything of that nature one might expect under those circumstances. Their sole interest was initially finding the cause of the accident, finding the remedies to prevent it from happening in the future, and regaining their pride in producing the quality Shuttle motors. They were very positive, very cooperative, and we evolved into a good cohesive team.

ROSS-NAZZAL: Would you tell us about the testing program once you had come up with this design and how you wanted to test it? Would you talk about the different tests that you conducted on the motors?

THOMAS: We had some very unique test facilities that were constructed specifically for developing and testing the redesigned motor at both subscale and full-scale test articles. We developed and constructed a field joint test article facility that consisted of two inert full-scale half-motor segments with a forward dome, aft dome, and a nozzle simulator. We could place differing amounts of propellant inside test article and simulate the joint performance as the pressure increased at motor ignition on the launch pad.

We constructed another similar facility in the MSFC Test Division where the former Apollo J-2 engine test stand was converted into a motor test facility where we could apply the external loads associated with structural members that attach the motors to the external tank. This facility was brought online because there was some speculation that there were unusual loads induced into the motor aft field joint by these attach struts causing the joint to open and leak. We had to produce a test that could prove this hypothesis to be either positive or negative; and it turned out to be negative as we always thought.

We also constructed a test facility for the case-to-nozzle joint which was redesigned. It served the same purpose for the case nozzle joint as the field joint test facility did for the case field joint. Additionally, we tested small test motors, 48-inch vice, 12 foot in diameter at MSFC, as well as many smaller motors at Thiokol, to explore different concepts and to verify our analysis tools. Finally we had three full-scale motors; DM-8 and 9 [development motor] and QM-6 [qualification motor] that were tested in Utah. A second full scale motor test stand was constructed at Thiokol to test the motors as rapidly as possible and to modernize the stand data acquisition system.

The existing facility was designated T-24, and the new one was T-97. Everything redesigned and everything that was questioned prior to design had a test fixture or test stand to prove or disprove the hypothesis, or to demonstrate that the design was successful. For example, prior to *Challenger*, the motor had never been tested at low temperature, so we covered the test stand, installed a conditioning system, and brought the temperature down in the range of 40 degrees. The cover was then quickly removed and the motor was fired right away. We demonstrated that it would operate properly at the lower temperatures.

We also performed some unique testing that had not been done previously on large solid rocket motors and those involved intentionally flawing the joint seals and sealing surfaces in the redesigned joints. We began by inducing flaws the insulation, then the first O-ring, and followed with the secondary O-ring. All these tests were successful, and thus demonstrated that the motor would perform satisfactorily even if flaws found their way into the joints.

ROSS-NAZZAL: What did people think when you suggested that idea to perform a test with flaws?

THOMAS: When intentionally flawing the motor first came up, I was among those that said, "You mean what?" But the more we thought about it, and the more confidence that we gained in our design, we thought it to be a good idea.

ROSS-NAZZAL: And it proved that the SRM was safe?

THOMAS: Right, completely safe. The only unusual observation to date was a small amount of combustion gas by-products, soot, penetrated the insulation J-Seal. They attributed the small blow-by to a change in the adhesive by the vendor. Many were upset about it, but it actually was of no consequence whatsoever. We in fact discussed the need for that adhesive after we got into testing; I didn't think it was necessary but we kept it as a redundant way of keeping the insulation joint mating surfaces closed.

ROSS-NAZZAL: I've been reading the book *Truth, Lies and O-Rings [:Inside the Space Shuttle Challenger Disaster]*, and Al [Allan J.] McDonald talks about after some of the tests how you and he or Royce [E.] Mitchell would actually physically go into the SRM to check things out. Would you tell us about your recollections of that?

THOMAS: Yes, we entered the motors for pretest inspections and after every flight configured motor test; we did the same in the field joint test article motors. The full motors were tested horizontal so we would climb inside the motor and inspect the three field joints. To go inside the motor after the test required that we don bunny suits and oxygen supplied, breathing masks because the insulation contained asbestos. Everything looked normal in every case. We did essentially the same thing for the field joint test articles, except because they were tested vertically, it was necessary that we use a bosun's chair to go down into the motor and inspect the insulation seals. These post test inspections gave us an early indication of any anomaly, but understanding the real joint performance was not possible until the motors and test articles were demated several days following the tests.

We did similar inspections for the first couple of flight sets of return to flight motors when they were assembled at Kennedy Space Center. The forward motor segment has a different propellant grain configuration, called a star pattern, in the forward end that provides more surface area for burning that accelerates the motor ignition transition. There had been a propensity for some cracks to appear in the propellant, which required that we enter that segment in the horizontal position. We performed joint inspections using a bosun's chair as the segments were assembled in the Vehicle Assembly Building [VAB]. The motors are also inspected in the horizontal position as they are disassembled at KSC after they have been retrieved from the ocean following the flight.

ROSS-NAZZAL: Mr. McDonald also said that the redesigned SRM was tested six more times than the original qualification program.

THOMAS: I don't recall exactly how many.

ROSS-NAZZAL: How were you able to achieve so much so quickly, in such a short amount of time, in terms of testing and then requalifying the SRB for flight in a period of less than three years?

THOMAS: We were working quite intensely; many hours a day, six and seven days a week. We had a talented, dedicated team with focused leadership who did not have to get permission from many levels of management and organizations to implement designs, conduct tests, and perform analyses. This process allowed us to move quite rapidly in that environment.

ROSS-NAZZAL: Did any changes have to be made to the design you had decided upon after any of the tests that you conducted?

THOMAS: No changes were made in the joint areas after we baselined the configuration, but we did have to tweak the design of a nozzle component following test DM-9. I understand that there has been some refinements in the case nozzle and igniter joints in the years since returning to flight.

ROSS-NAZZAL: That's remarkable. Tell us about the media interest in the redesign effort out in Utah.

THOMAS: The media was quite interested both at MSFC and in Utah. Our Marshall public affairs organization was quite accommodating in releasing information and arranging for rather frequent, periodic press conferences where I would inform the press on our progress, our problems, how our design was evolving, and would respond to any questions they might have.

ROSS-NAZZAL: Had you had much experience working with the press before this event?

THOMAS: I had some experience in dealing with the media but had to come up very quickly on the learning curve. When we were executing Spacelab and Skylab, I had some media interactive training where specialists came in and suggested to us what to do, what not to do, and how to behave. That training was very beneficial.

ROSS-NAZZAL: How did the [William P.] Rogers Commission [also known as the Presidential Commission on the Space Shuttle Challenger Accident] affect the redesign effort, the analysis and the eventual outcome of what you were working on at that point?

THOMAS: The Rogers Commission finished their work and released their report in June 1986, which completed their task. They were therefore not around to influence the redesign, but NASA stood up the National Research Council [NRC] panel comprised of recognized subject matter experts that reported directly to the Administrator. They reviewed our work but did not try to influence us one way or another on any particular design solution. Instead they would come into either at MSFC or Utah for our team to brief them on our design solutions, analysis, and test results.

The only thing that they were really insistent upon was the joint heaters on the field joint O-rings. Of course they had their thoughts about other design aspects and objectively reviewed our solutions, analyses, and tests substantiating our decisions. I didn't think the heaters were necessary based on our tests, but it was a way of making the overall joint performance more robust.

ROSS-NAZZAL: Was it challenging to include the heaters in the SRM?

THOMAS: Incorporating the joint heaters was a nuisance more than anything else. In fact the Constellation Program has removed the heaters on the Ares I first stage, which is the same motor but with one additional segment.

There was another oversight group that was established by the Marshall Center to review our work, and that was an engineering group that was headed by Al [Allan] Norton, who was the former external tank chief engineer. His team was composed of a number of engineering managers including such recognized experts as Jim [James E.] Kingsbury from Marshall, Max [Maxime A.] Faget from Houston [JSC], and Horace [L.] Lamberth from KSC.

ROSS-NAZZAL: Did you find that to be challenging with so many cooks in the kitchen so to speak?

THOMAS: It distracted us a little bit, but it was probably productive.

ROSS-NAZZAL: Congress was also very interested in the redesign of the SRM. I think I saw that you had testified. Would you tell us about their oversight and the interest that they had?

THOMAS: We were before congress and staff several times, giving them the results of our design work and test results. They in fact produced a voluminous report of three or four volumes, based on their staff work. We had staff members that would come occasionally to understand what we were doing. We gave them the same type of information as that given the NRC panel and others.

ROSS-NAZZAL: Did they in any way influence the design or testing effort that you were working under?

THOMAS: No, they were more interested in progress

ROSS-NAZZAL: What about the astronauts? I know that there were some astronauts who were following the redesign effort.

THOMAS: The Astronaut Office assigned two crew members to participate with our team. The senior astronaut was Hoot [Robert L.] Gibson and the other was Steve [Stephen S.] Oswald and both stayed with us from the very start until we finished the design. There were others, like John [W.] Young, who attended our major reviews. The dedicated members didn't reside with us, but they came as they felt necessary to participate in the design process, testing, test reviews, etc.

ROSS-NAZZAL: Were they pleased with the final design that you had come up with?

THOMAS: Yes, all were in agreement with design and test results.

ROSS-NAZZAL: Mr. Mitchell had mentioned the Aerospace Safety Advisory Panel [ASAP] was also very interested in following the redesign effort. Can you talk about their efforts?

THOMAS: We briefed the ASAP giving them the same type of information that we gave our other oversight panels. I don't recall them having any direct opposition to any of our design or test plan or results.

ROSS-NAZZAL: It almost seems like there's so many people overseeing the work that you were doing that you may have spent more time handling these groups than maybe doing the redesign and testing. Would that be an accurate assessment?

THOMAS: No, even though it took quite a bit of planning, logistics, and briefings, they were actually quite supportive in their quest to be sure that we were considering all aspects that might have influence or led to the accident.

ROSS-NAZZAL: When was the redesigned SRM finally qualified for flight?

THOMAS: The certification process begins with design and design reviews through development and qualification testing to the flight readiness review, where certification of flight worthiness is executed. We had qualification motor tests, other full and subscale testing, extensive analyses, and manufacturing process records to support the certification for flightworthiness process. That certification process culminated in the flight readiness review prior to STS-26 that flew September of '88.

ROSS-NAZZAL: You had given us a broad overview, but I thought it might be nice to have on the record the difference between the redesigned SRM and the SRM that was flown for the first 24 flights.

THOMAS: First let me reiterate that the SRM design team's job was to understand the failure and determine the redesign and the testing necessary to assure that that did not happen again. Gerald [W.] Smith was the solid rocket booster project manager, and under him was Royce Mitchell who was the RSRM project manager. They had the task of going back and reviewing all of the failure modes and effects analysis, all the hazards analysis, and the pedigree of the production processes and hardware. There were some manufacturing process changes, management practices, and inspections and checkouts that were instituted as a result of their activity that was separate from ours.

The major hardware configuration difference between the previous motor and post-*Challenger* motor designated the RSRM, were differences in the field joint design covering O-ring material, insulation interface design, metal capture feature, and heaters. We also made some design changes in the case nozzle and igniter joints. There were profile changes in the external insulation that protected the motor from ascent heating and reentry and splash-down loads as it goes back into atmosphere and water respectively. There were other minor change but those were not related to the *Challenger* accident.

ROSS-NAZZAL: Pretty impressive efforts as you look back. Were there any new quality assurance or safety measures instituted during the redesign effort?

THOMAS: There were S&MA [Safety and Mission Assurance] changes derived from re-evaluating the failure mode and effects analysis and single point failures. This led us to incorporate additional ports to leak-check both primary and secondary O-rings in the same direction that they would be sealing during motor operation. Other changes related to the amount of inspections including sealing surface smoothness inspections, dimensional measurements on the two joint mating segments, and case roundness. We even had a "round maker" tool that could return the case joints to a completely round condition before mating to preclude unacceptable stresses.

ROSS-NAZZAL: You mentioned that you moved from Utah to Florida in preparation for the return to flight effort. Would you tell us about going out to KSC and working on that effort?

THOMAS: I relocated to the Kennedy Space Center when the return to flight motors arrived there as the Marshall representative to the KSC processing team. This was to expedite anything requiring Marshall's engineering disposition. At one point the processing team overzealous with the number of measurements and inspections, like grease discoloration presence of human hair and lint, etc. It got to the point where we were not making much progress, so the Center Directors at KSC, Forrest [S.] McCartney, and Marshall, J. R. Thompson, agreed that they would appoint me as the decision authority for processing SRBs in the VAB. As that became known, I never had to exercise that authority. The team just turned to and got on with the job.

ROSS-NAZZAL: Would you walk us through, for people who don't know, how the SRMs are properly assembled at KSC?

THOMAS: First, it is necessary to understand the facilities involved with SRB processing at KSC. The ARF [Assembly and Refurbishment Facility] refurbishes the booster forward frustum that houses the recovery parachutes, the aft skirt that contains some instruments, and the power system that operates the TVC [thrust vector control] system that vectors the nozzle for steering. The RPSF [Rotation, Processing and Surge Facility] is where the motor segments are received from Utah on railcars and prepared for assembly [stacking]. The other major motor processing facility is the Vehicle Assembly Building where the motor segments are stacked and all Shuttle elements are assembled for flight. There are other ground processing elements required to process the motors. The two major ones are the Mobile Launch Platform [MLP] and Crawler Transporter [CT].

Now for the assembly process; the MLP sitting atop the CT is positioned inside one of four bays in the VAB awaiting delivery of the SRB elements. Meanwhile the aft skirt is brought over from the ARF to the RPSF where it is attached to the motor aft segment. This assembly is then moved to the VAB and lifted onto the MLP. The other three RSRM segments are moved to the VAB, one at a time, and stacked onto the aft segment. Finally the SRB frustum is transported from the ARF to the VAB and mated to the RSRM forward segment, which completes on SRB/RSRM stack. This process is repeated for the other SRB. The ET is lifted over from another cell in the VAB and mated to the two SRBs. The orbiter is transported from one of the Orbiter Processing Facilities [OPF] and mated to the ET to complete a Space Shuttle.

Then following a thorough checkout of that integrated assembly, the VAB doors are opened, and the system is transported aboard the CT to the launch pad to be readied for flight.

ROSS-NAZZAL: How long does it take to process and assemble the SRMs?

THOMAS: It started out to be quite a long time, on the order of four months; but after the first two or three it began coming down, and now I think it's under of 30 days.

ROSS-NAZZAL: It doesn't seem like it would take that long.

THOMAS: Yes it does, but these are very large human space flight element that must be handled very deliberately with checkout and inspections performed as the assembly sequence progresses. The combination of the handling operations, inspections, and the checkout requirements lead to this processing timeline.

ROSS-NAZZAL: How did the redesigned SRM perform during the return to flight?

THOMAS: Perfect. We didn't have any problems in the return to flight motors.

ROSS-NAZZAL: Did you have any instrumentation on the SRBs as they flew?

THOMAS: We had some pressure and thermal instrumentation, but most of the solid rocket motors hardware performance information is obtained by inspecting the motors after they are retrieved from the ocean and towed back into Hanger AF and disassembled after the flight..

ROSS-NAZZAL: Had the return to flight crew followed the redesign effort very closely, or were they too busy?

THOMAS: They were mostly tied up in their training; but we talked to Fred [Frederick H.] Hauck and Dick [Richard O.] Covey from time to time

ROSS-NAZZAL: I understand you remained at the Cape for the next flight of STS-27.

THOMAS: Yes, I stayed for the two flights and then returned to MSFC. I think it was on STS-27 that the Shuttle came back with a large number of damaged thermal protection tiles. I was asked to form a team and determine the culprit. We determined that the damage was attributable to insulation material shedding off the SRB nose cap during ascent and impacting the very fragile tile. Following that assignment I retired from NASA in April of ’89 and joined Lockheed at KSC launching Shuttles.

ROSS-NAZZAL: I wanted to ask you about the ASRM, when you started working for Lockheed. Can you tell us what the advanced solid rocket motor was compared to the redesigned solid rocket motor?

THOMAS: There was a perception that there were still some safety issues with the redesigned RSRM because it had the same type joints, although they had extensive modifications. Moreover, there was a need for more Shuttle payload performance and the ASRM could provide another 12,000 pounds lifting capability. The ASRM concept was developed, an RFP [Request for Proposal] was issued, and Lockheed Missiles & Space Company [Inc.] was awarded the contract.

The major configuration differences between the ASRM and RSRM were: 1) the ASRM was a three-segment motor rather than four for the RSRM, and that reduced the number of joints, and 2) the ASRM had bolted flanged joints which are inherently more stable and reliable than the RSRM pin-and-clevis joint. That was perceived, and in fact it was, a safer design. The ASRM used about the same type of insulation that was on the RSRM, but it had a more energetic propellant to gain the additional performance. Another ASRM goal was to introduce more automation into the manufacturing processes by more automation particularly in insulation application and propellant manufacturing.

The current method for installing insulation in RSRM motor cases is a manual process where the insulation is cut into large sheets and technicians go inside the motor case and lay it up on the internal case surface until the proper thickness and profile is achieved. The ASRM developed an automated process of strip-winding the insulation layup. This involved placing ribbons of insulation into a machine that automatically applied the material to the internal case wall until the proper thickness and configuration was achieved. That process produced a more consistent insulation lay-up than the hand lay-up, and it was faster, more efficient, and less costly.

More significantly, the process for mixing and casting propellant in the RSRM uses mixing stations where certain quantities of the propellant ingredients are loaded and mixed in the large kitchen style mixer. The mixing bowl containing the propellant is then transported over to the casting building and dumped into the motor segment. This process is repeated several times until the motor is filled with propellant and left to cure or harden. The ASRM was to use a cutting edge technology process of continuously mixing and casting propellant into a segment in the cast building. In this process all the ingredients are mixed and piped into the case continuously negating transportation of many different mixes. This new process was intended to produce more homogeneous and higher-quality propellant.

ROSS-NAZZAL: That brought to mind a question, since you said there were only three joints for this new design. How come it's not possible to have an SRB that doesn't have any joints?

THOMAS: That is in fact the practice with smaller motors. That is what's called a monolithic motor, where there is just one large cylinder filled with propellant. But these large motors are heavy and difficult to lift, handle, and transport. The most significant drawback is transporting the large motors if they are produced any appreciable distance from the launch site. The ASRM plant was constructed adjacent to the Tennessee Tombigbee Waterway that branches off the Tennessee River and makes its way through Mississippi and Alabama into the Mobile Bay. This permitted the ASRM to have larger [longer and slightly larger diameter] segments because they were going to be barged to KSC. So you see it would be impractical to produce large monolithic motors the size of the Shuttle motors and transport them to the launch site, and to construct launch processing facilities with sufficient height and crane capacity to accommodate such a long monolithic motor.

ROSS-NAZZAL: I was curious about that. Was NASA interested in a solid rocket motor that could propel more because of the [International] Space Station? Was that part of the interest in a redesigned SRM?

THOMAS: Yes, I think the Shuttle at that time was not producing quite the originally advertised payload performance so they were looking for ways to increase performance. They had already reduced the mass of the original external tank to a lightweight tank configuration, and were looking at further reductions with a super lightweight tank by changing the material to aluminum lithium. This would produce on the order of 6,000 to 8,000 pounds whereas the ASRM could provide 12,000 pounds additional performance.

ROSS-NAZZAL: Why was the advanced solid rocket motor canceled?

THOMAS: I think it was mostly political. There was an administration change and different NASA Administrators since the ASRM inception. Dan [Daniel S.] Goldin became the new Administrator and did not embrace the need for the ASRM and there was quite a bit of political activity between various segments of the country on whether the ASRM was needed. The Utah contingent was dead set against it, and of course the southeastern states were supportive. It was finally canceled in 1994.

ROSS-NAZZAL: Seems like such a shame for being so close.

THOMAS: We had an expenditure of over $1 billion at the time it was terminated.

ROSS-NAZZAL: I did want to go back to STS-26 and ask you what your thoughts were during the launch. Were you at the Launch Control Center at that time and could you tell us about that day?

THOMAS: I was very confident and excited, but a little bit apprehensive, because it was the first flight following *Challenger*. Several of us tried unsuccessfully to learn to hold our breath for two minutes [the SRB burn time in flight]. I was in the Launch Control Center with the NASA management team comprised mostly of Center Directors, Associate Administrators, and the Administrator. There was a high degree of confidence that we had corrected the *Challenger* accident problem; but still to this day, when CapCom [capsule communicator, JSC] gives the "Go" at throttle up [the point at which the *Challenger* accident occurred], it gets my attention. After SRB burnout and separation, there was great relief, satisfaction, and congratulations all around. I should point out that there has not been any hot gas reaching either the primary or secondary O-ring seal in the field joint on any test or flight since our redesign was incorporated post-*Challenger*.

ROSS-NAZZAL: I can imagine [you're proud of] being a part of that whole effort.

THOMAS: Yes, it was a great reward to have a part in recovering from such a devastating period in this nation's human space flight endeavors. I was very fortunate.

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

WRIGHT: I just have one. You were talking about your design team in Utah and moving toward final design and all the progress. Did you encounter setbacks where you thought maybe you weren't going to be able to encounter that progress?

THOMAS: We had some disappointments but they were mostly related to schedule; we were trying to do things very rapidly to return to flight as soon as possible. But I don't recall any great hurdles that we ran into that just "it doesn't look like we're going to be able to pull this off." Early on, we took a motor of the *Challenger* configuration, attempted to trim away some of the insulation at the joint, and incorporate a different insulation seal configuration. When we finished manufacturing that design we looked at it and said, "We don't want to do that, it's not as safe as we'd like to see, and for sure we don't want to lose another motor."

WRIGHT: Did you explore using different vendors and manufacturers, or did you stay with the ones that had been chosen to do the original motor?

THOMAS: We stayed with the same suppliers because they were providing quality hardware and were not at fault in the accident. It was also more expedient to remain with them from a schedule perspective.

ROSS-NAZZAL: I did have a couple of other questions. Were there any new facilities built as you were working on the redesigned SRM?

THOMAS: Only the new test stands were constructed.

ROSS-NAZZAL: Did you make any changes to the manufacturing process at all?

THOMAS: There were changes made to accommodate the new joint design, but no fundamental changes other than improving the cleaning processes.

ROSS-NAZZAL: I think we have answered all the questions that I had come up with. Is there anything else that you think that we should know about the redesign effort?

THOMAS: No, I don’t think so. You questions were very comprehensive.

ROSS-NAZZAL: Well, we certainly thank you for coming in today. We very much appreciate it.

THOMAS: Good, I hope it will be helpful in your project.

ROSS-NAZZAL: Yes, absolutely.

[End of interview]