Mr. Lee Solid's

Oral History

Kennedy Space Center

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Roger Launius: My name is Roger Launius. It's the 27th of June 2001. We're at the KSC oral history project at the Kennedy Space Center Headquarters. We're talking to Lee Solid today and with me is Henry Dethloff and Lisa Malone. Let's begin by having you tell us a little about your background. Where and when were you born? You know what was your family situation like? What did your parents do? Things of that nature.

Lee Solid: Well I was born on a farm in western South Dakota.

Launius: OK.

Solid: And it was a wheat farm, but we had cattle and all the other things that farmers have. And in fact I was born right there on the farm and the old farmhouse is still there. We still have it as a matter of fact all these years…

Launius: It's still in the family?

Solid: And I went to school there. I went on to college. Really I went on to college on a basketball scholarship not even thinking I was going to do anything other than go back to the farm. But the basketball scholarship didn't work out. I had an accident and that was the end of that and I didn't play any ball. The team went on to do very well but I wasn't a part of it. It's there that I got interested in engineering, and I went on into engineering school and got a mechanical engineering degree from the

South Dakota School of Mines and Technology in Rapids City, South Dakota. And from there…

Henry Dethloff: Excuse me, what year was that roughly?

Solid: In 1958. My idea, all along I had just thought as the eldest son I would go back and my father had a rather large and prosperous farm and I was gonna just take it over and that was his plan and I guess it was mine too, that I never thought about really doing anything else. But once I got into engineering school I thought working hard to get this degree, I ought to go do something I ought to try it and so I did. I first went to work for an architect. And I had interviewed companies in my senior year in college but I really wanted to work in the architectural field. And my idea was that I would start my own company in mechanical engineering and I went to work for this architect but that only lasted three months. I get this call from Rocketdyne, at that time a division of North American Aviation, and they were desperately looking for young engineers and for some reason the specification was with a mechanical background and they particularly liked young engineers from the Midwest and so I guess they were out looking for us. And they gave me a call and I looked at myself and I am standing there in snow four feet deep and thirty degree below weather and I am saying to myself that sounds pretty good so why don't I do that.

Dethloff: That was California that called?

Solid: That's right…

Dethloff: Was that California?

Solid: …Right. And when they called and talked about swimming pools and palm trees and all that stuff I thought that sounded pretty good even though I didn't know the first thing about a rocket engine. I hadn't taken any courses in it. In fact the School of Mines where I went didn't even have aerospace related [courses]. I mean they had the traditional mechanical engineering, civil engineering, electrical engineering, whatever. And so the first day on the job out there they take me through the plant and where they're building rocket engines. I didn't know what nozzles were and injectors and all that stuff, so this was a real education for me. But I fell in love with the business immediately and so that's how I got into it.

Launius: Had you paid any attention at all when you were in school, I mean Sputnik is just a year before you graduate. Did that cause any excitement with you or with your classmates?

Solid: Well yes it did. Realize at that point in time and especially where I grew up we didn't have all kinds of television and so we didn't know a whole lot about what was going on. There weren't big newspapers but we knew about that. And I can recall the day that it was announced to us that they had just launched a satellite, I was in a lab

at the school and we all jokingly went to the windows to see if we could see this thing coming over knowing that well we couldn't…

Launius: Right.

Solid: …you know a hundred and some miles up. But I remember that. And yeah, we knew it was something very significant that happened. Did it affect my life goals and my choices? I don't think so. Even though when special presentations or seminars or things like that would present what was going on post World War II in the missile arena I was interested in it and I generally attended it just out of interest.

Launius: Right.

Solid: I had kind of made up my mind when I graduated that I was not going to go to work for an aerospace company or a farm machinery company. I'd had about all the farm machinery I wanted in my life. So I kind of decided that. But when Rocketdyne came along I did interview them and then ultimately went with them.

Launius: You'd mentioned a moment ago that they liked Midwesterners. Do you have any insight into why they wanted to recruit Midwestern engineers?

Solid: I don't know other than maybe in the years since, it is kind of amazing to me even the company that I was with, the senior executives that came from Iowa,

Nebraska, the Dakota's, Illinois, you know it really is kind of interesting. And to answer the question why? A lot of us did grow up on a farm. There's a sense of responsibility I suppose and accountalibility that goes with being a farm kid and that may have something to do with it. I was speaking with a retired Air Force general one time who chose people from that part of the country in his command…

Launius: Hmm.

Solid: And I asked him why he did that. And he had this answer, he said, "There's a mental toughness that I like in people from that part of the country." Now I can't explain it further than that.

Launius: Yeah.

Solid: But that was his answer.

Launius: Well it has something to say about the culture I think it's very interesting. You went to work for Rocketdyne out in southern California.

Solid: Yes.

Launius: What was the corporation like at that particular point? I mean it's a subsidiary of North American, which is a legendary aeronautical manufacturer at that

time. It's becoming I guess the major rocket manufacturer as well at this particular time. What was it like to work there, what was the culture like? How were the people to work with? Who were some of the guiding people that you saw in your environment there?

Solid: Well, as a young engineer fresh out of school of course I wasn't associating with you know CEOs and people like that; but this is in 1959. When I first got there we were told that the Navaho program has just been cancelled and that a lot of people would lose their jobs. Now those of you who we just hired, you're protected for a year. That's our company policy. So I mean I guess I didn't even know what the word lay off meant. I mean you know I'm just fresh out of school. And immediately we were thrust into the work environment. I was sent to Santa Susana, which is on the west end of the San Fernando Valley, where we tested the rocket engines, and I was put into a test engineering position and in no time flat was conducting rocket engine tests. This was all part of our training. And after a few months there, they put me into the development side of the house. Now Rocketdyne, I didn't know a lot about what was going on in the company; I knew that we were building engines for the Thor, for the Jupiter, which were being deployed in places like Greece and…

Launius: Turkey.

Solid: …and Turkey, and Thor, which were being deployed in England. And we were building Atlas and in fact the assembly line that they first took me to was an Atlas engine assembly line and I knew it was a big company involved in big programs and I

knew it was part of North American Aviation. And as I was there, why I learned more about what North American Aviation was doing and of course in those days the aircraft side of the house was a still a big operation. Space System's Division was just getting involved in some of the early activity associated with Apollo. And you know I just was focused on engines. Now I loved the development part of it where I could tell those test engineers what to test. And I first started out on a program called the X1, which was an experimental engine program that developed a lot of the special features that would come along later on the H1 and the J2 and others. And that program was cancelled in December of '59. The first year I was there, it was cancelled so they put me into Atlas engine development and it's because of that that ultimately got me to the Cape. I served there until one day they come up and said would you go to Cape Canaveral and help us launch the first of the new series of Atlas, the E series. And I looked on a map to see where Cape Canaveral was, I mean that's how much of a novice I was. I had never been east of the Mississippi, and decided that that might be an exciting thing to do so by this time I was married and we came here. That was in May of 1960.

Launius: OK, all right. So the Atlas, you working for the Air Force as a contractor at that point it sounds like?

Solid: Right, right. Everything on the Atlas was Air Force. They were the procuring agency and even what we were doing here of course was developing them as an ICBM and everything here was for the Air Force. Now within a short period of time, they started using the Atlas for some…

Launius: Right.

Solid: …for some space related you know, experiments…

Launius: NASA launches, right.

Solid: …and that's when the transition started.

Launius: What was it like when you arrived here? 1960, we've heard people talk about this place was essentially a swamp, not a lot here…

{Laughter}

Launius: What do you recall?

Solid: In 1960 when we got here, of course there were none of the roadways that we see around here now. There was very little shopping. We rented a little house down in Cocoa Beach, right off the beach. And this was all a new experience for us. We had to make our way to Cocoa to do any serious shopping like groceries and that wasn't always easy because it was a single lane and those bridges, they'd manage to stick open every so often. And so yeah, it was kind of primitive. There weren't condos. There were very few apartments. There were duplexes and small houses on Cocoa Beach and that's what we all lived in. Now they were starting to build in Cocoa and

Rockledge and people were living there. Satellite Beach was probably the first that really attracted homeowners.

Launius: Yeah.

Solid: And then Merritt Island started to grow.

Launius: OK.

Solid: In 1963 we built a house on Merritt Island and have lived on Merritt Island every time that we've been back in this area.

Launius: OK. Working for the Air Force with Atlas test work that you were undertaking here, what do you recall about the interface between Rocketdyne and the Air Force? Was it a smooth relationship? Were there difficulties? What were the challenges that ya'll had to deal with?

Solid: The Air Force, as I was to come to learn much later, is managed a little different than NASA. The Air Force contracted with us to do a job and then expected us to do it. The only oversight that we had was with whoever their SE & TD contractor was and in the early days it was STL. STL what does that stand for?…

Launius: Space Technologies…

Lisa Malone: Industries…

Launius: Laboratories.

Dethloff: Space Technology and Laboratories.

Solid: I forget. Anyway, it was STL and it would later become Aerospace.

Launius: OK.

Solid: And to this day it's Aerospace Corporation. But you know they had bright, sharp guys in each of the specialties that sort of oversaw what we contractors did. And so we soon learned that whatever we did, whatever technical decision we might make, whatever technical evaluation we might perform, that we needed to communicate with the SE & TD guy, STL, or Aerospace. But we also had our project management representative that we would keep informed. I don't know it was just sort of drummed into us, that you keep your customer informed. You let him know everything good, bad or indifferent that's happening. And everything will come out OK in the end. And so I don't recall of any bad relationships or strained relationships with the Air Force. Oh yes, everyone was different. I can remember in the early Mercury days the colonel we had to satisfy was a Colonel Mullady. You know, tough, tough guy, but we got along great. He had an affection for us rocket engine guys. He thought we were a special breed so he treated us very well and we treated him very well.

Launius: All right. We ran some numbers on launches and found that there was something in the neighborhood of thirty percent failure rate for this period. For all kinds of reasons. How did ya'll deal with failures?

Solid: Well of the series of Atlases, and I'll answer your question this way, the E series that I came down to support, three of the first four failed. And for different reasons, none of which were the rocket engines by the way. Now later on we would have failures that were rocket engine failures. And so we treated this as a test program…

Launius: OK.

Solid: And I guess I was taught early on that we are in a high risk business, a tough business. You know when you have a failure you learn as much about it as you can and treat it as a learning experience. In fact I learned that on the test stand, because more often than not we would have failures. In fact the very last test that I conducted before they shipped me out to Cape Canaveral we blew an engine up on a stand, and I recall standing there the whole night just tearing through data to see what we could learn immediately, before I got in the car and left to come to Cape Canaveral. I mean we were trained to deal with failure. We were also trained to be as safe as you can be…

Launius: Sure.

Solid: …and so people didn't get hurt in this process. But you knew that you are pressing the envelope and you were going to fail now and again. And we did that. After a failure we would go out and we joke about this but it's absolutely true, we'd go out and pick up the pieces depending on where it blew. And more often than not, it blew in the very first few seconds. And we'd go out marching through the palmettos, and up and down the beach, and we'd pick up pieces, and we'd bring them back, and we'd lay them on the floor in one of the hangers and try to dermine just where the failure occurred. I can recall one of them, as we brought the hardware in, now this one made it to the ocean, and so we had a team out there that was pulling hardware out of the ocean and I was particularly interested in seeing the pump on the sustainer engine. I just had this gut feeling that we had misinstalled an instrumentation transducer. I don't know why I felt that way, but I did. So I was really anxious to see this piece of hardware, and sure enough they brought the pump in and here's this burned off stub in the wrong port. And so on one like that we knew exactly what had happened, immediately upon finding one piece of hardware. And it was an error. I mean the drawing was clear as to what we should have done and we didn't do it that way. Now the vehicle contractor did all the work. Us Rocketdyne engineers we just gave them instructions on to what to do.

Launius: Sure.

Solid: So this was probably the first time where there was a little bit of a problem between the contractors. You know who's really at fault here, the guy that gave the

instructions or the guy that actually did the work. But we would deal with those, and the Air Force would expect us to deal with those.

Launius: It sounds like there was a general acceptance that this is a difficult thing to do. We're in the learning mode, pretty serious learning mode, and that there's going to be failures. And there was, obviously there are repercussions whenever you have a failure, but an acceptance that you're going to have them. And there's going to be mistakes and that you're going to learn from those, and press on. That seems to have been the case. Is that true?

Solid: That's true. The mentality was development and test, and they went together. You're developing a piece of hardware for a given mission and you gotta test it. And the test is the proof of the pudding. So they all went together and when the test failed it was just a glitch in your development process. You figured out what you did wrong and charged ahead.

Dethloff: Excuse me, and that was an engineering mode of operation. That really had nothing to do with Air Force or NASA, that was part of your training and part of Rocketdyne, just the culture that you were in.

Launius: The approach to how you did your work.

Solid: Yes. That's the short answer, yes. I can expand on it by saying it seems to me like in those early days of really hard development where we've taken a new system that was designed for a specific mission that there wasn't, of course there political ramifications and there was politics involved, but you know us engineers as far as we were concerned the hardware was either right or wrong, and if it was wrong, you had to do something to fix it. We didn't worry ourselves with the politics or the cost, somebody way above us was…

Launius: Was worrying about that.

{Laughter}

Solid: …was worrying about those things. I would ultimately come to know…

{Laughter}

Launius: Yes, that's undoubtedly true. 1961, John Kennedy stands before Congress and the American public and announces we're going to go to the moon by the end of the 1960's. What was the reaction of the working engineers down here at the Cape when they heard that kind of story? I mean you obviously remember it. So did you guys talk about it?

Solid: Yes, we did. And it's interesting, I was thinking about this when I was told that these kinds of questions would be asked. We were not cynical in those days. We had a can do attitude that you know I think we accepted the challenge. Now personally it's like when we put Alan Shepard on a Redstone, I could not reconcile within my own self why we were doing that, this soon. I thought that was highly risky, I did not believe we were ready to do that. I mean we had just blown up a Redstone and we had blown up a few other things and I just didn't think we were quite ready to do that. I remember leaving work that day, I was working on the Atlas program, went home got my little eight millimeter camera, went out on the Jetty because we couldn't have cameras on the base, went out on the Jetty, and I still have my little eight millimeter shot of that Redstone launch somewhere. Because I wanted to record history, and it went, and it went great. Any fear that I had, I think that first launch took care of it. But we did not believe that we couldn't do what we were being challenged to do by President Kennedy. Even though I wasn't in that side of the business, I was on the Atlas program and completing the Mercury program, and then I became the lead engineer, and then I became the base manager before the Gemini program was over. And so I got involved with that because Rocketdyne did build all of the OMS and RCS on the Gemini capsule itself. So I got involved in those programs quite deeply and then ultimately on to the Apollo program. But we did not believe it couldn't be done. And we were just charging ahead to do our part. And it's kind of amazing, we look back on it now with a little bit different attitude perhaps, and that is we look back and see what kind of energy and resources and money and the numbers of people that were employed. And you see it

certainly was an all out effort, and we look at it now with a certain amount of envy you know…

Launius: Right.

Solid: …that those kinds of resources could be made available to do something. At the time I wasn't in a position where I was thinking about it from that standpoint so much. I mean we had to develop the largest engine that had ever been conceived by mortal man. The F1…

Launius: Right.

Solid: …and I was still at Santa Susana just before I left in 1960, May of '60, and witnessed the first test of the F1 engine. All it was, was an injector and a boiler plate nozzle, but man, after we ignited that thing, all that was left was a ten foot hole in the ground.

{Laughter}

Solid: I mean it rattled the whole of Santa Susana. In fact I was over in an adjacent test area, and I mean it rattled us good. After that we moved the test of the F1 out to you know the rocket test site at…

Launius: Oh yeah.

Solid: …at Edwards. But, so I was there for that first F1 test. We had a long ways to go and a relatively short time, but it was amazing, in the development program where one problem after another came up and we would deal with those. And it was kind of amazing that we could develop those engines and those systems and put them on vehicles and test the vehicles and get them down here and launch them in that time frame.

Launius: And they worked.

Solid: And they worked.

Launius: Yeah.

Launius: At some level there seems to, I've heard from people like Max Faget for instance who made the comment he said, "You know a lot of us were very young and there was a sense that anything was possible if we just put our mind to it." Would you agree with that?

Solid: I think that's kind of what I was trying to say. We never saw a single launch as a failure. You know it was just a single launch failure, as a setback really. It was just a step in this process, and we would overcome that, we'd learn something from

it, and we would move on. And that's just how we felt, that was our mentality. I think the whole development of the Apollo was pretty much with that same mentality of the whole Apollo program and all of the components. We can do this. And you know it was a pleasure to be a part of it.

Launius: You bet. They began, they launched Atlases with John Glenn and the other Mercury astronauts aboard for the orbital flights, that's directly your program. What did you think about all that? How did you go about, I guess, ensuring that your part of the world that you had to deal with, the engines itself, that they were checked properly, and rechecked, and so on because you now have a person aboard.

Solid: Well you know we went into a program that, where we certified the hardware as man rated. And that meant that you gave a little extra attention to it. When you tested you analyzed the data a little deeper, you instrumented the acceptance test hardware a little more. So you had more data. You were very careful in your selection of the hardware. And so yes we did treat it different. As it turns out it was the same hardware, it just got a little bit more scrutiny and a little bit more attention. I mean we didn't go in to the manufacturing line and say, okay this particular valve body is going to be allocated to the first manned flight, I don't think we did that. We selected the hardware and then just gave it special attention as we were putting it together and assembling it and testing it. I mean we certainly understood the gravity of what we were doing and importance of what we were doing. And I was on launch pad fourteen through all of the attempts that we made. You know my seat in the blockhouse was

next to Scott Carpenter's, so I got to know him very well and we talked about the things that could go wrong. And we of course recognized that the engines represented the highest potential for catastrophic failure simply because of the pressures and temperatures and speeds and so forth that you're working with. So yeah we gave it extra special attention, no doubt about it. Now after the John Glenn launch we blew that Atlas out at Sycamore Canyon, which was the Atlas test site, and what happened there was the inducer to the sustainer rubbed and when you have rubbing in a pure oxygen environment you will have an explosion. And we did. And of course it initiated right there at the inlet of the sustainer. Now we went into an immediate program to make sure that we could continue launching Atlases down here. That it wasn't going to happen on these vehicles what happened on that one. And almost overnight designed a kalif (?) liner to put in the inlet and tested it and installed it in the hardware down here before we launched any more of the Mercury astronauts. And that was an incredible program because it was done almost overnight. To design something, and build it, and test it, and certify it for manned flight. You know an incredible program.

Launius: Right.

Solid: And so those were the kind of things that we had to do to keep that part of the manned program on schedule.

Launius: OK. In dealing with NASA versus the Air Force were there differences in the way in which you interfaced with them? Did NASA do things differently, and how so? I suspect they did at some level.

Solid: Well you know the transition down here for me in working for the Air Force to NASA was really on the Atlas and Thor program, which would soon become known as the Delta program and the word Thor disappeared. As the Goddard guys took over, the Goddard Launch Operations under Bob Gray took over here, and we started working with that NASA first and then there was the Lewis folks. Let's see Lewis was on the Atlas and Goddard was on the Delta. And so our interface with NASA started with those two centers. Then the Saturn I program came down here and the NASA folks that were here were part of launch operations command, or launch operations division, as I recall which was a directorate of the Marshall Space Flight Center. So our first association with NASA was Goddard and Lewis, their launch operations people and then the Marshall Space Flight Center and their launch operations people and then of course that launch operations directorate would become the Kennedy Space Center.

Launius: Right.

Solid: And, yes, our interface was a little different. I can't say that the early days on the Atlas when we working with the Lewis folks, it was like working with the Aerospace people or the STL people. They were strong technical people in the specialty and they always picked a guy that knew propulsion and knew rocket engines,

and so he could ask the right questions and keep us on our toes. I don't know that it was really that much different with NASA in those early days. Now as time would pass, yes the relationship with NASA, as NASA built up and became a full blown center here we Rocketdyne, since Marshall was the procuring agency for the hardware on the Apollo, the engines, the F1's, the J2's, the H1's, and they also bought the support.

Launius: Yeah.

Solid: And whether we were supporting Chrysler on the S-I and the S-IB or McDonnell Douglas on the Saturn IVB, or Boeing on the SIC, or our sister division, Space Division of North American Aviation in the early days, in 1967 it would become Rockwell, because that's when the merger took place. Whichever one of those vehicle contractors we were supporting, our services were paid for by Marshall. There was that competition between Marshall and the Kennedy Space Center, especially since Kennedy had now broken off and become a full-blown NASA center. For example the J2 project manager at Marshall might direct me to do something down here on the J2 engines, and Hans Gruene, who was running the launch side of the house and his man Andy Pickett, who was the launch vehicle operations guy and Ike Rigell, the chief engineer. I'm throwing names out here…

Launius: Right.

Solid: …that you should be familiar with…

Launius: Yes.

Solid: And they didn't want the project manager in Marshall telling us down here what to do on engines that were here. You know, in the test stand or on the launch pad. We, the contractor, had to be real careful how we did all of this, and so I developed relationships with these key people and I made sure they understood what the directions were and got Marshall to put a system in place that would indeed get directives from the Marshall Space Flight Center to the Kennedy Space Center…

Launius: To these guys.

Solid: …to these guys as opposed to us…

Launius: Right.

Solid: …So yes, we had to deal with those kind of things. That was just part of the job. By this time I was the Base Manager for Rocketdyne down here and so everything we were doing on the Delta, on the Atlas, on the S-IB, the S-II, the S-IVB, and the S-IC, everything we had, you know, even the small engines on the Apollo fell under my perview, in those days.

Dethloff: Did that get smoothed out pretty well in time, the relationships between the centers and KSC, with you in the middle?

Solid: Yes, it did. You know we put processes in place; special requirements. I can't even remember, you know everything has got an acronym in our business, and all of these things had acronyms and I don't even recall. But there were processes we put in place that were actually directives to go do something. And Marshall had a relatively large resident office here, and they put good people in that office that I think strengthened the interface. So it was the kind of thing you couldn't afford to have a battle.

Launius: No, right.

Dethloff: That's right.

Launius: It's counterproductive to do your task.

Solid: Right, right. We had a lot to do, and a short period of time to do it.

Launius: One of the things that George Page told us yesterday was that there are procedures, you can put procedures in place, but that does not substitute for the interpersonal relationships that one has to another person. And all the procedures in the world won't work if you don't get along with each other, and I'm assuming that you're saying kind of the same sort of thing.

Solid: Right, exactly. From early on, from the first responsible position that they put me in, I realized that when there was some kind of a glitch, if we had a failure on a test stand somewhere and the word was going to get out, I needed to notify the right people immediately. And I never held anything back. I was chatting with a guy one day here several years ago and he said my recollection of Rocketdyne is that all you guys from the technician to the program manager, you all knew what was going on. You must have had an incredible communication system, and all I could say was, we did. There were no secrets. If we had a problem on an engine somewhere, the word was out, and because it might have an impact. To this day, on the SSME it's amazing how these things come up just before a launch. We were going to launch a shuttle out here in a couple of weeks, and there's probably going to be a problem on the test stand out at NSTL that's going to cause people if there hasn't already, that's going to cause people to wonder how it's going to effect this launch. It seems like the business is just sort of like that. You know all the time that you're testing engines, you're going to find little funnies that you got to go explain. And why does that not exist on the one you're about to launch. And so it seemed like our communication in those days, since we had so many engines, and we were testing so fast, and we were testing at the single engine level, and we were testing at the cluster level, and they were testing at the Mississippi Test Facility it was called in those days, and we were testing at Marshall Space Flight Center, and we were testing at Santa Susana and so you know we were just testing everywhere. Every time there was a test glitch, I knew that I had to tell the guys I've mentioned to you. I needed to tell Hans Gruene and I needed to tell Andy Pickett. In those early Apollo days, you know, about the problem.

Launius: Right.

Solid: And it kept me out of loads of trouble.

{Laughter}

Dethloff: OK. So Gruene and Pickett would be your main liaison, contact people for KSC.

Solid: In those days, that's right. I mean we had each vehicle contractor that our engines were on, I mean there was a guy at McDonnell Douglas, a guy or two in each of the vehicle contractors, that we had to let know immediately. I just learned to do that, that was just part of the job.

Launius: Along the same lines, and I'll just emphasize this, cause it sounds like it's what you're saying. Tony Spear who was a project manager for the Pathfinder project that landed on Mars said, "Nothing substitutes for communication with the team. It's just like a marriage. You got to talk to each other all the time."

Solid: Well, that's right. Yeah, a lot of those problems, it was interesting. Dr. Debus liked to get into the hardware. And in some of those more significant problems, why I would get the call that you need to get up to Dr. Debus' office and explain this latest glitch. Of course, you see in those days we didn't have computers, and email,

and Power Point. What I had was the latest technology, which we did get all of our drawings on engines on microfilm. And I could print out on a machine in the office the drawing and I'd roll those things up and I'd go into Dr. Debus' office and it was laid out pretty much like its laid out today, and I'd throw those drawings out on the coffee table and he'd get down on his knees and I'd get down on my knees, where you could see this and I'd explain what the problem was. We had enough problems that I had to do that several times.

Launius: How was Dr. Debus to deal with? What was your sense of him as a leader and as a person in charge of the Center?

Solid: Oh, I think he was absolutely the right guy at that time in history. And you know from a personal standpoint, that was really my only association with him. He had a feel for rocket engines. He had a special place in his heart for us rocket engine types, too. So this was a release for him to get into the nuts and bolts of a rocket engine. So yeah, I really admired the guy.

Launius: January of 1967 the tragic Apollo fire takes place here, which of course, the engines had nothing to do with, but do you recall where you were and what you were doing when you heard about that, and how did it effect the folks around here?

Solid: Yes, I know exactly where I was. We had been invited to the neighbors that night for dinner. I had just walked over there and it was next door and we had

forgotten something, so I walked back to the house to get whatever it was that we had forgotten to take with us, and the phone rings. Our people were in the blockhouse, our J2 people were in the blockhouse, and so this was a call from my lead engineer on the J2 program, telling me that there's just been something really bad happened and we're not sure what. So that was the first indication, and of course, from that point why we got the information several different ways. You know it came out on the radio within the next forty-five minutes or so, there was a radio report, and then it went from there. Yeah, I remember it very well. And yes, it was tragic, there isn't any doubt about it. I have to separate out how we felt at the time, as opposed to how we might have felt later after learning more about what caused it. What some of the really deep deficiencies in not only the design, but in the testing, and in the processes associated with it, in the relationship between the contractor and NASA, etc., all of those things. And you know, books were written, and so I have to separate out those feelings. If I go back to the time itself, we recognized this as a tragic setback. In fact, I guess, I was one who believed we had just done it in our quest to get the moon. You know, by 1969 or by 1970. And even so, with a test, and get on with it mentality, I knew that we would turn around. But it certainly was a tragic event and I went to all the ceremonies and I remember it because of how sad it was. I would later chair the Astronaut Memorial Foundation board and spend a good deal of time with one of the astronaut's wives and in hearing her feelings and so forth, I got some different impressions about what really happened. And so this is why I say we have to go back to that point in time. It was another serious test failure…

Launius: Right.

Solid: …that we had to deal with and as history will record we certainly did, and turned around and still made the goal. But yes, probably…

Launius: OK.

Solid: …the low point, very definitely the low point, in the program.

Launius: I've been doing a little searching for information about the recovery, and how people felt about the recovery from the Apollo accident and one of the things I've been looking at is political cartoons. And I found that except for the Apollo 11 landing, which is where there is political cartoons everywhere, Apollo 7 has the largest number and the most positive that exists for all of Apollo. It seems to suggest to me that along with other data that the Apollo 7 flight really does signal a return. That we recovered now from the accident and those guys went up and did the earth orbital mission as was supposed to, and the hardware performed like it was supposed to, and of course the next mission we went to the moon. Was there a sense here at the Cape that with Apollo 7 there was really a return and you all could make this deadline to get to the moon by the end of the decade?

Solid: Oh yes. There wasn't any doubt in our mind that Apollo 7 was a key milestone. At the same time I don't think there was any doubt in people's mind that we

weren't going to be successful. Once having defined the weaknesses and the design problems with the capsule itself, having once determined what those were, the ability to build new hardware and turn it around and put the system together and test it was almost a given with the kind of mentality that we had, us development, test kind of guys.

Launius: The landing on the moon on Apollo 11 in 1969 obviously is the high point, the triumphant point of really, of space flight to be perfectly honest. How did everybody down here relate to that, where were you, what were you doing, and what was the reaction here? I'm sure it was a great source of pride for everybody.

Solid: Well, there isn't any doubt. As we were preparing the hardware, having the status meetings, and the reviews, and all of the things in the process, I was the Senior Executive for Rocketdyne here in those days, and so I was reporting, the guy that had his thumb on me in those days was Rocco Petrone…

Launius: Oh yeah.

Solid: …and, he would for some reason, in every one of his meetings, why he'd make sure that us rocket engine guys were ready. And he'd really probe us. And I found myself having to learn more about F1's and J2's, see I'd cut my teeth on a different system. The Thor, the Atlas, the H1, were basically a family. Then the J2 comes along as the first LOX hydrogen and so I had to really spend a lot of personal time learning…

Launius: Yeah.

Solid: …that J2, if I was going to represent it to guys like Petrone. And then that F1 used a lot of technology from the Atlas and the Delta so forth and it was basically a gas generator cycle engine and all that. But it was so big and it created other kinds of problems like the infamous rough combustion problems that we had to deal with. And so Rocco would really press us, and he never let us forget what we were doing. And that this is the hardware that's going to take these guys to the moon. And so, yes, we put extra effort into it. I spent more time out on the stand in the VAB and out at the launch pad. You know, even though we had responsible people in each one of the systems, we had a special focus on that hardware and that point in time.

Launius: I have the sense from talking to other people like Tom Kelly, and George Page yesterday said this as well, the workload was enormous during this period, mostly because you felt the clock ticking. That you had to be successful and so sixty hour weeks were not uncommon, people's personal and family life suffered, and so on. Is that the experience that you're familiar with as well?

Solid: Well yeah, we put in a lot of long hours out here. There isn't any doubt about it. And it was just sort of expected. I can recall working Saturdays and Sundays just on the engines so that we wouldn't be the long pole.

Launius: Right.

Solid: And at the same time you didn't want to do anything to keep from being the long pole, you didn't want to do anything that was going to compromise the performance of the hardware. And so it wasn't a matter of ever hiding anything or suppressing any data, you just worked that much harder to make sure that everything was working the way it was supposed to work. But yes, there certainly was a tax on families. And I look at my career and my life, about all I did was work and raise a family.

Launius: Yeah.

Solid: And I didn't do much of anything else and both of them turned out OK as it turns out.

{laughter}

Dethloff: But you stayed excited, intense, committed through it all.

Solid: I couldn't think of being involved in anything more exciting than what I was doing. As a farm boy I never thought about anything like this. This is just way beyond anything I'd ever dreamed of. And so, yes, I was doing the most exciting thing I could think of and I wasn't about to let anything happen that was going to diminish my company's role or my people's role or my personal role in this. We didn't want the engines to inhibit what we were trying to do here. So those engines, I mean we really

focused on those engines in that first launch. Boy an engine failure would just be devastating.

Launius: Right.

Solid: To not make this goal because somebody screwed up on an engine would just kill us.

Launius: You made a comment a moment ago about not being the long pole. And that's a very interesting one because my suspicion is that each of the groups with the responsibilities for the various parts of the hardware all felt the same way.

Solid: Yes they did.

Launius: …and there was a competition perhaps…

Solid: Right.

Launius: …to ensure that we're not the cause of this delay or failure.

Solid: Right. See early in the Atlas program the Air Force had a process that involved what was called a flight test working group, FTWG, flight test working group meeting. And the last one before a launch was the key one where we went in and

declared. It was like a flight readiness review today at a much, much lower level. But we had to declare that our hardware was ready to go. Invariably, and I won't mention the contractor, but invariably one contractor would be having a problem and nobody would know about this problem, and they would hope that I can get this problem fixed before the launch or somebody else will have a problem and I can fix mine under this umbrella. But more often than not, it would bite them. We'd get to that last flight test working group meeting and everybody would be ready to go, and so they'd have to own up. And sure enough…

Launius: At least they owned up.

Solid: …we'd slip a day or so. And so yeah, every one of us contractors would play that game. But we decided in Rocketdyne if we had a problem we were going to tell people about it. We just couldn't not tell people about it. So that was our practice and it served us well.

Launius: Yeah. It seems like we're just about out of time, but we'll go on for a couple of minutes yet. OK, we've still got eight minutes. The difficulties that you had to overcome in terms of flying to the moon, you know taking the Apollo hardware to the moon. Were there any particular challenges that stood out that had to be addressed, any particular anecdotes about those that you'd like to relate?

Solid: Well, each engine system had its critical failures that we had to overcome. I mentioned the one on the F1. We had to deal with a rough combustion and we had to bring in specialists from a lot of places to help us deal with that. Of course that meant designing new hardware and getting in to test and redoing a lot of what we had already done in the development of the hardware. The thing that I remember most about the J2 was the incessant problems that we had with the electrical control assembly. And I wasn't an electrical type and so I couldn't contribute much in solving those problems. But it seemed like that we were hauling electrical control assemblies back and forth to California with great frequency. And what we would do, is that we would pick our biggest technician, a guy that was large enough that he could carry one of these things, because it was about this big around, about this high, and I don't remember about how many pounds it weighed, and we would buy two seats on an airplane…

Launius: And make him carry it with him.

Solid: …and in those days we had direct flights from Melbourne and we would take this electrical control assembly and we'd sit it in one seat and put the seat belt around it and we'd put our big technician that could…

{Laughter}

Solid: …carry it, and we'd put him in the next seat. That's about the only anecdote that I can think of you know.

{Laughter}

Solid: But we did things like that, to make things happen. Beyond that, I don't know, it seemed like business as usual. The rocket engine business was never dull. You know we were dealing with some kind of a technical issue all the time. Over the years you'd hire a fresh young engineer and before very long you'd determine what kind of an analyst that he was, on the basis of his approach to defining a problem and resolving the problem. And when we found one of those kind of guys we'd set him off to the side here, and we just kept pumping data into him so that he could analyze this problem while we were off doing other things. And we had several of those kind of guys, and those were the guys that ultimately told you what you had to go do to fix it. And so, the rocket engine business has always been exciting. We never lacked for anything to do and we never lacked for anything to challenge our brain.

Launius: OK. We need to wrap up this portion of it because she's going to have to change tapes.

Solid: OK.

Launius: So we'll take maybe five minutes and stand up and stretch and we'll swap the tapes out and we'll carry on. Talk about the shuttle so forth.

Solid: OK.

Solid: I was just going to say it took a Rocco kind of a guy to pull the forces together down here and provide the energy, and he did that.

Launius: Well I've heard he was really hard.

Solid: And he was.

Launius: Yeah.

Launius: You mentioned a few moments ago about working for Rocco Petrone. How was he to deal with? He's one of the legendary figures in NASA history, so what was your experience with him?

Solid: Rocco, you know, was the driving force, in my estimation, in the program. And once he came out of the program side and into the launch directorate side of things, there wasn't any doubt in anybody's mind as to who was in control. We had to satisfy Rocco. And I am one of those who believe that it was Rocco's management style and his energy that to a large degree pulled this thing off. And even though he wasn't the most popular individual with a lot of people there wasn't any doubt in any of our minds of who we had to satisfy. And he certainly motivated me. And in fact, it was Rocco that caused me to burn the midnight oil and learn as much as I could, and be as up to speed on everything in the engine world at all times, because Rocco had a knack for being one step ahead of you. And if we had a failure on an engine at the Mississippi

test site however he knew I don't know, but he might probably would be the one that would know about it first.

Launius: Really?

Solid: And so I would work hard to stay abreast of what was going on in the program and what the impact might be to us here. I didn't inform him directly as I said before, for the most part my interface was Andy Pickett and Hans Gruene. They kept him informed.

Launius: OK. You mentioned there was one instance where you got called on the carpet by him, would you like to relay a little about that?

Solid: I was sitting in a flight readiness review and I get this tap on my shoulder that I am to be in Rocco's office in thirty seconds and since he was just downstairs from where we are here on the second floor I could make it in thirty seconds. And I came in and he and Andy Pickett were there and I got the lecture on allowing our people to do work down here on a directive from Marshall without the Kennedy people knowing about it. And I got the lecture, and I understood the rules, I just thought that when I directed my people to change out this inlet duct on a J2 engine that the other communication had taken place between the two Centers and it had not. But that was the kind of thing, he did not, if he were a football coach, you know, Vince Lombardi had this philosophy

that if a player makes an error on the field, he knows it, all the other team members know it, a hundred thousand fans in the stands…

Launius: …Right…

Solid: …know it, and everybody watching on TV know it, but you still got to talk to him about it…

Launius: Yeah.

Solid: And Rocco was like that. And I knew I was going to get the lecture and I knew he was right and that I was wrong. But he was a step ahead. And he managed to keep the team here highly motivated and focused on what we had to do. There was never any doubt. I recall one night a meeting started probably at 1:00 and we were still in his conference room directly below us and it was getting dark and a full moon was coming up over here, and he turned around and with his back to us and he sat there for a few minutes looking at that moon and we just sat there knowing that he was going to say something, and sure enough you know he did. And it was something to the effect that within six months, or whatever it was, I don't recall, that's where we're going to be. I hope you guys know that that's what we're all here for. And it was that kind of thing, now there's a couple of points there, one he didn't have short meetings…

Launius: Yeah.

Solid: I mean if we started at 1:00 and we were still there late enough to see the moon, that was sort of typical Rocco. I had great admiration for the guy.

Launius: But at some level his management style was not all fear and intimidation I assume.

Solid: Well he would ultimately leave government service and he became the Senior Executive of the division of Rockwell that I ultimately would work for. I didn't report to him directly when he was there, I reported to the man that replaced him as the Senior Executive of that division of Rockwell. But when he came to industry, yes, I believe he slacked off a little. He was a typical theory X manager and even though he remained that way coming in to industry and being responsible and accountable for a major chunk of business in a rather major company, he got put in positions where he certainly had to perform a little bit differently.

Launius: OK.

Solid: And from all that I know he did well as a senior executive in industry.

Launius: Apollo is successful, obviously we land on the moon six times altogether, and the program and NASA in general starts to decline in budget. Actually a little earlier than the landings, but by 1969, 1970 there's starting to be an aerospace recession. How did that effect Rocketdyne and the people that were working with you?

Solid: Well, significantly, because in very short order Rocketdyne that had an employment of about twenty thousand went to thirty-five hundred. And yes, there's the classic stories of engineers who couldn't find jobs as janitors…

Launius: Right.

Solid: …you know, in southern California. But several of the companies were in southern California that were involved, McDonnell Douglas, our sister division, Space Systems Division. After Apollo 13 the company moved me back to the home plant and to a nice promotion, I guess this was my reward. At a time when the company was really going down, there was a little resentment to that in some of the ranks. But so much of my job even taking over a division of our company was to reduce folks. I became the director of what was called the Field Engineering and Logistics Division, that was what it was called then, now its got a different title, but the field site still reported to me, this site, the Mississippi Test Facility, Vandenberg, anything outside of Rocketdyne proper reported to me. In fact we even had a small office in Japan as we were starting to sell technology to the Japanese. And so I was engaged in the sort of depopulation of the Apollo program at the field sites as well as at the home plant. And yes, it affected us greatly, we went through not only cuts in people, we went through cuts in pay. We postured ourselves so that we would be competitive on the space shuttle main engine program. So all of those were hard times for people in management. Now the Apollo program of course, yes, it's amazing how fast the excitement and the general public acceptance of what we were doing diminished. And

that's been discussed and written about and I've got my own personal opinions about it. But I think that the Apollo program did what it was designed to do and went as far as it needed to go for that particular mission.

Launius: What do you think accounts for, you said you had your own opinion, accounts for the, kind of the decline in interest I think in the public perception of Apollo as it went through the program. Apollo 13 is the last instance where's there a lot public interest in it, or so it seems.

Solid: Well, it became for some reason the public wants to be engaged in the exciting thing, the new thing now. And it just so happens that Apollo became old very quickly. Yes each mission did some more things, stayed a little longer, traveled a little further, explored a little more, but you see that was routine. And the public interest really, really declined. In fact, the excitement associated with a launch, you know it, there was a time when people ran out of their places of business here, where they wouldn't miss a launch. Then it got to a point, where you heard it, oop they're launching another one out there. And then after awhile, why yeah, you heard it but you didn't say anything about it. I mean it just, as the routine takes…

Launius: Right.

Solid: …over and the interest declines, and it just was sort of a natural thing.

Launius: Yeah.

Solid: Now we…

Launius: Very much like…

Solid: …In my personal opinion, we didn't in the industry and in the agency, we probably didn't do enough to keep the interest alive. We didn't publicize what we were doing to the depth that we should have, or in the forums that we could have, to have kept more interest alive. Because this thing went from an exciting race with the Russians, to now a program, and hey, we accomplished what we set out to accomplish, what's next? It isn't so much what have you done, but what have you done lately, and what's next?

Launius: Right, right…

Solid: And we didn't really come up with exciting things next to peak the interest and keep the interest and so how much are we to blame or how much is this just the natural order of things. The first, I am sure that it was exciting, the first model T that came off an assembly line. But the hundredth one was dull.

Launius: Yeah, yeah.

Solid: I mean you know…

Launius: Well, what you describe is what took place in aviation as well. 1908, 1909, 1910, everybody ran out the door to see an airplane flying. You went off to the air shows; it was a big deal. Nobody pays any attention to them and hasn't for a long period of time, when there's take offs and landings anymore, its routine.

Solid: Right, and we just complain about the service we're getting or not getting.

{Laughter}

Launius: In some cases there are reasons to complain.

Solid: Or the delays or the cancellations, or the, yes…

Launius: It's just a part of the infrastructure today, and nobody thinks about it.

Solid: Right.

Audio: Part 2:

Launius: When you went out to Canoga Park out in California in the early 1970's, you mentioned that a part of your job was essentially to reduce the size of the workers

associated with Rocketdyne, but you also did some other things. What were your principle projects that you were working on?

Solid: I stayed in that job a relatively short time. The company came up, by this time this is 1970, the merger between the Rockwell family and the North American Aviation family was well under way. And the goal of course was to get aerospace related technology into the private sector and vice versa. Get some of their management techniques and so forth into what we do in aerospace. And all of those were grand plans; they didn't work out too well. But I was part of a small group of people that they wanted to transition into the industrial side of things. So they put me on a program where I would spend six months in a function to learn. For example, they decided that I knew enough about design and development and tests and operations, but I didn't know much about manufacturing and I didn't know much about the financial end of things, I didn't know much about procurement and contracting for jobs and that sort of thing. So I was to spend six months in each of those and once I got through those, I was going to be a plant manager at one of the industrial sites that…

Launius: OK.

Solid: …that Rockwell had out in the field. I went through the first one which was in advanced programs, or in procurement. And largely what we did was expedite the hardware for the first, by this time we'd won the space shuttle main engine.

Launius: Right.

Solid: And I was on the proposal team for that by the way and on the Red Team for that proposal, mainly from an operation standpoint. But then after that, I spent my six months in procurement learning how to procure hardware. And we were trying to make hardware for the space shuttle main engine out of materials that had never been used before and so it was a tough job. And I learned a lot about procurement; I learned that I do not want to make this my career, I learned that. But anyway when that was over I went into advanced programs where we were already talking about new rocket engine concepts, and that was exciting. About halfway through that six month period we had really gotten in trouble on the space shuttle main engine. We were already in trouble building our facilities, we were in trouble in meeting our budgets, and we were really in trouble on this complicated new electronic control device, that was referred to as the controller. And those three things caused a boarding party to come to Rocketdyne and see why we were not performing.

Launius: This is the boarding party…

Solid: …the boarding party…

Launius: …from NASA?…

Solid: …the boarding party from NASA. And it was engineered by my old friend Rocco Petrone…

{Laughter}

Solid: …who, by this time had become the Center Director at Marshall Space Flight Center, and he went in there and made significant changes. The engine project manager, the systems guys, all of those names changed almost immediately upon Rocco getting there. And Rocco was very disgusted at Rocketdyne and our early performance on the space shuttle main engine. And so the senior executive of Rocketdyne decided that since Rocco was an old friend of mine, and that I had a communication channel to him, that I should represent him to Rocco at the Marshall Space Flight Center.

Launius: OK.

Solid: So they asked me to go to Huntsville. And the first two times they asked me to do that, I turned them down. The third time was one of those, your paycheck is going to be in Huntsville and if you'd like to get it…

{Laughter}

Solid: …you perhaps should travel there. And it was one of those kind of things. And so I went there to try and help the company out of this bind that we were in on the space shuttle main engine. Rocco was only there another, I think, four months after I got there. So my very reason for being sent there was basically gone. But I stayed there and helped manage the operation up there as we transferred some of the work up there, we did some subscale testing up there. And I brought down a couple of really sharp guys on engine systems that could interact and interface with the Marshall development team on the engines and I feel good about the time I spent in Huntsville in helping recover with some of the early problems that we had on the space shuttle main engine.

Launius: The SSME is the most sophisticated engine ever built I think…

Solid: Yes.

Launius: …I don't think that there's any doubt about that, even the F1 is…

Solid: Well, and I've said it many times, and I still feel this way. That the space shuttle main engine, is probably one of the most complex devices ever conceived by mortal man. I mean it is incredible in its technology. There still is no technology been developed that surpasses what we've done on the SSME. Yes, Rocketdyne is building the RS 68 and for the Delta 4 and yes, we've learned much about materials, and about some critical manufacturing techniques, but we learned most of those on the SSME

because it was indeed an incredible design and an incredible device. It's got to be the highest efficiency mechanical device that's ever been operated. And I don't know of anything to ever come along, nobody's ever refuted that claim. So yes, incredible device. As a matter of fact it's so complicated we came up with an engine system for an orbit transfer vehicle that was a stage combustion cycle like the SSME is and people that had to evaluate whether or not you procure something like that said "Look, that particular system is so complicated and so complex, that its hard to deal with it on the ground, let alone having to deal with it starting the first time on orbit." And so there probably will not be that complicated of a system ever put into orbit. I may be wrong, but the systems that they're coming up with now, the systems that various folks are buying from the Russians, they're not stage combustion cycle systems like the SSME.

Launius: Right, right. Yeah this is the one that they put on the Atlas, the Russians…

Solid: Right.

Launius: …yeah.

Solid: And let me just finish that story. I stayed there until it came time to start doing things down here and the company asked me if I would come back here and set up Rocketdyne's operation for the space shuttle main engine down here. And again I was kind of reluctant to do that, I'd been here, I'd lived through a very exciting launch

phase, and so I would have probably accepted a position somewhere else if there had been one. But, with my family, decided to come back here, that was in 1979 late, and so I've been here ever since. I ran the Rocketdyne operation here, through the 80's and in 1990 I became the senior executive of the Space Systems Divisions Operation here, which you know, they were the designer and builder of the orbiter and we had the logistics depot down in Cape Canaveral.

Launius: Right.

Solid: And by this time, this was all a Kennedy Space Center contract. And in this whole period Kennedy Space Center became a major procuring agency…

Launius: Right.

Solid: …with shuttle processing and with the orbiter logistics and with payload processing as well as the other support activities.

Launius: Well bringing shuttle online was obviously the most significant thing that was done beginning in the late 70's here at KSC, obviously. George Page talked about it extensively yesterday from the NASA side of the house. What are your experiences from doing the same thing, from the corporate side?

Solid: Well, you know the engines were not ready. Which I guess I have felt every time we deployed a system I have felt, even the F1's and J2's, it seemed like we were launching the first one before you were really to the point in the development program that you felt good. That when you started it up it was going to run, and run for the duration, that it was supposed to run. And, we were still having all kinds of problems on the space shuttle main engine when we delivered those first ones down here. And yes it was tough, and during that time, those couple of years, two and half years that it took to finish the orbiter, that provided us an umbrella to do a lot of finishing on the SSME. We put the SSMEs in the orbiter. We took them back out. We brought them down here to the O&C Building and did a bunch of nickel plating on the steer horns on the nozzle, and a bunch of other very significant mods, and then we took them back up there and put them back in. We took them out again, and did some more very, very significant modifications. You know, which all came out of the continuing test program at NSTL. And so yes, those were tough times. We didn't know how much more engine rework and development we were going to have to do before we finally launched these things. And so needless to say when we finally launched them, well, I mean, we were excited during the flight readiness firings.

Launius: Yeah.

Solid: Hey, they did what they were supposed to do.

{Laughter}

Launius: OK, what were some of the, and you've eluded to some of them, some of the specific kinds of challenges that had to be dealt with? I know the complexities of the valve systems and all these other kinds of things that were a part of it. Are there any particular challenges that stand out in your mind, in terms of bringing it online, so that we could actually fly this thing?

Solid: Well, in my recollection it seemed like we were always dealing with pump problems. Not pump performance problems so much but pump hardware problems.

Launius: OK.

Solid: Cracks in the blades.

Launius: OK.

Solid: The Center Director at Marshall at that time was Dr. Lucas, and he was a materials kind of a guy, and the guy running the program from NASA Headquarters, the associate administrator was John Yardley, who was a stress guy. And again I feel like these were the right kind of people, at the right point in time, from the customer…

Launius: Right.

Solid: …perspective, because of the specialties that they had. They could ask the right questions, and help us bring in the right kinds of specialties to solve some of these problems. And, I would say that the turban blades was one of the major challenges that we had in developing the SSME. The other was the controller. It just seemed like putting together that computer that's going to control this thing and assess performance on a continuing basis and feedback what you got to do to resolve the issue, open a valve a little more, or close it a little more, or whatever the action or the reaction was to be, it seemed like those two things caused us the most pain in the early going. The other hardware, the valves, the nozzle, even though we had to do all that extra work on the nozzle, the injector, the basic hardware, the ducts, we went through a period where indeed we did have ducting problem, and we had to resolve those problems. But turban blades and controllers are the things that stick in my mind in those early days.

Launius: OK. All right. And you talked about controllers earlier, so that's a program…

Solid: Oh yeah.

Launius: …that's an issue that plagues it for the whole period it sounds like?

Solid: A rocket engine is a mechanical device, it's a heat transfer device, it's pumps and valves and ducts and nozzles. And it's like I say, heat transfer, regenerative

cooling devices, and it's all of that kind of thing, and so that's a mentality of a rocket engine company. And along comes this sophisticated electrical device, and we were not equipped really. And now we pulled in Honeywell, they were the major supplier, and they were the contractor to build this device, but we never managed them well. We had to learn how to manage that major subcontractor and so we had to find some of the right people to do that. And Rocco helped us do that.

{Laughter}

Launius: I'm sure he did. The SSME, I think I've seen a specific impulse on this thing of like 455 or something like that, it's one of the highest ever built. Obviously with a great thrust as well. Speculate if you will on possibilities for higher thrust, higher ISP and chemical propulsion in the future, is there a good likelihood, can we go there?

Solid: I believe that we've peaked out on ISP, I think, and we're using the two highest energy propellants that you can use. Well you could use fluorine if you could control it.

Launius: Yeah.

Solid: But you can't control it, so it's kind of out of the mix. So you're there with hydrogen, LOX hydrogen. I don't think that you could up the cycle that's going to maximize the use of that LOX and that hydrogen, either in terms of mixing it or in

pressures, I think you're there. And I know that there's not another rocket engine anywhere in the system that comes close to the ISP.

Launius: Yeah.

Solid: And it is higher than that by the way.

Launius: Oh, is it?

Solid: I've lost my memory. I should have gone back and reviewed some data on the SSME. But it is, I believe that it's the theoretical max.

Launius: OK. All right. Now this thing, obviously there's a unique blend for at least a human rated system with the shuttle that's got these solids as a part of it as well. In terms of the thinking and how you were going to operate the two together, did you deal with that at all? What was the thought that you all had about how to make this work?

Solid: We did not.

Launius: OK.

Solid: From a rocket engine standpoint we knew what we had to do from liftoff to end of flight. And that was all, of course, determined as a part of a booster system that included those two big solids. The original design had a liquid system…

Launius: Right.

Solid: …that would of put a little bit different performance profile on the space shuttle main engine.

Launius: Right.

Solid: But I didn't get involved in that.

Launius: OK.

Solid: I was in the operations end of this thing from day one.

Launius: Yeah. Wernher von Braun was very much opposed to the solids, he wanted liquids.

Solid: Right. And us liquids guys did too.

Launius: Yeah.

Solid: You know…

Launius: Well any rational argument – you can control them, you can turn them off, you know…

Solid: Right, right, right. But hey they served us well.

Launius: Yeah.

Solid: Except for that one time, they served us very well.

Launius: Right. Well let's talk a little about the launch of Columbia in 1981. Obviously that's a big deal, first successful test of this thing. Where were you, what were you doing, what was the progress of the day?

Solid: Well, I was in the backup firing room, I was not on the primary console. I was in the backup firing room with the likes of J. R. Thompson and his technical team from Marshall, as well as the Program Manager and the technical team from our home plant. And we had a section there in firing room two. In building up to it, and all of the series of reviews that you go through, it seemed like I spent half my time in Huntsville, going through just our latest happening in Florida, and what latest tests and checkout…

Launius: Right.

Solid: …event, and it seemed like we were reporting and evaluating constantly, in those last few months, actually before the launch. And so I was deeply engaged in everything that was going on, it seemed like day and night. At the same time we were testing at NSTL and we were coming up with new problems that we had to deal with. We'd have to convince ourselves that that problem does not apply to the engines that we're trying to launch down in Florida. And yes, it was an intense time of really just convincing ourselves that these engines were ready to fly. And so when it finally did fly, I suppose in my experience, in my thirty-nine years in the business, from the very beginning, there'd been a lot of emotional times, but none like that first flight.

Launius: Really?

Solid: It actually just exhausted me. I mean you know when they lit that thing off and it flew, we could see it flying and then after it goes out of sight we just anxiously awaited every event. I mean those eight and a half minutes were like an eternity to us.

Launius: Yeah.

Solid: And then when its finally over, I mean, guys like J.R. Thompson and Dom Sanquini, who was the program manager from Rocketdyne, and I mean we were all bawling like babies.

Launius: Yeah.

{Laughter}

Launius: Yeah. George Page told us yesterday a very nice story about it, in which he said he had been known to have a little bottle in the bottom of his desk drawer. And on certain occasions he would take a little nip and after that launch, and it was successful and everybody is congratulating themselves, he went back and took a little nip and the first in line he said was Jim Beggs…

{Laughter}

Launius: …the NASA Administrator who also felt the same way.

Solid: Sure. We'd delivered the Orbiter way ahead of time, went through all of that turmoil. Put on tile, take them off, put them on again, rebuilt the vehicle, brought all those people down here from the West coast and this just intense activity that just never stopped, never let up. And you'd get into it and then bingo you'd have another serious problem that you had to go deal with. Just one thing after another. And yes, that was, in my career that was the most intense time, were those couple of years prior to the first flight of the space shuttle main engine, the space shuttle.

Launius: An enormous sense of relief at…

Solid: Oh yeah.

Launius: …that it worked…

Solid: Oh yeah.

Launius: …and these guys were in orbit…

Solid: Yep. And of course we were anxious to see the hardware when it got back so we all went out to Edwards to be sure to be there and see it firsthand when it first got back. And yeah. Interesting, challenging, exciting time. No doubt about it.

Launius: Was there a sense that everybody had, that we've really entered a new era of space flight?

Solid: Oh yeah, yeah.

Launius: That seems to be everybody's recollection.

Solid: I mean the ALT program and things like that, we knew that this thing would fly. It just was a matter of getting it up there and proving it.

Launius: Right.

Solid: And so now we're what a hundred…

Malone: About 100.

Solid: …this one coming up is a hundred and three or four?

Malone: Yeah, I don't remember exactly…

Launius: Yeah, over a hundred missions.

Malone: Twenty years, yeah.

Launius: It's unbelievable. Begs the question how long are we going to fly these particular vehicles, but…

Solid: And I suspect that we're going to fly it for quite some time. I suspect we are simply because there's nothing to replace it with.

Launius: Yeah.

Solid: And I am disappointed that the whole X-33…

Launius: Right.

Solid: …thing didn't work out. Some of us didn't believe that it would going in. I happened to be one of those that has a hard time believing that we will have a single staged orbit that really can carry a significant payload…

Launius: Right.

Solid: … to orbit. I believe we're always going to be dealing with at least two staged devices. And anyway, I may be wrong. I may be proven wrong yet in my lifetime. I don't know.

Launius: Well, one never knows. But SSTO seems to be the Holy Grail, I mean, that's one of the things…

Solid: Right.

Launius: …that we really would like.

Solid: Right, right. And maybe one day we'll be able to do that.

Launius: Yeah. Obviously there were a series of flights that took place through the early 1980's. The system seems to work relatively well, the flights take place, NASA moves into its so called operational phase with shuttle, and we fly lots of payloads, lots of people that would never have gotten a chance to fly like before, like members of

Congress. And then of course we lose Challenger in 1986. Where were you at that particular time?

Solid: I was in the backup firing room, firing room two, with the same group of people, by this time some names had changed. J.R. Thompson was no longer the Program Manager. Our Program Manager from California was no longer the Program Manager. So some names had changed. But basically the same arrangement in the backup firing room, with the two technical teams from NASA and from Rocketdyne. And, of course, we immediately knew that there was a problem. And we believed it was engine related. And immediately everything was impounded.

Launius: Sure.

Solid: And so we're not seeing any data. The firing room was locked up and we were out of communication with everybody for several minutes, I don't know, it was probably fifteen, twenty, seemed like an eternity but it probably wasn't longer than that, minutes. When we were able to communicate with our guy on the second floor of the firing room where he could tell us about inlet pressure data. And at the point it exploded the inlet pressures on all three engines was still up. And that told us that the engines were running until they were deprived of fuel and hence that probably was not an engine problem. And then, of course, over the next several hours we were able to confirm that. But let me tell you in those fifteen or twenty minutes after the failure, I

mean, other than the fact that we knew we had just taken seven lives and you know all of the emotion and the feeling associated…

Launius: Sure.

Solid: …with that, the fact that we might have been the cause of that with something on an engine, certainly added to the feeling, I can't even describe it. The Program Manager from Rocketdyne was so affected by it, I mean it took him some time to really get over this. Just the thought that something we might have done or not done caused this problem. Like I say it was an eternity, those minutes. Now were we relieved? Of course we were relieved that it wasn't an engine problem. We weren't relieved from the standpoint of this tragic thing that's happened in the program. But we were certainly relieved that it wasn't something we did or didn't do that caused the problem, so.

Launius: Was there a sense that there was a great pressure to launch on this particular day?

Solid: Well…

Launius: Do you recall that at all?

Solid: …you know…

Launius: We've heard some people say there was, other people say no there wasn't.

Solid: Yes, and some of us were surprised that we were going to launch. Was there pressure? Yes, there was pressure to launch. There isn't any doubt about that. You know, we had tried a couple of times. Many of the major players had actually left here and were not here for the launch itself. One of those was the senior executive of the Space Division of Rockwell, Rocco Petrone at the time. He was very vocal as history records, very vocal about not launching. And I don't know whether that came out of his launch experience or whether it came out of his technical awareness of the whole system. And there were a number of people as history has recorded and you know, I don't have to repeat any of that…

Launius: Right.

Solid: …in fact I can't. But yes there was pressure. Now let me say something on the engine side we concerned ourselves with problems at the micro level, i.e., the problems with cracks in the turban blades.

Launius: Right.

Solid: We would deal with something so small that you had to have mega power to see it. At the same time it seemed like other systems and I don't want to cast any,

I'm not making accusations or I'm not casting aspersions on anybody. But when the SRM folks had cracks in the blades in their HPU, you could stick your finger through the crack. And it didn't seem like they got near the scrutiny for a hole that you could put your finger through that we got for something you couldn't see unless you were looking at it under a thousand power. And so, we're sitting through some of these same meetings had our opinions and our feelings about this. We'd say, hey, we certainly would never test or fly with conditions like that, us engines guys were too conservative for that. Now I can recall sitting through one review after another on the O-rings on the SRMs and those charred O-rings just bothered the heck out of some of us. We'd sit there and look, but hey we're the engine guys, we just were in the same meeting because all of the Marshall elements were in the same big review. So we'd sit through the SRM, we'd sit through the ET, and then we'd come to the engines. And we'd go have these all day reviews and we'd sit there and look and listen and shake our head and wonder hmm, you know. And so, yes, but don't take out of that…

Launius: Yeah. No I understand.

Solid: …any I told you so, or anything like that, because it just seemed to be a different standard in the design culture, between the elements. And so we had our own private feelings about that. Now I was just peripherally involved in some of the discussions that took place the night before. And simply because we were all Marshall contractors.

Launius: Right.

Solid: And we congregated at the Marshall Resident Office and there was just an awful lot of bumping into each other. We were located basically together in firing room two. You know the little groups were contiguous. And so we kind of knew what each other was doing. But our focus was on our own system.

Launius: Right.

Solid: We didn't go over there and say, "Hey you guys shouldn't fly because of those O-rings are going too stiff." Nobody did that kind of thing.

Launius: Jim Beggs has said, as you know he'd taken a leave of absence at this point, and Bill Graham was acting, he said that had he been in place, he would have, and hind sight of course is twenty-twenty, saying this after the fact, you know, who knows, he would have never allowed them to launch. Not on any basis of data, but he said, I looked at that gantry and I saw those icicles hanging off of it, and I'd said we shouldn't do this. Was there a sense that that might have been the case as well? Or did anybody suggest that sort of thing around here at the time?

Solid: Yes.

Launius: OK.

Solid: You know I can't give you a point in time, or even names. We had feelings about those ice cubes, those icicles hanging down. We didn't want one of those chunks of ice to hit a nozzle.

Launius: Right.

Solid: And we had serious discussion about what if, and what kind of a blow a nozzle might take and what area, between which bands and so forth, that would be most vulnerable. And we had discussions about that we would have rather not have had.

Launius: Sure.

Solid: The orbiter people of course had feelings too, because of masses of ice hitting tile and that sort of thing. But yeah, it was sort of unplowed ground for us. We had never, ever tried to launch in this kind of an environment. And design criteria and design parameters not withstanding, you were in an arena that you hadn't experienced before. I would like to think that Mr. Beggs is right. The right person in that job at the time would have said don't launch.

Launius: Yeah.

Solid: You know. It's amazing how whenever there's a catastrophe there's always a set of circumstances that just seemed to come together…

Launius: Right.

Solid: … in a strange way, and that's what happened there. It was a series of circumstances that put us at that place at that point in time. And you can look back at it and hey we shouldn't of done this, we shouldn't of done this, we shouldn't of done this, we should've seen it here, but we didn't.

Launius: Well again, hind sight is twenty-twenty. I mean…

Solid: Right.

Launius: …you look back at the Apollo fire and you say, boy this was really stupid the way they did this, and George Page said that yesterday. "Boy what we did was stupid, but we didn't realize it." You can only see it after the fact. There was obviously a big investigation and both internal to NASA and I'm sure Rocketdyne had its own and other corporations did as well as the Roger's Commission, and then lots of hearings on the Hill and people getting beat up and so forth. The hearings on the Hill at some level are theater and not necessarily investigation but as a result of that there is a whole series of recommendations that emerge and there's a lot of review and change to the shuttle program. Obviously the solids are rebuilt and reengineered. Was there a similar

sort of review for the SSME and a change to those as a result of anything that might have come out of Challenger, and the investigation?

Solid: Oh yeah. And we were involved in a number just like everyone else. A number of special reviews and studies. My personal involvement was not so much from reevaluating design changes that we wanted to put in place and were now going to take advantage of the time, the down time, to put these in place. I wasn't so much involved in those. I was involved in what we were going to do operationally to change how we process space shuttle main engines. And so I responded mostly to the committees and teams down here. The shuttle processing contractor had a rather significant process review in place that I was a part of. There was a team that was headed by Fred Haise and someone else that took a look at just how you process the hardware overall, and I was involved in that. Roy Estess had a team looking at the relationships between the contractors, the shuttle processing contractor, and the element contractors, and does the launch support services thing, the LSS function, does it really do what it was designed to do and so forth and so on. And I got deeply involved in that because I had quite strong feelings about that. And the outcome, the basic outcome, the significant change that was made in the processing of hardware here was that we decided post-Challenger that after every flight we would take the engines out, take them to the engine shop, do whatever it is we needed to do to the engines offline…

Launius: OK.

Solid: …and put the engines back in. In the meantime that opened up the aft for them to do everything that they needed to do. Because before that we were trying to develop the capability to remove and replace components on each engine, pumps were the big thing. You had a limitations on pumps, maybe a one flight limitation, or a certain temperature speed limitation, or something that would cause you to remove pumps. And we would try to do that in place and that became a very time consuming, intense process, to remove and replace hardware. So that was the big change and to this day that's what they do. One of the first things, when you roll the orbiter into the OPF is you take the engines out. Take it to the engine shop and process it offline. In the meantime they would have been working on engines and got them to the place where they could reinstall them back into the orbiter. And so that was the big change from the engine standpoint that came out of the studies we did post-Challenger.

Launius: OK. All right. There's a return to flight in 1988. I'm assuming that it's a similar sort of reaction and most of the people here made it happen like with Apollo 7 after a return from the Apollo 1 accident. A great sense of relief and joy and actually pride I guess…

Solid: Oh yeah.

Launius: …recovering.

Solid: The same kind of a feeling. You finally got to the point where you've gotten back to where you were. You survived the glitch in the program, and I don't want to minimize what happened by calling it a glitch because it was major, major, major.

Launius: Right.

Solid: But yes. You know the same emotion hits you, we've recovered and we can get on with business.

Launius: From your perspective is there a difference in the way in which you interfaced with NASA during the shuttle program versus the earlier era with Apollo? Pretty much the same or had it changed?

Solid: It seemed like in shuttle, NASA was much more involved in the detail level decisions that we made. It is rare that we did anything outside of the NASA people and after Lockheed took over the shuttle processing contract the processor as well as the element contractor, I mean almost every technical decision was made by that triad; the element contractor, the key NASA guy, and the processor. And so yes, it seems like the depth of involvement by the principles in a given system, and I speak for engines, I don't want to use the word intrusive because that makes it sound wrong somehow, but that really is the word. The involvement was deeper and to a much greater detail.

Launius: OK, did you have any specific questions?

Lisa Malone: Oh, I was wondering how you felt, about, I think on the engines, there are like over twenty percent of the criticality one hardware I believe on the whole vehicle, did you ever think about that as you were being responsible for that amount?

Solid: Oh yeah. We always looked at the criticality of the hardware, but from a macro point of view, we always believed that we represented the highest potential for catastrophic error of any system on the space shuttle. And I assume that the Rocketdyne guys out there still feel that way because it's true. You can't deal with the kind of pressures, temperatures, and speeds that you deal with on those engines without recognizing that as a high potential for, and if something goes wrong, it's catastrophic. And so that's why I'm answering your question from a macro standpoint because as opposed to, gee, this is a criticality one, or a one A, or whatever it might be.

Malone: Um-huh. I just think that's an enormous amount of pressure in itself.

Launius: Yeah.

Malone: To have to deal with it, and dealing with that as you go through each day and each issue that you have to struggle with and resolve to get to flight. Can you describe it, you were able to sit through a lot of the firing room, in the firing room for a lot of the launches, and probably even in the early days, what's that environment like for you, sitting in the firing room, being part of the launch team?

Solid: Well, I mean, you want to guard against what you do as becoming routine, because you know, a lot of the tasks you perform are repetitive, you go over the same things that you went over the last time, and so you got to kind of discipline yourself that what we're doing here is for now, and its for this launch, and for this point in time, and for this hardware, and its uniqueness because every set of hardware has got some unique features. I mean there are no two engines that are absolutely, identically alike. I mean you can't look at the performance data and repeat it from one engine to the next. I mean we're getting closer and closer. Almost each engine takes on a personality and you've got to discipline yourself to concern yourself with the personality of the hardware that you're dealing with now. You know. And so it's really kind of a mental thing. And I think the guys…

Malone: You're very focused…

Solid: …mastered that.

Malone: …about that particular test or event versus…

Solid: Right.

Malone: …thinking oh, I'm part of the launch team down here at KSC.

Solid: Right, right.

Malone: That doesn't even enter into it, does it?

Solid: Right. It really doesn't.

Malone: Because not that many people get to have that experience.

Solid: Well, that's right. I saw, and I may have, I don't know how or if anybody's ever kept records. I have seen every shuttle launch except one and that was the hundredth. It was just not too long ago. I missed the hundredth because I had a commitment but other than that I had seen every shuttle launch and until I retired every one of those from the firing room. Let me just add to that, I've seen every manned launch except for that one, the hundredth, you know, from the very first Mercury Redstone, there are people who'd give their eye teeth to see one…

Launius: Oh yes.

Solid: …and I've seen them all…

Launius: Oh yes.

Malone: Well I was just going to say, you've been through the whole program, I mean the whole space flight program, you've seen a lot, and you've been around a lot

of folks, a lot of failures, successes, and so forth and if you had to project in the next forty years, what would you expect we would be doing with space flight?

Solid: You know I used to predict and prognosticate a little bit, I guess I really don't know. We're going to continue to utilize near space and geosync, there isn't any doubt about that simply because of what we can do. Are we going to make a commitment to go to another planet? Are we going to make the commitment to go back to the moon for whatever reason we might think it necessary? I don't know. See, it's going to take a John F. Kennedy kind of a thing to make that happen. I don't believe that those of us in the business and the industry and the agency are probably going to make that happen. I also believe that our commitment to the Space Station needs to be consummated, so to speak. We need to go do what we set out to do. All of this negative press and criticism of huge overruns and so forth not withstanding, I think we've got to go to do or it won't be what it needs to be. If it indeed is going to be a research platform to come up with new drugs, new medicines, new processes, new and better whatever, the laboratory aspect of this thing has got to be developed, and it's got to be completed, it's got to be consummated. And so I really believe that. And so I want to see us committed to finishing what we started here. There was an awful lot of also "if we build it they will come" in the whole Station approach. And smart people are going to come up with ways to utilize that capability.

Launius: That's right.

Solid: But the capability is what's got to be developed and completed and consummated, and I just personally believe that.

Launius: That's actually a pretty good place to stop, I think, so I want to thank you for being with us today. This has been a wonderful interview, thank you so much.