ORAL HISTORY TRANSCRIPT

JOSEPH H. LEVINE
INTERVIEWED BY KEVIN M. RUSNAK
HOUSTON, TEXAS – 12 JUNE 2001

[Note: This transcript has been edited and approved for use by Mr. Levine. However, his modifications from the audio record, both additions and deletions, are not delineated in the text below. Please refer to the other version of the transcript for an exact record of the oral history session.]

RUSNAK: Today is June [12th], 2001. This oral interview with Joe Levine is being conducted in the offices of the Signal Corporation in Houston, Texas, for the Johnson Space Center Oral History Project. The interviewer is Kevin Rusnak, assisted by Summer Bergen and Jennifer Ross-Nazzal.

I'd like to thank you for taking the time out to spend with us today in our project. If we could get started, tell us a little bit about some of your background experiences, your interest in aviation or engineering growing up, going through college, those sorts of things.

LEVINE: My earlier relevant history started even before I went in the service (USAF). I worked at an Air Force depot as a hydraulic mechanic. I actually got out of high school at age of sixteen, so I was too young to go in the military service at that time. I worked for Kelly AFB Field in San Antonio, Texas. At that time I specialized in being an aircraft hydraulic mechanic and worked on such aircraft as P-38s [Lightning] and B-24s [Liberator] and other aircraft of the day (1943). That experience stimulated my airplane interest and made me determined to go in the Air Force when I reached the age of eighteen years. I wanted to fly so I joined U.S. Airforce to train as a pilot.

I joined the Air Force as an airforce cadet, and unfortunately in 1944, they had more pilots than was needed, but I did fly. I flew on B-24s and specialized in armament. I became an armament gunner and was sent to several schools to accomplish that specialty. I later teamed up with a B-24 combat crew at March Field, California for crew training. Our B-24 crew consisted of ten people. After approximately 4-5 months of phased training, we received orders for overseas duty in the Pacific theater of war. We were due to go by ship out of Seattle, Washington. The U.S. dropped the nuclear atomic bombs on Japan during August, 1945. The decision was made that we were not going to be sent overseas as a crew. I thought, well, this is my opportunity to get out of the service and further my education.

Unfortunately, the U.S. Air Force was not ready to release me. During the 1945 time period, the military used a point system. The point system included points for age, marriage, and years of service. I didn't have many points. So the Air Force decided they were going to send me to Okinawa to fly on B-29s [Superfortress]. I was stationed in Okinawa for about six months. I ended up being honorably discharged in 1946.

I elected to immediately attend college and graduated in 1950 from Southern Methodist University [Dallas, Texas] (BS in Mech. Engr), and before that a junior college in Arlington, Texas. My first position after graduation was for the General Dynamics [Corp.]. (called Convair at that time).

General Dynamics was responsible for the development of a heavy bomber called the B-36. I don't know if you've heard that aircraft in the past. The B-36 was a six-propeller driven engines high-altitude bomber with four turbo jet engines attached under the wings. It could climb to extremely high altitudes, up to 40,000 feet. At that altitude the fighters of the day could hardly reach it. It was somewhat of a freedom bomber, but it never really went to war, although General Dynamics produced about 400 B-36s. I was assigned to Flight Test on this initial assignment.

Later, I joined Vought, named Chance Vought [Corp.]. Chance Vought had an excellent reputation as a designer of Naval aircraft. They designed and built a large number of F4Us, (Corsair). The Corsair was a carrier based fighter aircraft. The Corsair was later modified by Chance Vought for the Marine Corps as a support fighter. I was assigned to work in Flight Test on this aircraft. Later at ChanceVought I worked on the Regulus Missile Program in the Electronics Design Group, which was an air-to-flight-type missile program. It was driven by jet engine. I also worked on the F7U while at Vought, which was a high-performance fighter. (1954).

I joined Hayes International Corporation (1955). Hayes International Corporation was given a contract to develop an early interim fuel tanker program to refuel fighter aircraft in flight. At that time, the AF really didn't have an in-flight fueling tanker designed aircraft. The B-29 was assigned to the task for this interim in-flight fueling system. The B-29 was proposed to be modified to house three mounted fuel drogues. Later, a decision was made to use the B-50 for performance and other reasons. I was assigned to design a control panel to for the inflight fueling system.

Since I was interested in pursuing an advanced educational degree, I ended up back at General Dynamics to permit my attendance at SMU. At General Dynamics, I was assigned to the Electronics Design Group. I later joined the Nuclear-Powered Airplane Program, which was was later canceled during the 1960 time period.

You may have seen the "American Portrait" television film that documented the reasons for this cancellation. Safety was the primary reason that contributed to the cancellation of the Nuclear Powered Airplane Program. As a matter of fact, nuclear power applications in the United States today suffer from a tremendous fear of safety. Nuclear electric power plants have been built in the United States to the tune of something like 100 or so. I do not believe there has been any new starts of Nuclear Electric Power Plants for a number of years. There is a tremendous interest in getting back to nuclear electric power applications, especially in the California area.

After the cancellation of the Nuclear-Powered Aircraft program, and other nuclear powered projects, I could have stayed at General Dynamics and worked on an advanced fighter program, but my interest began to turn toward space. At that time the U.S. was beginning to introduce manned spacecraft programs (the Mercury Program and later Gemini and Apollo). The race to the moon was underway. And I was interested in the work underway at the Johnson Space Center (called the Manned Spacecraft Center initially). A large number of people were to be recruited starting with a Space Task Group (made up of something like fifty, fifty-five people or so) that was formed from Langley [Research Center, Hampton, Virginia] to the Houston area to start the program.

I joined NASA in July 1962. There was no Space Center built yet. We were in rented buildings all over the Houston area. I was located at a building called Office City. It's still there, right across from the Gulfgate [Shopping Center]. The Gulfgate Shopping Center is being demolished and rebuilt as a matter of interest. At this time I was my assigned to the Apollo Program Office in Reliability, and Quality Assurance [R&QA].

RUSNAK: Since you're on the topic of getting into SR&QA, what in your background had led you specifically into this arena?

LEVINE: I began to find in my work in nuclear radiation effects at General Dynamics that radiation effects was the study of the effects of the reliability caused by the deterioration of materials and components. It was my job, at that particular time to do analysis and studies to determine the effects of radiation on aircraft components. Once you study that particular area, this leads to an understanding of the reliability of these components as well.

I was extremely sensitive to flight safety, and probably more so than most people because I had seen many friends of mine that had actually been killed in experimental aircraft. So that made me extremely aware and interested in the reliability of aircraft. At this particular time period, there wasn't a lot of people that had any background in the disciplines of safety, reliability, and quality assurance. There were a few specifications that had been published by the military., such as I think it was Mil. Spec. 27542, I think the number was, that attempted to try to embrace this area, but nothing was prepared that was unique to the space program.

When I arrived here at MSC (Manned Spacecraft Center) in July, 1962, there was no one here that worked in this particular area. The entire Space Center population (3600-4000) did not have anyone specializing in any aspect of R&QA disciplines. They did have an advisory group that was attempting to do some work in safety, but no one had put anything together in a space oriented SR&QA document.

For this reason, one of the first things I got involved in was to put down on paper what the requirements should be for a reliability and quality assurance document. The reliability and quality assurance aspect was the primary emphasis of this initial document. This R&QA document was put together largely by myself and a few support contractors (G.E.) that were around at the time.

Based on my previous experience, and some of the work that had been done by the military, we put together a document that was published at MSC, and finally published by NASA Headquarters as NPC250-1. Later, a NASA handbook was released NHB5300.41-D. One of the things that became immediately apparent is that our goal was not to build a fleet of spacecraft. We would be building spacecraft that was mostly one of a kind.

For that reason there would be very little ability to be able to statistically test these components, although there was a tremendous concern on high reliability, safety and the need for a rigorous quality assurance for the Apollo Spacecraft fleet.

Although there was concern in the need for statistical verification of the spacecraft, there was no practical way to accomplish this particular feat. So I was a pioneer. Those of you who understand the definition of a pioneer is one who gets his rear full of arrows. [Laughter]

One of the areas that was important in the formation of this R&QA requirements document is that you had to be concerned about analysis techniques as well as other applicable R&QA techniques. For example, one discipline included the design review process, which required people to gather together and put their best thinking caps on, in terms of being able to evaluate systems and components of a particular arena.

Statistical analysis techniques were not practicable because there was not enough test time and components to be able to demonstrate the apportioned reliability for each system that was required for the Apollo Program. The Apollo Program had a statistical number requirement of 90 percent for mission success and 99.9 for crew safety. But the number itself was meaningless since it could not be demonstrated. It just was, "Go try to do the best you can, guys."

We found out pretty early in time that the best we could accomplish would be the use of qualitative R&QA techniques. There was a powerful analysis technique available, and in existence called the failure mode and effects analysis [FMEA]. The failure mode and effects analysis is prepared by postulating failure modes of various components, how they fail, what the causes were, what are the effects of these failure modes, how these failure modes and causes could be detected, and finally what was the criticality of that failure mode and cause relative to crew loss and mission success.

There was the requirement to analyze, by the FMEA technique, many thousands of components of the various spacecraft systems. Later in the Space Shuttle Program the scope of the FMEA was even more complex. There was a significant number of Apollo Spacecraft components with many failure modes that were Criticality 1. Criticality 1 was the effect at which a failure mode could be a crew safety problem; Criticality 2, a mission success problem; and Criticality 3 being all others.

So that the FMEA was a very powerful analysis technique; however, the result required management support to ensure their support in not tolerating a Criticality 1 failure mode and cause, or as a minimum reduce its potential of occurrence. I'll talk about this aspect more as we get into the Space Shuttle Program discussion.

RUSNAK: What was the origin of this technique?

LEVINE: The FMEA was actually developed by the military, although they were apparently trying to use it in a statistical vein, so they would postulate failure mode and cause analysis and then try to put numbers to the failure modes and causes. One of the shortcomings of their use of the FMEA is that the statisticians basically took over the task, and statisticians were not, at that time, respected by the engineering community. There was not a strong affinity to do anything with the FMEA analysis technique by anyone but the statisticians.

Other R&QA techniques, controls, or disciplines were tests. I was extremely interested in making sure there were sufficient tests, both qualification tests as well as acceptance tests, to give confidence that the item that we were to fly had been properly tested and qualified.

Although the test discipline may look straightforward, what was occurring was design changes, and failures that brought up the question, "Do we have to go through this whole qualification program all over again because of a failure resolution or design change"? So there were endless arguments of how much of the test program had to be repeated because of failures and design changes.

Failures were required to be formally reported at the beginning of component acceptance tests and qualification tests and on. There was something in the order of sixty to eighty thousand reported failures during the Apollo Spacecraft Program. All of these were not major failures, but they were failures that had to be evaluated and resolved.

One of the questions that came up was, how do you address these failures and who signs off and says that that each failure had been adequately identified and rectified? A important organization change was initiated at the Johnson Space Center during the '65-'66 time frame. Subsystem Managers were assigned to each subsystem in the Apollo Spacecraft Program. They were responsible to approve all tests, designs, FMEAs, and failures resolution.

I assigned Reliability Subsystem Engineers as counterparts to these Subsystem Managers to participate in all the design reviews, tests, readiness reviews, and to assure that the failure mode and effects analysis was evaluated and signed off by those responsible subsystem managers as well as the reliability subsystem engineers. All the failures would also be evaluated and approved by these same people. The Contractors (i.e. Rockwell and Grumman) and other contractors were responsible for the creation of these reviews and documentation. These contractors were organized in somewhat a similar manner as noted above.

So we had broken the statistician fence that I discussed earlier, where the statisticians were on one side and the engineers on the other side. Suddenly, here was a team and a well-respected team. These Reliability Subsystem Engineers were for the most part support contractors. They were assigned to my Division. My Division had a very small number of civil service people. If you were to talk these support contractor people today, I believe their reaction that they felt like they were part of my team.

So these people, as a team, were a fundamental part of the success of the Apollo Spacecraft Program. We demanded that all of the analysis techniques, the tests, the failure mode and effects analysis, acceptance tests, and failure evaluations, be looked at microscopically by this team of technical people.

In my own case, I was a Microscopic Manager. You probably heard people using the microscopic management term at Johnson Space Center. Many people took offense to this type of management. Some would say, "You guys are a bunch of idiots. You should stand off and let your people do the job."

With a program as important as the Apollo Program was to the nation, I and others could not take the risk of conventional management approaches. I knew I had to be a fundamental part of this program. I found myself traveling upwards of 80 percent of the time. My wife used to accuse me of using the house as a laundry chute. But the Apollo Program was an important part of my whole career. I really enjoyed being a part of this important program.

You couldn't drive people away after hours from the center. Everyone was so enthralled with the Apollo Program. It was wonderful to be a part of this program. Here was a program that was not a defense program. You weren't building something to kill people; and you were building something that could embrace the imagination of people from all over the world. As a matter of fact, the U.S. did a pretty good job of publicizing the Apollo Program all over the world.

The Apollo Program went on for a number of years. One of the questions you asked: should we have done the early circumlunar orbital program where they took an early Apollo spacecraft and orbited the Moon. That mission was after the [Apollo 1] pad fire, and the immediate concern I believe was to demonstrate confidence in the program. Actually, I think we were really ready for that particular mission. We had the test experience. We had subsystem people who had reviewed and evaluated their components both here and at the contractors, and they were satisfied that they had a mature spacecraft. So I felt pretty good about that particular mission.

Let me go back to the on-the-pad fire (Apollo 204). That was probably a real downtime of my life and a lot of the people in the Center. Three Astronauts burned up in a spacecraft on the ground. They didn't even get up in space. One of the tasks that I and my boss were assigned, (Bill [William M.] Bland) was to chair an investigation panel, a Materials Panel, at the Cape for the Apollo 204 Investigation. A number of the people were assigned to different types of investigation panels. Many people were rushing around trying to instantly find the cause of the incident. I wasn't involved in materials controls at that time even though I had materials controls later as my responsibility.

This Materials Panel under Bill Bland was primarily reviewing the discipline of the control of the flammability of non-metallic materials. It became apparent to me as I worked on this assignment that irrespective of finding the unique cause of the problem, there was an array of exposed flammable non metallic materials all over the spacecraft (e.g.- Velcro all over the place that would burn), and particularly in an oxygen environment of 16.4 [pounds per square inch] oxygen, pure oxygen.

If you saw any of the test films of how those materials could burn in a pure oxygen environment? You would come to the conclusion right away that there's two big things you have got to get rid of, and that was exposed flammable nonmetallic materials and the pure 16.4 oxygen environment, although they used pure oxygen on Mercury and Gemini Programs somewhat successfully. They were lucky.

The nonmetallic materials flammability program was later assigned to me. I put this materials program under similar R&QA control disciplines that required written evaluation and tests and responsible people that had to approve applications an sign off. I made sure it wasn't a willy-nilly type of control program. People who had been working the materials program had really not had any controls placed on them. I mean, nobody knew exactly what materials were where and their flammability characteristics. There was a requirement for a data system that forced every exposed nonmetallic material, to be recorded, what it was, its flammability characteristics and controls and waivers if they did not meet the specific requirements.

I recruited a C.S. individual and support contractor group that was responsible to work in this activity. Later, the R&E, research and engineering people, picked up these responsibilities under Max Faget. I published a handbook at that particular time to put down some of the controls in that particular area, which I think is in existence today. We continued to act as a checks and balance in this materials control program.

One of the things that we did not do initially because of the concentration on exposed nonmetallic materials, (or I wasn't sensitive enough), was to analyze the flammability of materials contained inside components that could burn. As a matter of fact, this gave rise to the Apollo 13 incident where, as you may know, on Apollo 13 they had an oxygen fire of a component that had been exposed internally in a component and an ignition source was available. This gave rise to an explosion in the service module. Fortuitously, we had the LM [lunar module] attached, and the crew was finally returned successfully to Earth. This problem gave rise to the need to look at every component that contains potentially flammable materials.

The Apollo Program as a whole resulted in several significant conclusions. We had put together a R&QA requirements document and organization that forced the marriage of the reliability people and the subsystem people to work together as a team. I did not know of any case in any aerospace program where a similar team approach had taken place.

While I worked at General Dynamics, after the Nuclear Powered Aircraft cancellation, I participated in a proposal for the Reactor in Flight-Test Program. I was loaned to San Diego-GD to work on that proposal. I attempted to work closely with some of the GD-San Diego reliability people. The first thing I did was to put together a list of the components and a radiation effects analysis for each of these components. I was concerned that the reliability people did not know of the existence of the configuration of this vehicle and therefore a source for the preparation of a reliability analysis. They appeared to have no idea what was proposed for that spacecraft. It was obvious that there was no cohesive team between the reliability and design engineers.

Back to a summary of the Apollo Program, as far as conclusions is concerned. I think the Apollo Program gave rise to a requirements document that for reliability and quality assurance worked well. I felt very good that we had done the best we could at that particular time.

Configuration management on the Apollo Program was used in the sense that we had design reviews, change boards, milestone reviews like flight readiness reviews, but we did not have the top configuration management document to the extent prepared for the Space Shuttle Program. So the Apollo Program was a "Let's do it and do it as rapidly as we can." At that time we felt like we were in a lunar landing race in competition with the Soviets. We wanted to land on the lunar surface as safely and as quickly as possible, so we were doing things not as shortcuts, but basically there was a no-nonsense, "Let's not do things that are not necessary" type things.

I worked with all the Apollo Spacecraft Contractors. I worked with the Rockwell people, the Grumman [Aircraft Engineering Corp.] people, and, I worked with the Delco [AC Spark Plug Division of General Motors] people. I traveled all over the country to work with all of them. They knew me well and I knew them well. They were organized along similar lines as we were as to subsystem reliability responsibilities.

They were enthusiastic, and I felt confident because a lot of these people were brought up in traditional aircraft programs so they did have a good background and experience base to drawn upon. As I mentioned earlier, many of the early aircraft programs were not organized as a reliability team with the engineers. The fact that I forced these contractors to form a similar reliability/engineering team at places like Rockwell and at Grumman was quite a feat.

Another thing I found, in my own case, that it was very necessary to know everybody on the program, like Max Faget, George [M.] Low, Dr. [Robert R.] Gilruth. I had a working relationship with all of the JSC program managers; like [Robert F.] Thompson, they all knew me. That, to me, was very important, that they felt like they could get on the phone to get information directly from me, or that I could get on the phone and talk to them at anytime. We had teamwork and good entrée to management. We formed an alliance that I think was good as we entered into the Space Shuttle Program.

RUSNAK: Since we've picked back up, I had a couple of questions to look back and get a little more detail on some of these points you were making. You've mentioned bringing these teams together that traditionally had probably been more divorced from each other than married, and that combined with the amount of travel and such, you had mentioned before, and also in looking at some of the documentation from then, that some of these trip reports and such that you had produced, seems like that most of these contractors really didn't have much of a grasp on the depth and scope, really, of what the reliability and quality program for Apollo was going to entail. Could you maybe explain what their initial impressions from these contractors, what they were thinking they were going to do, versus what you had in mind, and how you really made this marriage happen?

LEVINE: That's a good question, because traditionally most of these contractors worked on military programs, where they had the statisticians on one side and the design effort on the other side and "Don't bother me, just go over there and do your job." The reason many of them even had reliability groups or quality-assurance groups is they were somewhat forced on them by the military because of the large number of problems that had developed on military aircraft. So the military said to these contractors, years ago, "You will have a reliability and a quality assurance effort."

So they said, "Okay, we'll have one," but they never appeared to understand how they really were going to use these people in their programs. The Apollo spacecraft contractors probably didn't really understand what I was going to force on them. They thought I was going to force a statistical program on them, and they were all geared up for statistical analysis-type programs and this type thing, and trying to demonstrate on paper that they could meet their part of the 999s for crew safety and the 90 for mission success.

I was interested in the qualitative reliability program I discussed earlier. I was forcing the contractor’s reliability personnel to become design oriented. I guess I forced several people to leave their jobs because they could not adjust to this type of team approach.

It was quite an effort to attain the reliability talent needed for the Apollo Spacecraft Program. As a matter of fact, I won no popularity contest, and many disliked me at first. On the other hand, the contractor's design people at these various locations respected me, and I knew them all including their management.

I knew the people at Grumman in the design effort, and the same thing at Rockwell. I made a point to know them. I would introduce the reliability people to their own design people. So for the people that remained that could adjust to that particular team approach, they liked it. They thought they were really then becoming a fundamental part of the program, and before that, they did not feel that way. I don't know if that answered your question.

RUSNAK: No, it certainly does. I don't know if you've had a chance to look at Tom Kelly's new book about building the lunar module.

LEVINE: No, I haven't seen the book. I mean I haven't read it.

RUSNAK: He discusses a lot of Grumman's problems with instituting these programs and certainly recognizes the values of them and that they certainly had these growing pains of their own coming in, as you mentioned. Did any of the contractors or subcontractors really stick out in your mind as being particularly recalcitrant or maybe even particularly exceptional in adopted these?

LEVINE: Grumman probably stood out as being a problem area to me only because of the New York attitude. I don't know how familiar you are with some of the New Yorkers, but they didn't really accept me for about five years as being their customer. They were used to having the Navy being the primary customer there, and they would install them in a nice office, and say, basically, "Leave us alone," type thing. "We'll do the job. We don't need you. Send money." They thought that they could work that way with NASA. They appeared to have a terrible problem adjusting to NASA.

As a matter of fact, Joe Shea (Program Manager) on one occasion took a team of people, including myself, up to Grumman in New York at the time of the World's Fair. At that time we thought we had firm reservations at this particular motel, but many of the flights were coming in late because there was a real problem with the controllers, controllers' strikes, and we would overfly New York for hours on end. We got in there about 11:30, 12:00 o'clock midnight. They didn't have any rooms. So Joe Shea would not let anybody take any room even if they had only one. He would not tolerate it. He finally got a hold of the vice president of Grumman, or either the president of Grumman, and turned this thing around. I don't know if Tom Kelly's book kind of portrays that particular area or not.

RUSNAK: Not in that sense, I don't think.

LEVINE: People like Owen Morris. Have you talked to Owen Morris?

RUSNAK: We did.

LEVINE: People like Owen Morris would spend the night, all night long, at Grumman. He had the LM program as the manager. At one time he was my immediate boss. He had a terrible problem with the New York attitude, but he overcame it and, as a matter of fact, was very much respected at Grumman later.

RUSNAK: That's interesting, because usually when we have heard of comparisons, I guess, between attitudes, mostly it's between Grumman and North American. Usually the California attitude is maybe a sort of more lackadaisical approach versus the Eastern more hardworking ethic. That's usually what we hear rather than the sort of personal attitude, I guess, in New York.

LEVINE: As a matter of fact, at Rockwell, the people at Rockwell would say "yes" and mean, "If you catch us, yes." This doesn't mean that Rockwell did poor work. It was just an attitude. This division of Rockwell, being in the Southern California area, had people located there that came to California not necessary to work on the space program but basically to go to California. Nevertheless, the team that we finally evolved with turned out to be a pretty dedicated team.

. You think we are all one homogeneous nation, but we have various people who have different attitudes and ethnic backgrounds. In New York, people tended to not move around very much. People live in the New York area, in Long Island or Manhattan area all their lives. They'd been there for generations. Not true in California. Many of these people have been there a few years. So that does change attitudes.

RUSNAK: And certainly the national scope of the Apollo Program brought all these attitudes together into one project.

LEVINE: What was interesting about the Apollo Program is the fact that the U.S. was in need of a national goal. But, in addition in California they were having some pretty bad financial problems in terms of the decline of the Aerospace Defense Industry. The Apollo Program came along at a good time for funding that injected a tremendous spike as far as their defense industry was concerned.

I don't know if anyone talked about that particular time period, but in the 1960-'61 time period, there were people at Rockwell that had been laid off had been pumping gas. They didn't have any jobs in the defense industry. So the Space Program came along, and this was a tremendous spike to the Aerospace Defense Industry. It might be interesting to follow up on this time period from a historical perspective as to what was the state of the nation in terms of the 1961-'62 period. Here were people who were engineers who didn't have any jobs who’s talents were used in working in gas stations.

RUSNAK: By the end of the Apollo Program, it was competing for funding on the same type of work, meaning aerospace engineers, whoever, for defense contractors for the Vietnam War. Some people have suggested that because of this, that separate economic draw is one of the reason why Apollo didn't receive continued support for perhaps further missions or whatever.

LEVINE: Because of the 40 billion dollars a year that was spent on the Vietnam War.

RUSNAK: Right.

LEVINE: You were correct that the Vietnam War was going on, and those who worked on the Apollo Program at the same time found it difficult not to be concerned about that war. I guess the historians today have to try to determine the effect of the Vietnam War on the whole nation. Even today it's probably going to take a lot of years to sort out.

I have my own feelings on the Vietnam Was. I matured during the World War II time period, and in the World War II time period, it was clear that the nation was looking for freedom for all people and we were fighting a war, to clearly win. The U.S. had something like 16 million military people under arms. In every town, a number of their sons were in the military. The whole nation was behind World War II. It wasn't true in the Vietnam War. We appeared to be a divided nation.

RUSNAK: With you spending all the time you did working on the Apollo Program, did you find yourself paying as much attention to these other world events going on?

LEVINE: Yes, I did. There was a friend of mine, I don't know if you'll ever have a chance to interview him, he later worked for me. He's retired, and his name is Harvey Fritz. Harvey Fritz came up through the military, and his attitude was pretty similar to mine. It was very difficult for us to grasp a war that had no fronts that we were not permitted to win. It was difficult to grasp the significance of the Vietnam War because we were used to a war where we had a definitive goal to win. But this has nothing to do with my role in the Space Program.

RUSNAK: In a way, working on Apollo there, you were fighting a war in the sense that you could win. You did have this definite goal. Did you have a sense of the competition going on between the Soviet Union and the United States in the space race?

LEVINE: Very much.

RUSNAK: Was that a motivating factor for you at all?

LEVINE: Oh, very much. We were very sensitive to that. There is a Time Record series, I don't know if you've heard about that set of records. It was put out by Time and perhaps Life, which discusses the Space Program and included the Apollo Program and the background details.

RUSNAK: No, I haven't listened to that.

LEVINE: One thing I neglected to say on the Apollo organization is that NASA Headquarters began to involve themselves as part of the whole program, although they had great difficulty becoming a technical part of the program in the sense of day-to day controls. Some of the headquarters engineers wanted to be technically in control, but they did not have the staff, and they didn't have the capability to really become that involved in day-to-day control that was required for this complex program.

As a matter of fact, there was a lot of managerial movement to the NASA Centers. That is one of the reasons I believed that people like Joe Shea came to Johnson Space Center. as well as George Low. They were at NASA Headquarters earlier. It was evident that they could not technically run the Apollo Program from NASA Headquarters.

. Turning to the Space Shuttle Program, one of the lessons learned from the Apollo Program was to formulate methods to not fundamentally make the same mistakes on the Space Shuttle Program. I don't know if you've ever heard of the term "configuration management" in terms of what it is. Configuration Management is involved in putting together the requirements for the whole program. There are change boards to review changes and waivers. One of the things we made sure of is to include the reliability type requirements in the configuration management volumes.

If you remember our discussion earlier, I was concerned in the Apollo Program with involving the relevant managers in an approval and sign off when a requirement did not get met. For example, through the FMEA process, critical items were surfaced that could cause loss of crew. There was a requirement that did not permit Criticality 1 items that could cause loss of crew, and if you did, it had to be signed off by the Space Shuttle Program Manager with appropriate technical rationale. So there were many Change Board activities dedicated to sign off on these Criticality 1 items.

Bob Thompson as the Space Shuttle Program Manager was the type of person who took that responsibility in hand and really took his responsibility to heart. Some people would tell you that they can't operate unless they are placed at the right level of management.

I say that's baloney. It's the person. You can make a person reporting directly to the President of the United States, but if he isn't respected, it's meaningless. I was going to do the same job regardless of where my placement in the organization was and I believed it worked that way.

It may not have worked as well had I not been a civil servant and working at NASA. A person who wanted to work and do a good job was not inhibited. There was a sense of freedom. I had freedom working at Johnson Space Center that I would never have had any other place. I mean, there was fantastic freedom of being able to get the job done, and any ideas that you had that you wanted to promulgate or promote, there was no restriction of that, none. It was amazing.

On the Space Shuttle Program, the configuration management documentation contained most of the technical requirements, and they were contained in a series called JSC 0700. There was a Volume 5, and in that series of documents, contained mast of the technical requirements. There were technical requirements that included things such as checkout and test requirements as well.

Since the Apollo Spacecraft was not reusable, some of the lessons learned from that program did not directly extend to Space Shuttle. For example, a question that came up was, "Since the Space Shuttle is a reusable spacecraft, do you have to check out everything every time?"

The Space Shuttle Program has a requirement of a two-week turnaround, and the issue was could you meet a two-week turnaround and be able to check everything out? Well, there was arguments going back and forth, My concern was the answer depended a good deal on the maturity of the spacecraft. One of your questions, as a matter of fact, was that when will the Space Shuttle be operational? One of my concerns was that it is difficult to state with confidence that after a certain number of flights you're going to be operational.

You take a conventional aircraft, like an airliner, they do a multitude of flights well before they released it to the airlines. We didn't have that opportunity and program. Here we were with a few spacecraft (4-5) trying to become operational with a few flights. I think the operational aspect had more political significance than was technical. It had no technical significance to me at all, because I thought of the Space Shuttle Program as an R&D program even to this day.

RUSNAK: Yes, we actually talked to Don Arabian down in Florida.

LEVINE: Interesting person.

RUSNAK: Yes, he is. Since you brought him up, his point that he made several times with us was that a lot of this redundant testing, from his perspective, would cause perhaps premature wear or failure of these parts, so he thought a lot of the checkout at the Cape, for instance—I think that was his big area of concern—would cause more problems than it uncovered. So I was wondering what you thought about how you countered those arguments.

LEVINE: Well, of course, you counter this argument because you don't wear these parts out because they aren't used that much. On an aircraft, you use similar parts for thousands and thousands of hours continuously, and many of the Space Shuttle components are not used that much. They're in a quiescent stage except for flight and except for things like fuel cells.

But even so, many of these flights were seven, eight-day flights. They weren't used that long as compared to the amount of use on an aircraft.

We were hearing from the Cape, "We can't turn the Space Shuttle around because you, JSC forced us to do too much checkout." Examples included an item like the APUs [auxiliary power units] that I was concerned about. Here we have a system that has a significant role in launch and particularly reentry control. If you had only one APU you might necessarily control the Space Shuttle on reentry. You had to have at least two. APU's for confidence. Even though the APUs are operated a very short amount of time, because you turned them off after you are in orbit, there was arguments about checking these APU's out on the ground.

My attitude was that redundant functional critical items should be checked out at liftoff so you knew that you had the required redundancy. That's the power of having requirements in the configuration management volumes I discussed earlier in that it couldn't be an arbitrary decision.

. For the first time in the Space Shuttle Program, there were many people that have accountability, not just the program manager, but the Change Board as well. This is reliability controls. They don't always have the title "reliability," but they are a fundamental part of reliability.

There are a number of critical items in the Space Shuttle configuration volumes such as the 8080 standards. The 8080 standards were lessons learned. One of the standards is associated with not putting all your redundancy in the same area. Guess what's happened recently to Houston caused by the Allison Storm? In Houston, many of the hospitals located their primary and emergency power in the same location, namely the basement where flooding caused loss of all power.

RUSNAK: The basements?

LEVINE: And what was the primary cause? Water. So it wiped out all of the electrical power redundancy. So you had emergency power. Why did they design it to be in the same location? Because it was convenient and you also try to keep the noise level down so you the electrical power in the basement. Also, by putting the power down there, the emergency power lines were close to primary power. So it's cheaper to do it that way. But what a disaster to the hospital system. Hermann Hospital, for example, at the time of this interview is still not out of the woods as we speak. Some of the others are beginning to come back. Have they learned anything? Is there a lesson learned there? I don't know. I don't know if they really understood what has happened to them.

But back to the Space Shuttle Program. Do you want to ask any questions in relation to that program that I haven't covered?

RUSNAK: In relation to Shuttle?

LEVINE: Yes.

RUSNAK: Well, if you want to continue making some remarks about it, that's okay, or I could ask you some specific ones.

LEVINE: Why don't you ask me some.

RUSNAK: Okay. A sort of transitory question from Apollo to Shuttle—

LEVINE: One thing I didn't cover, and I'll come back to the Skylab Program. There's not a lot to say on that. In fact, why don't I cover that program. The Skylab Program was, to us, basically a utilization of the Apollo Spacecraft. The LM was not involved. It was basically an Apollo-type mission to a workshop fabricated from one of the Saturm Modules.

. Basically, the same reliability disciplines used on the Apollo was just a continuation on Skylab. There wasn't anything special, other than the latch-up itself and the new equipment that was used in the workshop. This program was valuable for lessons learned for Space Station. Bill Pogue probably provided a number of interesting remarks on his Skylab experience.

The ASTP Program used the Apollo Spacecraft to rendezvous with the Soviet Soyuz spacecraft. This program probably contributed something to international relations.

RUSNAK: In this transition period from where you're going from Apollo and doing these follow-on missions, the Skylab and the Apollo-Soyuz, where you're doing hookup with the Russians, are you at the same time then gearing up for Space Shuttle, are you then running all these activities simultaneously, the end of Apollo, the beginning of Shuttle, and then some of these Apollo follow-on programs?

LEVINE: Yes. Basically, where there's a new program coming up, even though there was a small contingent of people that were assigned to things like Space Shuttle, I personally got involved in this new program. I wanted to make sure that some of the problems we had on Apollo would not transition itself over to Space Shuttle. So some of these configuration management documents that I've referred to earlier such as the 07700 series, Volume 5 required my people reviewing these documents to make sure that things like the 8080 standards and all the reliability requirements are included not as guidelines.

Even on earlier studies like Space Station we began to participate as we could. You didn't ask questions on Space Station earlier, I spent probably a year or two on Space Station-type work. I'll talk more on Space Station later.

RUSNAK: You were mentioning the documentation again. That got me thinking about the importance of documentation overall, of all these steps of all the process that you're going through, through the testing and manufacturing and such. Could you maybe share a little bit about the development of that going through Apollo and what stage it was as you were going into the Shuttle Program?

LEVINE: You mean the stage of development of Apollo versus Space Shuttle?

RUSNAK: Yes.

LEVINE: I think at that particular point in time, Apollo was reasonably mature, as you can make a program of that type mature. I mean, we were going to conduct several landings on the lunar surface, and we had reasonably great confidence that we could make landings of that type. A number of us were looking forward to other things, but all of our attention still gave priority to the next flight. There wasn't a flight readiness review that I didn't participate in. In other words, my attitude was that every flight is unique, and if you lose one mission, that's enough to wreck the whole program.

So even though a part of your brain begins to look forward to greater visions of the space program, you cannot afford not to keep your attention on the current program. I don't know if that answers your question, but it was important to me and many others not to get distracted to the extent that you didn't look at the current program, and I didn't let my people get distracted that way, either, but I would, in fact, review documents to make sure that the next program didn't create the problems similar to the earlier program.

One of the problems that I see with long-term situations of people working at NASA is the need to see that the new people are properly trained. How are they trained? Who trains them? I trained my people, but when I left, you know, I didn't leave that legacy, except with the few people that were there. One of the problems, is that new staff was not being added. Chris Kraft, could add a lot to this discussion. I don't know if you interviewed him, Did you have a chance to interview him?

RUSNAK: No, he was waiting until after his book came out to talk to us.

LEVINE: He might probably tell you, we had a hiatus of no hiring for about fifteen or twenty years, so we didn't bring any new people on board. So here was people that were not that far away from retirement, and the average age, at the center was increasing. Every year, the average age increased a year because there was no hiring. So suddenly, people began to retire, and as they retired, they still didn't bring any new people on board.

Then years later they began to allow hiring, but there was nobody around with the knowledge to really train them. So even at this point, I think if you were to bring these people and sit them down and have the discussion that we're having at this moment, I'm not sure how many people would even be familiar with what I'm saying. It would be interesting to do that, to sit them down and ask them the questions associated with this experience.

RUSNAK: Now, fortunately, they have begun hiring people, and there are a handful of old NASA hands around that were there from the Apollo Program, but the number is very small.

LEVINE: A few of them. Well, I say a few of them. A good number of them went to work for contractors like Glynn [S.] Lunney, who is a friends of mine, who went to work for Rockwell and who was later with USA [United Space Alliance]. He's very sensitive about things we discussed, but he's probably ready for retirement. Bob Thompson is retired. So the people who were there when the lesson learned was fabricated are gone or not available.

You all are history majors?

RUSNAK: Yes.

LEVINE: If you study some of the tribal things that took place in the Indian nations, American Indian, they had a tremendous respect for the elder person that survived. Why did they? Well, those that survived had a sense of experience of lessons learned that they could pass on to the braves in terms of for example, "Hey, you'd better not take on the white man yet. You might all get killed." So they were able to bring on a maturity that would not be present, and then they would welcome these people as chiefs or give them some kind of title, but they kept them around. They didn't cast them off.

In our society today, I'm not sure how many of them are cast off. They're casting off maturity. I think that there's a lot of that takes place in the United States. I don't know if you picked that up in some of your history lessons or really have sensed that particular area or not. Have you?

RUSNAK: Yes, a little bit. Do you think that same thing is applicable for NASA specifically?

LEVINE: Yes, I do. I've talked to different people, and I'm not sure that they have the same sensitivity. I would have periodic reviews of subsystems. I'd make the guy get up and tell me about his subsystem. I'd quiz them and.they liked it afterwards, because it made them sharper. It's like going through a master's or a Ph.D. dissertation. There's nobody that I know of that's doing that with them at NASA.

RUSNAK: It brings to mind an interesting comparison, I guess, with the very early space program with Mercury, Gemini, even the early days of Apollo, where you don't really have any old hands who knew about space because there wasn't any. So do you think that same kind of activity is possible now as then, when you had people with relatively little experience, a lot of young, eager people that got the job done, and maybe what are the drawbacks of that.

Leavine: Well, that's a good question. As a matter of fact, having never done it before was probably useful. But what they did do was bring on board a lot of people who had had a vast amount of aircraft experience as I had. With that aircraft experience, you were able to bring that to bear to the space program almost 100 percent. Had these people who had not had the aircraft background, and many of the people from NASA and Langley didn't have this experience, had they not brought on board the industry people like myself, it might have been a different situation today.

RUSNAK: That's interesting. Well, if we can stop to change out our tape here for a few minutes.

LEVINE: The concern, as we went towards the Space Shuttle Program, one of your questions was, what were some of the concerns on the Space Shuttle Program unique to your area? One of the areas under my purview was the Triple-E Parts Program, which stands for the Electrical, Electronic, and Electromechanical components. We ran into a problem of counterfeit parts. These parts were not unique to the Space Shuttle. They were military parts, and we used a number of military parts, for the most part, of a Level B nature, which were screened and burned in on the program.

Basically, we ran into this counterfeit parts program through notification by the FBI [Federal Bureau of Investigation] and the GIDEP Program. As a matter of fact, the (FBI) alerted us that some of these parts had been counterfeited and were marked as being authentic when they really weren't authentic. Did we have any on our program? Well, how did we know? So we did a large amount of research, and the expectation is that we probably did have some of these parts.

Now, how do we bail ourselves out of a problem of that type? One of the requirements we had was separate screening and burn-in of these parts. If there was any infant mortality or any failures of these parts, we'd be able to detect it. The other thing is, the parts were derated. They are not used at the highest power level that they're capable of being used. Just as important is the fact that redundancy was there and helps us to take the risk. Most of these parts were probably military parts that were rejected for minor reasons.

The electronic area is easy to attain redundancy because of the size and volume of these small parts. whereas you get into engines, it's difficult to have as much redundancy as we had with EEE parts.

I was visited by the FBI, and he discussed the background they had on this problem. They found the guy who was behind the parts problem. Some of these parts were actually military parts, but they were, for one reason or another, rejected, and this guy would mark them as being authentic. They weren't necessarily completely failed parts. It's like buying surplus parts.

This is an important aspect of the Space Shuttle Program in that we were at the mercy of components that we didn't initially design and build from scratch, except for the engine. We basically are at the mercy of buying parts not off the shelf, but military tagged parts. The initial computer was a [Rockwell] B-1 [Lancer bomber] computer that was adapted for Space Shuttle use. So the ability to do everything from scratch for the space program was not in the cards, and it wasn't even in the cards on Apollo.

So as to the uniqueness of the Space Program. Many people believed that "The space program built and designed everything from scratch," they did not. Most of these things had a heritage. Like the fuel cells, Pratt & Whitney fuel cells, we had used Pratt & Whitney fuel cells on Apollo, and on Space Shuttle we adapted them and used them on Space Shuttle. So many of these components, particularly in the parts arena, Triple-E parts arena, are not unique to the Space Shuttle Program.

I think, probably, if you look around for the APU history, which is the auxiliary power unit, they used them on an aircraft at one time, not necessarily the same exact design and unique technology. I don’t mean the same identical item, but a similar technology. Incidentally, that APU on the Space Shuttle was an example of where we had quite an argument in terms of placement of the APUs, because it's useful to have all the hydraulic lines running close together and so forth. But then one of the 8080 standards was separation of redundant paths. That's an 8080 standard. Well, the APUs are all kind of close together on a wall there in the aft bay of the Space Shuttle. One of the tests revealed, that the APU could fly apart on worst case conditions, but apparently the case containment was sufficient and debris didn't have enough energy to really go very far.

These three APUs, even today, lay pretty much in close proximity, which is convenient from a hydraulic standpoint and a line standpoint to have them located in the same area. The FMEA did, in fact, basically reveal it as a single incident of a runaway APU that could cause you to lose redundancy of the other APUs that were still present. There is a waiver, and in fact, this issue was discussed at length of being able to buy this waiver.

So many of these 8080 standards could be used by other industries. For example, medical centers could make a better decision relative to locating the emergency power with the primary power. They could not do any surgery at all. No elective surgery could be done in most of these hospitals.

How do we advertise this type of lessons learned? As we went through these programs, particularly the Space Shuttle, they set up a Technology Transfer Office at NASA Headquarters, under an individual by the name of Magavro. Have you ever heard of that name? Lou Magavro. He was very much involved, and if you could talk to him it would be useful. There was a Technology Transfer Office that was set up at each of the centers. They still have one here I believe. The major purpose of this technology transfer office was a more controlled way of transferring information from NASA to various users, regardless of who they are.

One of the advantages I had was that I have a diversified background, such as a master's degree in nuclear engineering and I had done the work in the nuclear area. I had the advantage of that experience that I could bring to bear. Communicate with other industries, be it nuclear waste management or nuclear electric power. I think that background was useful for technology transfer purposes. If you can't communicate with people in other industries they don't necessarily understand you. You've got to be able to communicate on their terms and their understanding.

You had some other questions of me on Space Shuttle. Do you remember any of those?

RUSNAK: Yes, I'd asked about some of the systems and perhaps the reusability of the Shuttle, what sort of demands has this placed on them over the previous programs.

LEVINE: Well, the fact that the Space Shuttle is for the most part reusable did, in fact, bring to bear the discussion of a repeated flights and ground checkout. It did not have the same kind of emphasis as it did on Apollo. Apollo, everything was checked out, and we used each spacecraft one time, it was a single-shot device. But on Space Shuttle, with the reusability aspect, then you begin to think in terms of making sure that you did sufficient testing. In many instances, there was a reluctance to do too much testing because physical time testing of some of these components to the duration's would use some of the life of these components up to 100-mission requirements. Some you could, cycles-wise test like switches and that type thing. But some, you couldn't do it. In other words, basically you had to demonstrate a sufficient amount of checkout time, and you would want to make sure that you didn't have a wear-out phenomenon occurring.

That's the reason I argued so fervently with people like Don Arabian in terms of full checkout at the pad, because I did not agree that we were operational after a few missions. I wanted to make sure we had redundancy at liftoff. Reusability was a big thing.

Another thing, although we've hit the 100-mission requirement recently, as far as Space Shuttle, not on a single spacecraft, but 100 missions. You begin to think that's quite a feat, and it was quite a feat, but when you think about it in terms of the number of hours, say 100 missions times seven, eight days, and compare that to some of the time used on commercial aircraft, it may not be that significant in terms of time. It's nice, it's great, it's wonderful, but it's not that huge a feat in terms of duration. So that's about all I can say on that particular area.

RUSNAK: We had talked a little bit earlier about how getting the contractors to understand the new reliability requirements as such on Apollo was difficult, but now that you're doing Shuttle you've got the same prime contractor, North American Rockwell. How did instituting this program compare with earlier?

LEVINE: That's a good question, because we didn't know in the bidding process there that we would have the same contractors. We didn't know that we would have Rockwell on the Space Shuttle Program. We might not have had Rockwell. We could have had somebody else. There was a lot of bidders. Grumman was bidding, and I think Lockheed was. We had a number of bidders on the Space Shuttle Program. The fact that we got the same contractor and basically the same people was a tremendous help to me, because I didn't have to go through the learning curve process again with a new contractor. There was a few people that had worked on the Saturn Program that had not worked on the Apollo Spacecraft Program that was around, and they wasn't hard to convert.

You had had a question earlier on the Saturn Program, on the Saturn V Program, in terms of an all-up launch program , and I never really answered that question during this discussion. Although I wasn't part of the decision-making, I did have a strong concern in that particular area. The unmanned work they did on the Saturn IB and the work that had been done before they got to Saturn V provided a good learning curve that provided confidence that approach would be okay. MSFC did an immense amount of test-stand work as well and that, I think, was the thing the convinced people that you could use it for manned launches for the first time.

RUSNAK: While we're discussing Marshall, with the Space Shuttle, you've got them integrated, I think, more into the program than you did in Apollo where there's very definite interface. In this case, you've got Marshall doing the engines, the boosters, that sort of thing. How did the reliability requirements for JSC compare with how Marshall had traditionally done things and how were those mated for the Shuttle Program?

LEVINE: That's a real good question, because, as a matter of fact, I found Marshall more quality-assurance oriented then they were reliability oriented. The way Marshall was organizationally set up initially under Von Braun, was that he set up labs, and he had a lab called a quality assurance lab under a man by the name of Dieter Grau. As far as reliability was concerned, I found them more inspector and quality-assurance oriented than I found them reliability oriented. They gradually evolved into a greater understanding in this area, but I never found them completely that way. Much of the reliability type of work was done in the engineering area. They have the NHB document and all this sort of thing, and they will follow that, or their contractors will, but the people themselves, I never found a Joe Levine (thank goodness) over there, although I hunted for one over at MSFC expecting to find someone that was really pushing that particular avenue. I did not find it. That's a good question.

RUSNAK: That brings up a general question just to provide some clarification for the record. Where are the dividing lines between safety and reliability and quality assurance? Where does one pick up and the other one leave off?

LEVINE: That's a good question. The safety aspects depend a lot on the disciplines that come out of reliability, except they do other things. They have an analysis they call the hazard analysis. Basically many of the hazards are devised from a failure mode and effects analysis. That becomes a hazard because it's a Criticality 1 event. Other hazards are devised from the man-machine relationship.

Some of their hazards that they pick up on uniquely is like they'll start with a top down effect in safety, like the potential of a fire. What causes this fire? Then they'll go backwards in terms of a hazard analysis technique, to evaluate that. So there's a top-down-type technique that they use. They do pickup a lot in that particular activity. Failures that occurred that we evaluate and approve. Safety would pick up also to substantiate their hazard analysis. So there was a degree of overlap. Not a huge degree of overlap, since they were looking at hazards as a top-down standpoint. But they basically were using the disciplines we were doing to a large extent.

In the quality assurance arena, which brings up an interesting area, many of the failures were caused because of workmanship problems. One of the responsibilities of the quality assurance people is to basically address workmanship and process problems. As you will see later, I developed a technique, which I call the process failure mode and effects analysis, that tries to address this. But I found that for the most part most of the quality assurance people, while capable in what they were doing were inspectors, they were not engineers. Although some of them were called quality engineers, many of them had the title, but they were not degree engineers.

Basically their techniques were mostly looking at the last time you could inspect something you can see before it is covered up, or you have what they call mandatory inspection points, that they call these MIPs. So down the line, they'll say, "I'll need an inspection point here to see if in fact that previous problem is potentially present, " so they'll lay out these mandatory inspection points."

The Quality Assurance people don't have hard and fast rules in terms of how many inspection points they have, because if they have too many inspection points, then the complaint goes out of the manufacturing area that "You are slowing us down because you've got too many inspection points."

Actually, the quality assurance area was probably the only area in industry that exists today as an entity. If you go to Firestone and all these other places, they'll talk about quality assurance. You will not see too much discussion in terms of reliability. They'll talk about safety from a standpoint of industrial safety, but you don't see that much aspect other than quality assurance inspection, because people understand that. They'll say, "Has this item been inspected?" and you'll get a "yes" or "no" answer. "How did they inspect it?" "Well, we saw that it was together, " or, "We were there during the acceptance test," or that type of thing, or, "We had certain mandatory inspection points," you know, that type thing.

So that's a very good question, and that's about the best way I can break it down in terms of that area, because when I came to NASA, when I put together a R&QA document, I put together a document that covered both reliability, test, and quality assurance. I covered all three of these. I didn't cover safety, in the sense that it's covered today, but the NHB 530041D document does cover that.

RUSNAK: I think that's an excellent description of how these work together and where the responsibilities lie exactly, which is something I wanted to ask you about.

LEVINE: I'm not belittling Quality Assurance because Jack Jones (Quality Assurance Division Chief) is a close friend of mine and competent. One of the frustrations that many of the quality assurance people have is that they want to be professionally on the same level as everybody else.

Many of the QA people I noted when I was at General Dynamics was they did not have the stature, although they wanted this stature. They did everything they could in terms of organization, professional societies (ASQC, American Society for Quality Control], and everything they could to begin to develop that stature. They've done a lot in that particular area. I think in order to get that stature that I think they're seeking, they have to be a more fundamental part of the program, as I've tried to develop it in reliability.

RUSNAK: That's interesting, because one of the things that this was bringing to mind was something you had mentioned earlier about how a lot of the contractors grew to hate you, or whatever, because of some of these problems, and I've heard some similar remarks about some of the inspectors, so at least in that way they're getting their job, I think, done in such a fashion or with such a diligence that they had to bring contractors around to that point of view.

LEVINE: One person that I don't know if you ever get to talk to was at the Cape, KSC [Kennedy Space Center], is a guy by the name of Joe [Joseph M.] Bobik. I don't know, have you heard that name before?

RUSNAK: I have heard the name.

LEVINE: Joe Bobik, when we were doing the boilerplates (early launch escape system demonstrations) and I met him at White Sands, I thought he did a real good job, and I learned a lot from him in terms of inspection and evaluation of those boilerplates early on at White Sands. I regarded him as a tiptop inspector. He knew where the bodies were. I mean, he knew how to get in there, and with a minimum just horse-sense-type thing, looking at wire lacing and wire layouts and looking at plumbing. I mean, he pretty well could pick out problems, and Jack Jones could also. He was very good in terms of picking out problems that were there that you can see from a top-down standpoint.

One of the problems that many of the quality assurance people is that they didn't have that overall perspective of looking at the system as a whole and just go in there and walk through an area and say, "There's something wrong here, here, and here," just by walking through it. I think at the Cape they are doing more of this thing about walking through an area, but that results from a degree of maturity and understanding. One guy could walk through there and see nothing, and another person could go there and, pick out a thousand different problems. I have great respect for that type talent.

If you ever can seek out Joe Bobik, I think he's down at the Cape. He was working for Lockheed at one time. If he's still alive, he'd be an excellent person to talk to.

RUSNAK: I didn't know if there were any other remarks you want to make on Shuttle before we looked a little bit at Space Station.

LEVINE: Well, I guess one of the things Space Shuttle is becoming more mature. We have had quite a few flights under our belt. There is the constant battle of trying to make sure that the spacecraft is not too highly regarded as an operational vehicle at a sacrifice for being lax.

The Space Station was one of my last interests before I retired from NASA. One of the concerns I had was how much can we transition our experience that we had on Apollo and Space Shuttle to Space Station. Now, what's interesting about Space Station is Space Station is not really a spacecraft in the sense of you send it up for seven to ten days or two weeks and then you bring it back. Here you have a laboratory, a facility, an ever-changing facility. One has to think in terms of preserving the facility for use in payloads, experiments and launching satellites and this type thing.

From a reliability standpoint, my responsibility for Space Shuttle payloads, in many instances was nothing. There the safety people took over completely. They had the complete responsibility. In fact, there is a payload safety document that's one of the configuration management series, and there you basically look at payloads from a safety standpoint. Some of them are satellites that were deployed from the Space Shuttle. It disturbed me because from a taxpayer standpoint. I said, "You know, you spend millions and millions of dollars on some of these things, some of which the government was funding and then the question would come up is, what if they don't work?

"Well, if they don't work, you bring them back and try again." I said, "Do you realize how many dollars per pound it costs to deliver a payload in orbit, and if it doesn't work, you've got to bring it back and start over again?" I said, "How much money is it worth to make sure it's right the first time and you can use it and the information?"

So because that responsible organization knew I was on their back, they developed a document called a payload document that began to categorize payloads into different classes. I forget the name of the document. They had what was called an "A." An "A" document is one just like the spacecraft. It received the maximum requirements. We didn't have many of those. And it had a "B" and a "C." A "C" document—I think it was a "C"—a "C" was everything else, and it had very little requirement other than safety. The “C’ level got reliability off our back. We don't need reliability help. So they categorized everything "C," almost everything that I ran into, were categorized "C". That way we didn't have hardly any involvement at all with payloads.

But what troubled me, and still troubles me today, and that is the economics of the thing. Why have an experiment or payload that don't work? So I felt the same way towards Space Station. As it began to work on Space Station, I said, "You're going to have literally hundreds, maybe thousands of these payloads, and you're going to spend the money and get them up there, and they may not work. Are you going to try to maintain them in orbit? You might not be capable of maintaining experiments in orbit. Most of the time you have to just package it up together and send it back." In fact, they're struggling now with the arm, you know. They're trying to get that thing operational, which is another story.

But the point here is that I've never really been satisfied that anybody has had a complete understanding and sensitivity toward payloads, the economics aspect. The safety aspect, perhaps, but the economic aspects, no. They're not sensitive to it. And the reason behind it is that many of these payloads are furnished by other people. There's nobody in charge of this whole thing saying the government doesn't want to spend this kind of money on something that don't work.

So on Space Station, one of the things that we began to work on almost immediately is that we were looking toward the number of requirements. As a matter of fact, I put together a briefing for the Associate Administrator over the Space Station at that time at NASA Headquarters. The briefing covered a number of areas. I said, "What is different between previous programs and Space Station?" Of course, the thing you hit is on the long-life aspect. You hit on the fact that Space Station is a facility, an ever-changing facility-type thing, and you hit on the aspect of the requirement of in-flight maintenance.

In-flight maintenance aspect began to be the most important difference from previous spacecraft programs. We had very little in-flight maintenance on Space Shuttle or Apollo. Some in-flight maintenance was used, where they could, they'd bring along another computer where they could plug it in on Space Shuttle and also on Apollo. You couldn't do much more than that. These spacecraft was not built for in-flight maintenance, unless you had a problem like Apollo 13 and that was not a tested technique.

So with Space Station, here's a situation that in-flight maintenance is a requirement. My concern is that with a finite crew, how in the world do you tie up a crew to do in-flight maintenance and leave little time for the reason they're up there to do basically experiments and science work. You tie them all up just to keep the facility going. Are you able to basically do in-flight maintenance, and nothing else. Who is studying that?

The briefing went across very well, and the Associate Administrator from NASA said, "You hit it right on the head." And everybody bragged about how good the briefing was, because although my briefing was a reliability briefing, I was hitting the major concerns from a top-down standpoint for the whole program. Unfortunately, even today, I don't think that NASA is sensitive enough to in-flight maintenance.

One of the problems that people did not really take to heart was the fact that that the Space Station was going to be an extremely long-life project that could go upwards to ten, twenty years, or even longer, and it would have to be maintained almost completely in space, with a very small amount of work force At the most, we were talking about if you combined the combined crew that were up there from an earlier crew of seven or eight people and with a Space Shuttle crew, you still don't have a huge work force for such a large facility even with help from the ground.

How much of this facility could you return to Earth? The ability to return a grappler they had a problem would be something else. But, anyhow, one of the things I looked at was the long life ability. How long can this stuff last?

We let a contract to Martin [Martin Marietta Corp.]. It was called a long-life study contract. That was the name of it. We were looking at, basically, wear-out modes? How long can things last? You're talking about a capability of being able to go for a huge number of hours and time and years without failure. How do you do that? When you think about it in your house, how long do things last? I mean ten, twenty years is a long time.

We picked up a lot of things. Probably the biggest thing they picked up on was that we didn't know much, and they didn't know much. We really couldn't really pick out and say something would last ten years or five years or so forth. One thing it did pick out, though, that became pretty evident to me, was that if you housed everything on the outside and caused the crew to do basically EVA [extravehicular activity] in suits on most of the equipment, then you didn't have a chance.

One of the redesign things that took place on the Space Station was as design effort to begin to move things in the inside. They still have stuff on the outside, but they've got a lot more on the inside than they ever had before, and I think that design effort took place after I left, as a matter of fact.

One of the things that we had as a reliability and maintainability program on the Shuttle is everything was designed for reuse up to 100 missions and ten-year life requirement. That was the requirement on Space Shuttle, with the exception of external tanks and solid rocket boosters and stuff like that. They had a twenty-mission limitation.

But on Space Station, I don't think there is a time requirement as far as I could see. Most items are assigned an indefinite operational lifetime, and its provisional and change-out ability have to remain operational indefinitely as needs demand. Payloads are optimized in terms of crew involvement. As far as redundancy is concerned, you could put in some rules on redundancy, like the vehicle subsystem can't be less than operational fail-safe. So a lot of the rules still apply.

The capability required is to perform maintenance and repair on orbit. Overall, the process is not to degrade the spacecraft by selected repair modes. How does one do that?

They may have five or more people up there, and, as a matter of fact, they have reduced the number of people on the crew, as I recall, to, what, four or five now, five as a maximum.

How does one do repair and in-flight maintenance while sleep and other mandatory tasks are required. When is there time to do useful work? That can be very tough. How much can they really do? So in-flight maintenance began giving me a tremendous concern even then. Here I'm talking about work in 1985 and earlier. Now here we are in 2001, and I haven't heard a good answer for it. They appear to not have a good answer for in-flight maintenance. I have not heard of how much useful work is being projected. NASA is still in an assembly mode right now. They are in assembly mode. When do we see useful work? And how much useful work will they be able to do? It's going to be an awesome problem, in my opinion.

One of the things, though, I got into in the 1983-1985 time period was what about critical spares and hardware maintenance capability? What critical spares, how many critical spares, how big can they be? The revisit capability may be on an emergency basis or resupply on a monthly basis or more. Not much faster than that.

So meanwhile, it depends on how critical the spare is. If the spare is very critical, you'd better have it stored there. One of the requirements that I proposed was to provide onboard critical spares and hardware in-flight maintenance capability. I had a lot of questions that I couldn't answer at that particular time. How do you do Triple-E parts controls in that particular area, and how do you balance reliability and maintainability together?

On Space Station, the name of the game of reliability is maintainability, being able to maintain it, and being able to maintain it in orbit, not on the ground. You don't have that capability on aircraft. So here we have an example in space that the aircraft industry has not had to particularly worry about. They just land. They have a problem, they land and they maintain. They don't normally maintain in flight, unless they have some unique thing they could do. I don't know what it is. Ninety-nine out of 100 cases, it's always easy to find a friendly airport and land there.

NASA has had some experience for doing in-flight maintenance like on the Space Telescope, Hubble, they were able to do a lot of work there, but that was quite a unique in-flight maintenance job when you begin to think of it. The crew had to practice for months and knew exactly what they had to take up with them. It was a unique mission just for that. They've done tremendous in that particular area, and they're still going to have to do some more work in that particular area.

When you talk about a facility as large as Space Station, which has the Japanese experiment module, the Russian module, and our own module, it's going to be interesting how much useful science can be accomplished, and that's our whole reason for being there. Useful science and the ability of having man on orbit for huge amounts of time.

I don't know if you've had the opportunity to talk to people like the Skylab astronauts, have you?

RUSNAK: Yes.

LEVINE: Who have you talked to?

RUSNAK: Actually, most of them, the ones that are still around. Al [Alan L.] Bean, Owen [K.] Garriott, Bill [William R.] Pogue.

LEVINE: You talked to Bill?

RUSNAK: Yes.

LEVINE: Yes. Bill is a friend of mine. In fact, we did some consulting work together.

RUSNAK: There was Jerry [Gerald P.] Carr.

LEVINE: Jerry Carr.

RUSNAK: Ed [Edward G.] Gibson was the other one.

LEVINE: Gibson, yes. I don't know what Bill Pogue told you about in-flight maintenance, but he will probably confirm what I'm saying here. You did talk to him?

RUSNAK: I don't know if he mentioned in-flight maintenance. I'm trying to remember back. It was a little while ago that I talked to him.

LEVINE: Yes, he should have, because we talked extensively in that particular area on in-flight maintenance. In fact, probably they had to do a lot on Skylab in that particular area because they basically had a failure. They had to deploy ways of trying to keep the coolant down with the umbrella-type aspect.

One of the areas that I began to develop was software reliability. Up until then, we were pretty much hardware oriented. Now the question was, is how does one do software reliability, basically talking about codes and computers? The computers we could handle, but what about the codes and what about the software as far as this reliability is concerned? Even today, I struggle with that particular question.

I did come up with a reliability technique of doing software reliability that we adapted from our hardware experience like design reviews. They call them peer reviews, where they have people who had similar software knowledge, they would look it over, look over the codes, in terms of it. Other techniques they used in terms of software review was just running it to death in different modes of operation. So we put together a guideline software specification before I retired. Even today I'm not real happy with the status quo of software reliability.

People struggle with software reliability. There's a lot of software being used on spacecraft As matter of fact, this last Space Station problem with the arm episode was probably software. So we are so dependent on software in everything we do now, I think that that's an area that needs a lot of exploration. I confess I didn't get deep enough into that particular area.

RUSNAK: Yes, we've talked to a couple of the NASA people who were very much involved with software from the beginning through Space Station, and it's certainly one of the issues that they had to discuss.

LEVINE: I mentioned this long-life assurance requirements and some of the studies we did. We really created five study results volumes. One of the volumes was a summary of long-life assurance guidelines, I think we talked about; Triple-E parts and packaging; long-life assurance studies of components; special long-life assurance studies; and long-life assurance tests and study recommendations. This study was done in 1982, which I thought was a pretty good look ahead.

We looked at integrated circuits, hybrid circuits, transistors, dials, resistors, relay switches, circuit breakers, transducers, batteries, temperature cycling, bearings, accelerometers, gyroscopes, tape recorders, valves, pressure vessels, pumping compressors, electronic packaging, system design usage factors, accelerated testing, screening, and ratings. So I think it was a good look ahead, unfortunately this work was not carried forward, to my knowledge.

We put together a list of things that had to be changed for Space Station. Reliability management. I indicated that they had to incorporate planning, integrate maintainability and reliability approach. That hadn't been done before. That was a change. A reliability maintainability plan, a software reliability approach that I talked about. Numerical trade studies to incorporate reliability, maintainability, in all trade studies as required using numerical probabilistic approaches where credible. Statistical techniques might be useful to work on specific areas of Space Station.

The FMEA needed to be modified to incorporate the maintainability requirements of retention rationale. In other words, if the item failed, what do you do in terms of maintenance? We didn't do that before. What we did before is that if it failed, you would want to make sure could you accept the rationale for that failure or use redundancy. Now if it failed, could you continue by repairing it? That's a different approach in the FMEA than you had before.

On parts control, we talked about what was the right level of parts we ought to use for such a long-life program. Do we need gold-plated parts that last longer? We really didn't come up with a huge change in that particular area, nor did anybody else. Materials control, we talked about trade study to control flammable materials for Space Station. I'm not sure how well that's done. You know, you've got yourself a big facility there and people running around with possible flammable materials. I'm not sure about the hazards of that particular Space Station long haul. It's ignorance on my part, but I'm not sure that that lesson learned has taken all that well.

Maintainability analysis. I thought that special maintainability analysis integrated with the reliability analysis were needed. We're talking a long time ago. We're talking 1983. Limited life control. In other words, those items that we know are on their way out ought to be incorporated in the maintainability area. Test control, a trade study to evaluate an overall test approach from ORU, that's orbital replacement unit, acceptance to integrate in module pre-flight and in-flight checkout, including modification. How do you do test control, including usage on in-flight? How do you take a spare up there, and what do you do before you incorporate it? You don't have a checkout facility up there. It's a different breed of cat.

Milestone reviews. I said we need to evaluate the present method of controlling milestone reviews. What is a milestone review? We have used FRR’s [Flight Readiness Review]. You have a continuing FRR on Space Station. What do you do in terms of a facility review before you allow something to take place? Who does it? Who's involved in it? Is it strictly the flight control people?

Problem reporting. I indicated you ought to modify the problem reporting corrective action format to ensure maintainability corrective action appropriately. If you have a failure, you always should say, "What can I do from a maintainability standpoint in the future?" I'm not sure that that's included in today's problem reporting system. It should be.

Alerts. You know what a GIDEP ALERT is. They have an ALERT system that was managed by DOD [Department of Defense], and in case of a generic problem, everybody gets alerted. Like counterfeit parts were an ALERT at one time. I set up a closed-loop system on alerts that says on every alert I want a positive approach that I do or don't have the problem, not an open-loop response.

I visited with all the Space Station study contractors. We had Study Contractors back in '83 to try to establish a state-of-the-art understanding in Space Station. I was interested in Reliability, maintainability, and integration. I didn't do well. Except at Lockheed, they were sensitive to the Space Telescope because it was designed for in-flight maintenance. But for the most part, I didn't see any breakthroughs. I was really on virgin ground. I just did not really feel happy with what I saw.

The last point I mentioned to the Space Station Associate Administrator in this briefing was that studies are needed to ensure optimum approaches for recognition of the high demand on crew time. It's going to be high demand. The challenge ahead is to develop the needed reliability, maintainability technology to fulfill the Space Station's needs. That's '83. I still think it's true today.

RUSNAK: I'm kind of struck by how many of those points that you're making are applicable to the Mir Space Station and some of our experiences when we had astronauts on board that, these issues about maintainability, fire hazards, all of that, the time the crew spends doing maintenance. So I was wondering how closely you followed that program and if you found the same kind of parallels.

LEVINE: I followed it as closely as I could, you know, mostly through the press and that type thing, and it just reinforced my feelings on in-flight maintenance. Even right now, it's because I'm not that close to it, I guess, I don't feel great confidence that they have a handle on in-flight maintenance on Space Station. I feel that way because maybe because I'm not close to it. It's going to be a major problem. We've got a huge expense ahead. We started with a program, what was it, $8 billion program, we're up to about 20 or 30 billion at least.

RUSNAK: I think it's a lot more than that now.

LEVINE: Yes. I don't know. We could develop a lot of information there, and it's got to be more than just human demands, you know. A person can live and work in space for a year or two. It's got to be more than that. You've got to have a lot of technology developed out of that program. I'm not sure who the czar is that understands that particular area and has got grips on it. Dan [Daniel S.] Goldin may. I don't know if you can get a little history from him. He may have a handle on the thing or have some sensitivity on the thing.

ADDED ITEM OF INTEREST: NASA Administrator-Dan Goldin -August, 2001 announced distinguished team to review the International Space Station Program. The diverse team will take a focused look at the budget and management challenges facing the International Space Station Program. NASA Brief in the August 10, 2001 JSC Roundup.

It would be interesting to interview these people and say, "What is your feelings on this particular area?" It would be a good interview with a top manager like Mr. Goldin. He's certainly lived through this area, and it's been a major problem that the program has gone through I don't know how many evolutions to be where we are today, and how many people have been managers on this program that are not managers today. They've killed off a lot of people, a lot of good managers, as a matter of fact. I don't know how much you've got into that particular activity. Have you been able to get into that?

RUSNAK: Certainly not in the depth that we've had on the previous programs.

LEVINE: There was a program manager that was one of the original program managers. I can't think of his name. He's with SAIC [Science Applications International Corp.].

RUSNAK: Neil [B.] Hutchinson?

LEVINE: Neil Hutchinson. Neil would be a really good guy to interview.

RUSNAK: We talked to him once, but we didn't quite get up to his Space Station days. He's planning on coming in again to talk about that yet, so we've got that to look forward to with him.

LEVINE: Neil is a good guy to talk to. He was originally in flight operations here, and he's still with SAIC, I think. He would be a real good guy to talk to, because he was the original program manager on Space Station. Since then, I guess they've had I don't know how many Space Station Program Managers. Neil would be a very good guy from a look-back standpoint to say what do you think the problem is. I think, personally, the problem with Space Station is that they couldn't evolve a configuration. There was too many shifts. I think Boeing has become a good contractor. Maybe they had too many contractors there at one time.

The original thought on Space Station was, we're really going to spread the wealth. We were going to give every NASA Center a bite of this thing, because we want to keep all the NASA Centers technologically adept in this particular area. So we'll give Johnson some of it and we're going to do it from Headquarters, we're going to integrate it from Headquarters. It went to Headquarters and back to the NASA Centers and back and forth. JSC was a lead center and then it went to Headquarters. In my opinion, it's been a managerial nightmare. We are not out of it yet. The fact that they've done as much as they've done is tremendous. George [W. S.] Abbey, you've got to pat him on the back. He's certainly had a part of this, because the fact that they've gone as far as they've done is tremendous.

Here we are, we've gone back to 1983. This Space Station Program has been around a long time. When you think about how long it's been around and it's still not operational. This Space Station will not be operational, if everything works for probably, what, a year or two, at least, and then how do you do an operational review of that facility, and who does it? How do you incorporate reliability, maintainability into it? And do you use the same kind of techniques that we've used in the past? Do you use flight readiness reviews?

Who looks at the Space Station and knows exactly how it's configured, and how the maintenance was controlled for each facility configuration? How many failures have we had on the various components, and who's got a good handle on that particular area? I don't know. I really don't know.

RUSNAK: I don't know that I can answer that for you either.

LEVINE: You've got my state of knowledge on Space Station. I started working on Space Station, I was sensitive to it, very sensitive to in-flight maintenance, and I think I was sensitive to all the reliability aspects of this facility, but I didn't stay around Space Station long enough to really get either get fired or influence the Space Station Program. I'd probably have gotten fired. Why don't we take a few minutes' break, and then we'll go on to some of the technology transfer.

RUSNAK: Okay.

LEVINE: One of the major reasons I had for leaving NASA was that I determined that after a certain point in time that I should try to do other things and try to use some of the experience that I had acquired to do other things other than be a manager at NASA. It does take a lot out of you to be a manager because you basically are dealing a lot with people and people do take a lot out of you when you spend a lot of energy with them. Not that I didn't enjoy it. I do enjoy people. But as a manager, you're constantly under stress. It's like the bank teller that doesn't want to take a vacation because the bank examiner may come in while he's gone. I just basically never really felt at ease even taking leave and vacations.

So I determined at a certain time in my career, I would retire from NASA. One of the things that happened is that about three months before my retirement, I knew I was going to leave at a certain point in time, the people up at the Nuclear Regulatory Commission [NRC] wrote a letter to NASA saying, "We sure would like to have Joe Levine involved in a study incident similar to Three Mile Island," but it was the Davis Besse incident. It was a nuclear electric powerplant that had almost had a similar incident. "We'd like to have him in on the investigation." I thought, "Ah, this is a good opportunity to do something different, and I'm going to retire in three months," and the Space Shuttle was going pretty good.

So Marty Raines, who was my boss, agreed for my assignment and be a part of this investigation. The NRC Investigation Team was not to investigate the Davis Besse incident, but to investigate the people who investigated the Davis Besse and also investigate the Nuclear Regulatory Commission and find out were they doing the right thing. So there was a team of people from FAA, and me from NASA, and the person that was in charge was a former political commissioner from Maryland, he headed it up. There was a person from

NRC. There were several people from NRC. One was actually from the Headquarters NRC, and there was about six people in that involved.

I changed flights in Atlanta [Georgia], people were looking at their television sets. What were they looking at? It was the Challenger accident. I was changing aircraft in Atlanta, and I didn't know what should I do. Should I come back, or what should I do? I called Marty Raines, and he said, "Just go ahead. Just continue on, and we'll call you back when we need you."

So I got up there and met with various people, and they said, "What happened?" Well, I don't know. What happened? I don't know. I have a suspicion of what happened. I don't think it was caused by the spacecraft. I think we did everything we could on that, and everything pointed towards the solid rocket motor. That's exactly what did take place, as a matter of fact.

So I was assigned to the Davis Besse evaluation, and we had a merry-go-round. We went to the contractors. We visited Davis Besse. INPO is an independent outfit that operates as a tax on the utilities to keep reliability reports of various failures that have taken place at various nuclear powerplants. I said, "Ah, this outfit, called INPO, Institute of Nuclear Power Operations, was similar. They must be doing a great job." I said, "Well, what do you do with the information you gather?"

"Oh, we do studies." I said, "But what do you mean, studies? What do you do in terms of the people themselves as far as complaints are concerned?" It began to dawn on me that although they were keeping some information, the distribution of that information was cautiously kept at INPO. It wasn't distributed very much, so one nuclear power plant didn't necessarily know what the other was getting. It began to dawn on me, as part of the Davis

Bessey incident, and looking at the accident investigation. It dawned on me that if nuclear electric power in this country was going to succeed, it had to be by using a standardized nuclear powerplant. They should all look alike.

In France, my understanding is that up to 80 percent of the electrical power in France is derived from nuclear power, and they have standardized nuclear power plants. One of the lessons I've learned when I was doing a little consulting work on the Black Fox Project PSO Oklahoma (Canceled Project) with Bill Pogue at Tulsa. I talked with the people there about configuration management, I talked to them about reliability. One of the things I found out in talking with them is that nobody had any past experience. The contractor who they had brought on was an A&E [Architecture and Engineering] contractor called Black and Veach, a good contractor, built bridges and buildings, out of Kansas City.

"Had your people ever built a nuclear powerplant? No, but we can do it," you know. One of the things that became very apparent is where was the experience base? We have built about 103 nuclear electric powerplants in this country. Many of those have reached their so-called useful life that's supposed to have a thirty-year useful life.

If we're going to have useful and safe nuclear electric powerplants, we're going to have to standardize. One of the things I found out while visiting with the PSO utility was talking to people who were going to design the plant. The people at Tulsa had about 150, 200 people there. Most of the background at Public Service of Oklahoma and all utilities are operational people. They can operate the plant, but they're not designers. The designers are the A&E companies, Brown and Root, Black & Veach, etc. They're the ones that are designers. But after they design and build it, where are they? They're on another project. They're not around.

So I may write a few pieces of correspondence to our Vice President, who has endorsed nuclear electric power, and begin to push on this standardized plant concept. I think the nuclear industry has wised up to this also. I think you're going to find that they're going to be pushing standardized plants for the whole thing. There's no reason why not. The not-invented-here syndrome should not apply to this type of plant.

So anyhow, I spent about two to three months on the Davis Besse Investigation. JSC called me back for a part of the Challenger accident investigation to testify to the Rogers Committee. My briefing was pretty straight forward in terms of our disciplines, and I had no difficulty doing that. I went back to Washington. I guess that three months was spent mostly on the Davis Besse investigation. I came back and shortly thereafter retired. Had a nice going-away party.

Then what did I do afterwards? I wanted to do consulting work. I didn't want to have any employees. One of the problems I had was, how do I do consulting work without having a secretary? I didn’t want a secretary. I didn’t want any employees. But how do you turn out reports? That's when I discovered the home computer. The computer in that time frame, we're talking '85 was , pretty good. It could do word processing, this type thing. First thing I did is I tried to use typing pools. Disaster. Complete disaster. I'd give them a draft, I'd get back a terrible draft. They said I can't read your handwriting. It would be a mess. I'd send it back, and everything got cold. No good!

I purchased a computer, my first computer, and I self-learned how to use a computer. Up until then, I really didn't know how to do word processing. I stayed up until 3:00 o'clock in the morning for weeks learning how to do word processing. No expert, but for the first time, I could change a draft immediately to something I liked.

So I began to get involved in consulting work. At that time, contractors were doing the post-Challenger accident work, and they asked me to work on a project called PCASS. PCASS was Program Compliance and Status System. "The Rogers Commission had a bunch of findings, and JSC, as the lead center, don't know what the Space Shuttle Projects are doing. You just take their word for whatever they're doing, but you have no window into what they're doing." And they were right. We didn't set up a separate problem reporting system to evaluate what Marshall's problems were and how they rectified them. Every center did their own. For example, JSC did the Space Shuttle Orbiter part.

So the PCASS system was set up to provide that window. JSC did do a measure of good on the problem reporting area. They hired IBM to do PCASS and IBM had a sensitivity to this project to an extent. However, one of the lessons learned in hiring a software company or that type of company, a computer company, to do that kind of work is they had little sensitivity towards the operational usage of the data. They would work towards trying to gather the data, but they didn't have any sensitivity in terms of problems that evolved out of Marshall or JSC.

One of the things I began to drift into is the evaluation of problems that was a Criticality 1. These problems required Level 2 approval. They didn't have that requirement before. So I got involved in that for a year or so. I got pretty deeply in getting the Space Shuttle Program Office involved in that particular area. I also got a pretty good window into the way Marshall operates, more than I had before. So that was one of the things I got involved in after I retired.

About the time before I retired, I began to become interested in the fact that half the failures were caused by quality assurance or manufacturing process defects. At that particular point in time, half the failures are manufacturing defects. These failures can occur anytime, and these are not design-caused problems. These failures can kill you just as much as a design problem. What do you do about this type of manufacturing or process problem?

So I began to explore a bit with the quality assurance people on how they operated as I discussed earlier, and one of the things I found is, they weren't all that disciplined in terms of how they looked at processes. I began to think about it as if everything is a process. I mean, if you're building a device, you go from step A to B to C to D to E, you know. Everything is a process. And if it's a process, then it ought to be amenable to a failure mode evaluation. How can that process fail? What are the causes of those failures? What's it effect, and can you detect it right then and there, or will it be detected downstream at the next step, or will it be basically never detected until it's out in the field?

I really got involved in that technique, because it had a lot of capability and you began to think about it and it's useful to everything, e.g. tire manufacturing, etc. Everything is a process. Medical procedures. I talked to one organization whose chairman evaluates hospitals. You may have heard about them. They basically go into hospitals and they certify hospitals. No hospital can be operational without their certification. They have had a lot of problems. He's a professor at a dental college here in Houston. He was disturbed, because certified hospitals were cutting off the wrong legs. You heard about some of these terrible things. They've had, it turns out, 100,000 goofs in the country, at least 100,000. I don't know if that's per year. He's worried about is their technique sound? What is their technique? Their technique is they basically go into hospitals with experts that are working in the field. So the fox is now looking at the chicken coop. I mean, these are not outside people.

I think today we still have that problem of looking at medical processes. How do you look at medical processes? That process FMEA aspect could take a look and make sure that the right leg is properly identified etc., much more detail for each procedure. You go through each step of that process. Every surgical process should have a PFMEA.

The PFMEA [Process Failure Modes and Effects Analysis] I developed was tested fully on the Space Shuttle solid rocket motor. They (MSFC) wanted to understand that they were on the right path in terms of what we're doing on the solid rocket booster. We did do a complete study that included Thiokol and the whole design group. I still believe today that that technique needs to be used and refined. It's still not a part of the requirements at NASA here to my knowledge.

When I tried to introduce technique to JSC quality assurance people my success was zero. But it's so straightforward. Here I was offering them a technique that they didn't have, that they could adopt in terms of processes, because that's their job. To my knowledge today, they've never adopted that technique.

So the PFMEA was one of the techniques that I developed that I have to say has not been widely accepted, but it's been developed to an extent and used. But, still, I'm not happy with the fact that it's not really an operational thing.

I did run into something from the Ford Motor Company where I think they've recognized it, but I don't know since I haven't talked to them. I saw a document that had the name, so they may have picked up on the technique. They apparently haven't done too well on Explorer automobile and the Firestone Tire episode, so there may be something amiss.

So that's some of the things I've done. In addition to that, I decided my health was not as well as it should be, so I joined Bally's [fitness center] about six or seven years ago and made a determination, much like I did in reliability. I began to go to exercise about every day, except maybe I missed a day. I'm perhaps alive today thanks to this program. Any more questions?

RUSNAK: I had maybe a couple from things that have come up as we've gone along that maybe I wanted to ask about. I guess not in any particular order, probably.

LEVINE: That's okay.

RUSNAK: Just some couple points. One of the things I wanted to ask, looking at the entirety of your career at NASA, safety, reliability, and quality assurance, all this is getting at one thing, which is what you mentioned at the very beginning, it's the flight crew safety. It's their lives. What role do the astronauts themselves play in doing this? How much interaction did you have with them and how would you respond to their concerns and relay those to contractors, that sort of thing?

LEVINE: Well, they had crew debriefings usually after every mission where they'd say this didn't work, that didn't work, and so. But you already knew the information. So to be truthful with you, because of the crew debriefings and you already know the information, I didn't get at them as much as I should have done. I knew several of them like Bill Pogue, I know him very well and had him over to my house several times. They were somewhat protected because there were a lot of people wanting to talk to them. I talked to John Young a lot.

That's a good question, though, and they deliberately arranged crew interaction debriefings and this sort of thing, and the FOD [Flight Operations Directorate] people do a lot of interaction with them from an operational standpoint, but from my standpoint, it would have been good. I did brief a lot of the new astronauts.

Their interest was to fly, you know, the new astronauts, and getting into the operational aspects and the training aspect. I'm not sure how enthralled they are in terms of the detailed engineering aspects.

RUSNAK: I knew that each of the astronauts, and I believe they still do this, had a technical assignment where they'd say, "Okay, you're going to go work on environmental control systems, you're going to go work boosters," and so on. So I didn't know if they had ones that were particularly assigned to safety. You had mentioned John Young. I know safety has always been one of the foremost things in his mind. So I just didn't know if through that kind of thing, if any of that trickled up to you.

LEVINE: After the Challenger accident, while I was doing consultant work, one astronaut, I can't think of his name (Bryan O'Conner?). I'm trying to remember his name. He and I would have endless arguments on statistical reliability. He was very number oriented, and was bound and determined that the program would be moved towards reliability numbers. As a matter of fact, they had a contract with SAIC at one time. I did consulting work with SAIC also. The numbers aspect was useful because of the logic of putting the system together rather than the number itself. He was very much determined. He was the only astronaut that I found that had any interest at all.

RUSNAK: I wanted to offer Jennifer and Summer a chance to ask any questions if they came up with ones. Jennifer?

ROSS-NAZZAL: I know that you came in during the Apollo Program, as you had mentioned, and that you had a good sense of what reliability was like when you came in. Can you give us a sense of what quality assurance or quality control may have been like in the Mercury and Gemini Programs and how it changed in the Apollo Program?

LEVINE: From what I could devise out of the Mercury Program, and the Gemini, they were pretty similar, the same contractor, they had some of the same techniques, FMEAs and this type of thing. But it seemed to me like it was somewhat loose in terms of the rigor, in terms of approvals and this type of thing .It was almost like they had a special team dedicated to those programs and everybody knew everybody else and they trusted each other and it wasn't as big a situation. John Yardley was in charge. Is he alive?

ROSS-NAZZAL: Yes, he is.

LEVINE: Have you talked to him?

ROSS-NAZZAL: Yes.

LEVINE: He probably had some interesting perspective on this thing. NASA was using the same contractor for Mercury and Gemini, and I got the sense that it was almost like a family and that they didn't need as much paperwork. They did not have that much paperwork involved and didn't appear to have a support contractor that I know of. So it was a little different kind of perspective.

On Apollo, a large program, a lot of people involved, thousands of people involved, large contractors, and you'd better have your data. Where Mercury and Gemini was a short program, had the family-type atmosphere, everybody knew each other, trusted each other, used a lot of inspection techniques.

The R&QA person at NASA did not take lightly to any criticism either. This guy passed away that was in charge of those programs here. (Harry Douglas?) He respected me because I had a tendency to speed read. I was on a flight with him one time, and he gave me something to read. I gave it back to him. "You didn't read that." I said, "Yes, I read it." I had to learn to speed read because every day I got stacks of information, and if I didn't speed read through those stacks of information, I'd die. So I learned to speed read, maybe not 100 percent, but pretty good. Does that answer your question?

ROSS-NAZZAL: Yes, thank you very much.

RUSNAK: Was that Jim Chamberlin you were talking about?

LEVINE: No.

RUSNAK: Or Chuck Mathews, maybe?

LEVINE: No, he was in reliability, this person.

RUSNAK: I think we need to change out the tape and then we'll just finish up with our last couple questions, I guess.

LEVINE: Did you talk to any of the early Apollo managers?

RUSNAK: Like who?

LEVINE: I'm trying to remember some of these people like. Charlie Frick. There was a whole raft of these people. They'd come and go like gangbusters. They were here maybe a year, make their mark and disappear. They didn't make much of a mark.

RUSNAK: I think most of the ones we talked to ended up being there for longer periods of time, so I'm not sure if we got any of those guys or not.

LEVINE: I couldn't have answered all your questions.

ROSS-NAZZAL: Well, actually, you know, you answered all the questions that I had written down here.

LEVINE: More than you wanted to hear. [Laughter]

BERGEN: You were talking about people, as we were changing out tapes, and I was wondering if there were any individuals that made a significant impression on you or had an impact on you during your career.

LEVINE: Well, they all made an impact on me. You always search for a mentor that comes close to that. I think Bob Thompson comes close to meeting that. Certainly I feel that way towards him. I don't know how he feels towards me.

Marty Raines made an impression. He was a different-type person. Marty Raines is a retired colonel, and his method of management was different than mine. I micromanaged. He did not. But he’s a very intelligent person. You talked to him, didn't you? I certainly think highly of him. Dr. Gilruth I didn't know very well, so he didn't come through as a mentor to me.

The contractors themselves, Dale [D.] Myers (Rockwell Program Manager) impressed me, and he was somewhat of a mentor of mine. That's about the ones that come through as ones that I had real respect for them. There wasn't hardly any of them I didn't have a lot of respect for. I did.

Bill Bland, I hope you do interview him. Bill Bland is probably one of the most dedicated persons around. He came from Langley, the original space group. I hope he does allow you to interview him. Do you think you will?

RUSNAK: I certainly hope so. We've been trying to keep in touch with him to encourage him to.

LEVINE: Yes, because he's good and he has a very good sensitivity. He worked on the Three Mile Island accident. He did a lot of work on that.

BERGEN: You mentioned that you did consulting with outside industries. Did you or anyone in your group go to any other outside industries to learn from them and bring that knowledge back to NASA?

LEVINE: You know, that's a good question. That question of technology transfer, although it was an "everybody should do it" type thing, to my knowledge, in my group I was the only one. Now, Jack Jones, after he retired, did do some work with the nuclear electric powerplant up in the Dallas area, Dallas-Ft. Worth [Texas] area. But to my knowledge, nobody had a technology transfer bent in terms of "I want to do this. I want people to profit from this" type thing.

Years ago they had a technology transfer conference that I participated in, I gave a paper at, and there was a speaker there that was one of the presidential advisors at the time. I can't remember his name. (Davies?) I think he was under [Richard M.] Nixon. But he did have a good speech, and I remember some of the details today. The speech was, how do you transfer technology today? He said, "If you go to the Library of Congress and you look at all the documents in the Library of Congress, how does anyone penetrate all the data that's in the Library of Congress and make sense of it?" Data proliferation. He said, "How do you transfer technology?" was the theme. He said, "Well, that's one way." Certainly, that is a way. He said, "Another way of transferring technology is using people like me. I go to work for someone else, and I take what I know to this other outfit, and that transfers technology. However, it's random. It's not deliberate. You're sure to have it happen. It may not happen. It's random. It doesn't work all the time." So that's the second way you transfer technology.

The third technology transfer method is by conferences and papers and stuff like that. But none of these had a real positive approach that he was able to come up with. When you think about the problems in industry today that you run into, it's a little surprising that you see the same problems repeated in one industry after another. I don't know if that answered your question.

BERGEN: Yes. One other issue I wanted to ask you about was when we talk about Shuttle, so often what we hear is that there was always a constant struggle with the budget and funding. I was wondering how that influenced your particular area of quality and reliability, in your areas how those funding issues affected you.

LEVINE: That is a real good question, because in the Apollo Program, I had 180 support contractors. Marty Raines asked me for Space Shuttle, how many people do I want for Space Shuttle? There was no funding problem at the time. I said 53. Well, at that time, the support contractor was General Electric. I thought they were going to have a seizure. I thought they were going to have a seizure when I said 53. And why did I say 53? Because I thought that was the minimum number, I didn't want to debate it, that I needed to do the job.

One of the problems that happen to you, and I mentioned this earlier, is people can eat up your time. That 180 people had people that would come over where I was and they'd sit down at a table. We were in a bullpen at the time. I'd look up. "Can I help you?" "No, I just wanted to do some work over here." Pretty soon his supervisor came over with his butterfly net and dragged him away.

One of the problems was, is that when we had unlimited resources there for a while, some of these support contractors would ask for help from their home offices. Some of the help was to, "Let's get rid of old Joe Blow." Where can we get rid of him? Houston. Get rid of him. I had a lot of people that were eating my time up.

So the 53 people was not done lightly. I did that on the basis of, you know, that was sufficient. Do you know, I didn't pick the 53; the contractor picked them. Do you know, I didn't argue with one of them. They knew which ones were the performers versus the non-performers. They knew it already.

You should talk to Ed Smith. Ed Smith was a Space Shuttle Program Manager at Rockwell. You talk to a guy like Ed Smith, Ed Smith will just tell you that we knew what the pocketbook was at NASA. I knew exactly how much money Aaron Cohen's gets. So he knew the pocketbook, and He would try to adjust within that pocketbook.

Ed Smith went to Northrop and worked on the B-1 program, I think. Yes, I think he worked on B-1. But he was very much involved in Space Shuttle and somewhat of a mentor of mine. You ought to try to talk to him.

BERGEN: I have one final question, just to clarify something in my mind. You talked about processes and developing and testing for the processes. Did you give the contractor the criteria for that and let them develop their testing, or how involved were your people in developing what actual testing that was done and how it was qualified?

LEVINE: That's a good question. As part of the qualification test, the requirement has always been you want to demonstrate for at least a two-week mission-type of work. That's part of the requirements. You want to demonstrate that and the environments. So you would try to condense 100 missions' worth of requirements if you could, which are the thermal and the dynamic environments. You try to condense that into one qualification test.

So those top-down requirements were given to the contractor. Then when he took those requirements, he translated that into "Here's how we're going to do it" aspect. But he still had those top-down requirements to satisfy. He comes back with "Here's how we're going to do it. We're going to do vibration first and thermal afterwards," and so forth. That had to be reviewed and approved by my people and the subsystem managers to say, "Yes, that will work." I don't know if that answered your question.

BERGEN: Did they use their facilities or did they use NASA facilities?

LEVINE: Mostly it depends on the component. If you needed a large thermal-vacuum chamber, you might use some of the equipment here in the chamber here, but mostly they used their facilities.

BERGEN: That's all the questions I have.

RUSNAK: I didn't have any others, either, but I wanted to give you a chance to maybe make any concluding remarks or any other items you wanted to mention or any other stories you wanted to tell before we closed.

LEVINE: As I mentioned earlier, I think what you're doing here is extremely valuable, because one of the things that has been prepared by NASA Headquarters is lessons learned. I think if you could take some of the lessons learned that are depicted in these interviews and encapsulate them in some manner it would be useful.

I think it would be invaluable to the people that are coming afterwards. If you could do that in some manner or get some help to do it, I think it would be very important, because there are a lot of lessons learned that are coming out of the discussions such as this.

The other thing is, while we're still on that subject, it would be useful if you could bring together a handful of the people that you already interviewed and together in a conference and you act as somewhat of a moderator.

As to my career and what I've done in the past, I think that the most rewarding part of my career was at NASA, without question. I mean the work I did before I came to NASA was interesting and certainly helped build the knowledge I had to do the work I did at NASA.

RUSNAK: We want to thank you again for taking up all your time this afternoon.

LEVINE: Oh, no, it went fast and it was interesting.

[End of interview]