

**NASA JOHNSON SPACE CENTER ORAL HISTORY PROJECT
EDITED ORAL HISTORY TRANSCRIPT**

EUGENE F. KRANZ
INTERVIEWED BY JENNIFER ROSS-NAZZAL
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ROSS-NAZZAL: Today is December 7th, 2011. This interview with Gene Kranz is being conducted in Dickinson, Texas for the Johnson Space Center Oral History Project. The interviewer is Jennifer Ross-Nazzal, assisted by Rebecca Wright and Sandra Johnson. Thanks again for having us out to your house today. We certainly appreciate it, Mr. Kranz.

KRANZ: It's wonderful to have the opportunity to contribute to the oral history program for NASA and for Johnson Space Center.

ROSS-NAZZAL: Thank you. We really do appreciate it. We know that you're busy with other things. I thought I'd ask you how you transitioned from working on the Skylab Program to turning your attention to the upcoming Space Shuttle Program.

KRANZ: There were many challenges during that period of time. The first, as we were finishing up the Apollo Program moving into Skylab, was to assure that we had as much continuity as possible from a standpoint of the lead controllers, the people who would be teachers to a new generation. It was obvious that the Shuttle Program would be the last hurrah of the Mercury-Apollo generation. There would be major changes in the overall leadership within the agency all the way down through the working ranks within Johnson and into Operations. We would lose many of the young controllers.

They were young when we started, but now they became very valuable to the program. They would move out of Mission Operations, into Engineering and the [Shuttle] Program office, and even up into the [NASA] Headquarters [Washington, DC] and other Field Centers. So this was a time of massive people movement.

We were fortunate, during that transition period, to have Chris [Christopher C.] Kraft and Sig [Sigurd A.] Sjöberg, who would basically provide for this transition period—and I'll talk about this transition period as it would relate to Headquarters and some of the difficulties we had with the people coming in at Headquarters. We also had transition within our contractor team, because we were seeing the ending of the engineers that we worked intimately with during the early programs, particularly Apollo. We were going to have a Rockwell team again, and we would have several of the players. But again all would be moved in the process of phasing out their jobs, new generations moving in.

Within the mission control team, this was one of the more difficult times because I lost, I would estimate, somewhere around 40 percent of my very qualified people. So we had to bring in a new generation of young people out of college. The transition of these people is very much like we had done in Project Mercury, where all we had was a program ramping up very rapidly, and we had target launch dates where we had to bring in the capabilities we needed. We had to bring the controllers up to speed, teach them what the business of mission control was about. We were very fortunate because we captured a large group from [the University of] Notre Dame [Indiana]. In fact to a great extent Notre Dame dominated the new groups that we brought in. I think we captured between 20, 25 people. We were very fortunate. They remained within the agency.

This was also a time of transition socially, because now women would be introduced into the mission control teams. This led to a new group of challenges for those good supervisors I had before dealing with the challenge of bringing women into what used to be, or was previously, an all-male team. We did many dumb things. This was a time of change from a standpoint of the mission that we would fly, the technology that we would work with, the leadership that we would have.

We no longer had the ability, I think, to bring leaders into NASA at the beginning of the Shuttle Program that had a significant amount of hands-on experience in running a program. These were all people like Jim [James M.] Beggs, who was at that time the [NASA] Administrator. He had run programs, but not those that involved rapid movement forward in technology. He had not run programs that had a high human content to them. As such I think he got off on many of the wrong tracks.

We were fortunate that we had Hans Mark at this time. Hans developed an almost personal affinity to work with the teams in mission control. So every time that we would end up in some kind of a conflict with Headquarters and the Administrator—and we'll probably get into that as we talk about some of the missions—Hans always tried to broker the teams' position to Headquarters, which was very very useful.

We also had Jim [James A.] Abrahamson come on. A very capable individual. It reminded me of the Vietnam generation up in the Department of Defense [DoD] where they had the [Robert S.] McNamara whiz kids. This, I think, would eventually lead us down a path that we started—not saying things we didn't believe, but basically we got tired of dealing with people who did not truly understand and have a good feeling for the business that we're in, manned spaceflight. They'd run all programs, but they were always unmanned programs. They had run

programs that involved technical risk, schedule risk, but they hadn't run programs that involved a high component of human risk. So this was a very interesting time for myself and the entire NASA team, particularly Chris Kraft, to try to meet the challenges of the Shuttle Program at the same time of this evolving management that was being put in place to run our programs.

There were the usual battles that you would see relative to the Johnson Space Center roles, and these never seemed to get well resolved. You had the Headquarters responsibility, who's going to be running the program, what is the Marshall [Space Flight Center, Huntsville, Alabama] role, who does the overall integration, etc. The only people who seemed to always have a clear idea of the roles were the people down at Kennedy [Space Center, Florida], because their job was to take whatever was given them and launch it and fly it.

We had several people that leapt into this breach. I'm trying to remember the ones down at Huntsville. They finally came to the point of saying, "Hey, let's work this problem out. We don't need Headquarters to integrate us." I believe that this process of coming together—I believe Bob [Robert F.] Thompson played a pretty key part in that process—it was, "Let us work together because if we have a failure, if we have a problem, if we have a setback, it really affects all of us. So let's work as a team."

By now I'd moved from the division chief for flight control into the deputy director for Shuttle operations. George [W.S.] Abbey was the boss at that time. Basically we had wrapped our arm around all aspects of flight operations: produced the simulators, trainers, mission controllers, trained the crews, trained the controllers. We did virtually everything except the flight software.

We had Flight Support Division—I think it was flight support at that time—who did the majority of the facilities stuff. We had Mission Planning and Analysis who did the trajectory

work. Basically all of these elements had worked before. So basically the coming together in support of this new program was relatively easy for the people in Operations. There were many challenges, but the fact is we'd done basically much of the same work that we had done before.

The major challenge, however, was to develop an operations plan in mission control. We, always tried and always did, sat down before a program and said, "This is the program; this is what we understand as the objectives; this is how we intend to implement this program."

This is where we started becoming a cropper in many of the program objectives. One of the first things was—and radically new to us—our highest flight rate in any of the programs we had flown before was about six missions per year. Now we were starting off at a relatively slow rate, but building up to the point where we'd basically launch once a week. The launch rate just was almost exponential in its growth. We said many of these things you're trying to do aren't reasonable, etc. But the entire economic foundation for the Shuttle Program was a very high flight rate, many customers, supporting the Department of Defense.

In order to do this we had to develop concepts that say, "We'll standardize crews. Once a crew has pulled together they'll never separate. Within each one of the crews they'll have specialists." This immediately became an issue with George Abbey, who was the director, and people over in Flight Crew [Operations Directorate], because every pilot wants to fly everything. They want to have all the experiences they possibly can. So this really became a real challenge as to how are we going to fly this very high flight rate and have this high throughput, from the standpoint of crews, without significant cultural changes. That is one of the things that we never really were successful at.

Within the mission control teams, again we adopted many of the same principles. We would have a group of flight directors who would always do launches. So we were in the

process of setting out standardization. But to a great extent I don't think anybody ever believed that this was a possibility.

In fact I wrote a paper that was presented over in Europe to ESA [European Space Agency]. I became a cropper within the agency of identifying what I thought were the problems with this entire flight program that we were building and why the flight rate would really peak at somewhere around 15 to 20 per year.

One of the key elements in this decision—and this is one that will go back into the program requirements documents—one of the real drivers that turned out to have significant impact on the design of the Shuttle was the Department of Defense, and the mission where we would launch them into a fractional orbit. They would deploy whatever they wanted to deploy up there, and then they would land on the end of that revolution. This drove the design of the payload bay, particularly the payload bay doors. It also drove the design of the thermal protection system, because of the high crossrange requirements you would have to have for that type of mission.

I sat the CCB [Change Control Board] with [Orbiter Project Manager] Aaron Cohen for about five years and went through the entire evolution of the design of the Space Shuttle. I had good work from a few of the astronauts. Ken [Thomas K.] Mattingly was one. Ken Mattingly was always a pleasure to work with, because he was one of the more radical of the astronauts. He was willing to step into changes. He was willing to really pose the question back to the other astronauts, "Well, why can't we do this?" So he would put them on the defensive to do this. Throughout this entire process I had to admire Aaron Cohen. Aaron Cohen was the finest, most tolerant, probably one of the most pleasant individuals I'd ever seen working in such a very difficult environment.

He had schedule pressure, he had cost, he had all the requirements it had to be. Mission control and the control team developed a very interesting relationship with him and the change board. I represented all of Operations at that time, both the Flight Crew as well as the Flight Control. I had an immensely talented group of young engineers, fine systems engineers. They could take a look at the design as it was evolving and say, "Hey, if you could do this to this, it would give you this additional flexibility." They were very good at identifying opportunities within the design to be more effective, provide more capability, or deficiencies in the design that needed to be fixed.

Throughout this entire period of time, you will never have a perfect space system. It requires constant tradeoffs. Unlike watching our current politicians, they're incapable of making the trades necessary to get the economy and the budget and everything settled. Basically the business of Operations Change Board is you have to make those changes or you'll never fly, or you're going to run out of money, or the schedule, you won't have the capabilities you'll need. So it was constant process of making these changes.

Many of which we developed in the Change Board what we called operational work-arounds. Aaron Cohen said, "I don't have the money or the time to fix this thing, but if you can develop a work-around for me, I will promise you that I will fix it at the first opportunity." So in addition to tracking all the Change Boards we were doing, we always started listing all these operations work-arounds that we were doing. Some were procedure, just the way we did procedures. Some were the way we designed certain aspects of the missions. It was just a very intimate and intricate ballet that we had at the Change Boards.

He had a secretary, Helen [B.] Statz. And these Change Boards would start in the very early afternoon, and they'd go into the very late evening. Helen was the one who kept us all on

track. If there some hero that is unrecognized within this space program, the early design, Helen is the one. She really made that program—her notes were impeccable. She didn't miss a thing. That was particularly true as you went through late afternoon in these Change Board meetings. You tended to get a little bit sloppy in your note taking and everything. Helen was the one that kept all of this together.

But anyway, this was a time of radical change as we were developing this space system. The things that were the drivers were the high flight rate, multiple customers, some of the unique aspects of the DoD missions. I think everyone working the program tried their best to satisfy all these requirements, but I think in our hearts we knew that something had to give. To some extent as we get towards the [Space Shuttle] *Challenger* [accident] era, everybody was looking and saying “Well, that guy is going to have to call a hold; that guy is going to have to make the change,” right on down the line.

But we continued to pursue this thing. I think as engineers, operators, program managers, everyone really did a fine job. One of the things that started to occur, however, is one by one some of these people who were instrumental in the early programs started leaving. They not only left, but they took with them their skills, their knowledge, their experience, their personal database. It left a hole. This as we moved to the point where we were getting ready to fly and the early few missions, after the flight, more and more people would go away.

Those that were left had to try to cover more bases. I think if there was one area that we did not do well—and this I think has been pretty much the history in Johnson Space Center—we did not provide for succession. Everyone was so involved in doing their job. I think the only outfit that did provide succession was Flight Operations, because by our nature we knew our

people would move out, move into program responsibilities other places. So we always had to have some person in place capable of doing that.

When Max [Maxime A.] Faget finally decided it was time for him to retire, and Deke [Donald K.] Slayton, there was just not a natural-born leader. You could fill spots, but you didn't have the same organizational potential when they left. It was a very difficult time. We're now moving to the point we're getting to fly.

This was not only happening to us at Johnson, this was happening within our contractor teams. I think as we got closer to the actual flying of the Shuttle, launch day, there were two people that came in that kept the boat afloat. That was John [F.] Yardley and Mike [Myron S.] Malkin. We used to hate to sit through the Malkin-Yardley meetings, which occurred generally every noon. These people kept our nose to the grindstone and basically kept us making decisions that would keep the program moving. There were many saviors of the program during that era, but I think that they had an awful lot to do with keeping this show on the road. Anyway, I think you've probably got another question by now.

ROSS-NAZZAL: You had mentioned you worked closely with Aaron Cohen on the Orbiter Project. Were you also working in parallel with some of the other components—the SRBs [Solid Rocket Boosters], the External Tank?

KRANZ: Only at the Program Requirements Change Boards. Only generally when we'd go up to work with the Level II and Level I organizations. Generally we were so saturated with the work on the Orbiter that we relied upon other people in the program office, Level II, to keep this whole package glued together. We'd run across them at flight readiness reviews [FRRs]. We had a

preliminary requirements review [PRR], CDR [Configuration Design Review], FRRs. We'd basically see them at the major reviews, or we would see the notes that would come out of the various meetings, and they'd give us an action item that would require us to respond back.

Basically the work that I did, that we were doing in Operations, was related principally to the Orbiter. Now this was not true of the Mission Planning and Analysis Division, because basically they and my trajectory teams, my flight dynamics teams, were now looking at such things as mission abortability and these kinds of things. If you got a problem during powered flight when do you want to terminate the mission? What options do you have? Right on down the line. That basically was carried almost through a separate channel, through the Mission Planning and Analysis Division into Level II. Again they established a series of program requirements that identified capabilities they needed to assure abortability at each phase as you went through the Shuttle trajectory, etc.

Basically that was almost a given to us. We relied upon the trajectory guys to give us that answer. In later years that changed, because the trajectory guys became my guys. So then we became the drivers of the system, but in the early years that wasn't the case.

ROSS-NAZZAL: As you were working primarily on the Orbiter, tell us how did you start coming up with these flight rules? One flight rule that's very common is if the payload bay doors can't be opened once you're in orbit you have to come back. When did you start working on those? How did you come up with those rules?

KRANZ: The flight rules process—I got to back up several steps before that. Before we get into the flight rules, one of the first things that you do as a mission controller—that's why I think we

have the finest systems engineers in the world—is to wrap your arms around the space systems that you’re going to fly. We did this. I had a separate contract in every program that we’d ever flown. Basically required the contractor to provide us the raw engineering information. These are the bundle assembly drawings, the program listings used for development of the software, etc. The controllers would take that raw information from which the space system was built, and they would translate that into integrated schematics. The key of that word is the integrated schematic. While the contractor would provide you electrical and instrumentation and structural and environmental drawings, the controllers, in order to get their job done in real time, would basically integrate. So the electrical schematics would have the instrumentation on the ground; telemetry, they’d have what crew displays are on board. They’d have the structural interfaces they need. They’d have the environmental interfaces they need, etc.

The controllers would wrap their arms around that integrated set of documentation that they would build that represented the space system. We did the same thing with the flight software, where we would decompose the flight software so that each one of the controllers responsible for a certain systems or flight software area basically had his own database. We would aggregate this into a series of handbooks, a Flight Controller’s Handbook, a Shuttle Operations Handbook. Once we had that done, we would then start developing the procedures.

These are the normal operating procedures used to fly and operate the spacecraft systems. Once that was done you then wrote the emergency procedures. Then only after that was done you would write the mission rules, because by this time the people had become intimately knowledgeable of the system design characteristics, operation characteristics, but also what kinds of things could go wrong. That’s where you start writing your mission rules.

Now in writing the mission rules there was a set of guidance that generally came from the Flight Director's Office to say, "Okay, here is how we intend to address redundancy within the spacecraft. Here is the level of redundancy you need to keep flying. Here's the level of redundancy that if it does not exist you're going to start looking for alternates." The mission rules process is a top-down, what I'd say strategy and a bottom-up implementation. That was probably the most useful document that we've ever developed. It isn't particularly original, because every time you fly in an airplane they have what they call minimum equipment list that the pilot has to have available and operating in the aircraft before he flies.

Well, this is just a much more sophisticated minimum equipment list. Each pilot and flight test [engineer] has got his own set of go/no-go criteria that you use for determining. This is basically just a much more sophisticated package of information.

The thing that turned out to be very interesting, and I'll now jump almost 10 years later from these mission rules. As computer technology [evolved], we were still working with very primitive systems. Good computers, but relatively limited in their capability. Now we move into the area where you got the engineering workstations. Basically you have the ability to program these mission rules. This is the first step into the artificial intelligence.

A great controller, a lot of difficulty working with him, but I loved working with him, John [F.] Muratore. John Muratore was probably one of the real sparkplugs around Johnson Space Center, because he came in as a young engineer, went through the ranks very rapidly, became a flight director. That basically wasn't enough challenge so he moved into the program office, right on down the line. Then he—I won't say became a cropper with the current administration, but he ended up down at the University of [Tennessee] Tullahoma. Just a marvelous guy.

He saw the potential for taking these mission rules that we had and just with minor modifications moving in with these engineering workstations, all of a sudden we had a very powerful set of tools that could start advising the flight controllers on what to do if this occurred.

But anyway, the mission rules, they've been key in every program that we've ever flown. It is not as much the rules that are written, it's the work and the knowledge that's developed as you build these mission rules, the relationships that are developed between the flight controllers and the flight crews because these get debated extensively. The mission rules ultimately, by the time we fly, represent a contract within the mission control team for how we will initially address problems that we see. It's a contract between ourselves and the astronauts, the crew that will fly on that mission. It's a contract between ourselves and the program office. [It's a] contract between ourselves and our manufacturers. So everybody knows what our game plan is and had the opportunity to look at it, say, "Yes, I agree with that," or "I don't agree with that."

Mission rules, as I say though, they came about as the result of a process that started back with learning the space system, and then growing through the sets of procedures you'll write for normal operations, emergency operations. Finally into the mission rules and then eventually into the flight plan. By the time we moved into the Shuttle Program, every product that went on board the spacecraft was produced by the mission control team.

If I go back into the very beginning, this is totally the opposite to the way we started Mercury, because every product that was used in Project Mercury was developed by the contractor. We found out they weren't good enough. They were developed by a contractor. People produced all their documentation. They were document writers as opposed to engineers. But now the technology is such, the entire pendulum has swung to the point where every product on board the spacecraft is produced by the control team. It's trusted documents.

They were also used over in the Mission Evaluation Room and out by the contractors at Palmdale [California]. This became the reference for dialogue.

ROSS-NAZZAL: Tell us about Mission Operations and their support of the ALT [Approach and Landing Test] Program.

KRANZ: Probably a better guy to talk about that would be Chuck [Charles F.] Deiterich. Basically the real challenge in ALT was to get into the mindset of doing the very early flight test with a very limited team. At the same time ALT was just a small subset of this much bigger program.

Everybody wants to work on anything that's flying, but they don't want to work anything downstream. So it was a process of taking this big organization I had and having a small subset, probably about 20 people total that pulled the entire thing off. They designed their own little control room, which used to be the control room that was used for recovery operations during the early space programs. Basically established series of platforms right on down the line.

The key thing was developing the relationships with the people out at Dryden [Flight Research Center, Edwards, California]. Again we developed our schematics and went through the same thing. But there are only a few things I remember about that—the relationship that developed at Dryden, which was really a marvelous place to go to. They had the experience. We had the experience in what I'd say the spaceflight operations, but they had the experience in aircraft operations. This is more an aircraft operation than a spaceflight operation, because we were launching off the back of a 747. Basically we had a very limited flight time. We would be

landing in the dry lakebed. So it was really a question of listening and learning from them on what the business of an aircraft flight test is all about.

We were also within the Los Angeles air traffic control area. There were various scheduling problems we had relative to patterns that we would fly, the profiles we would fly, etc. Again that was within the Dryden domain. They understood. They guided us all the way through there, etc. I think the guys that did that had an awful lot of fun. I had several controllers, one of which, Dave [David F.] Nicolson, went out there and basically lived out there all the time. He basically was our guy to go to if we needed anything from them when we worked here. So he was basically our liaison, the Center probably said liaison path. It wasn't anything particularly sophisticated, but it was a lot of fun for the people doing it. Don [Donald R.] Puddy was the flight director. He thoroughly enjoyed it. Everybody grew a lot.

The beauty of the work that we were doing during this time period was that it forced you to look at how other people did their job. There was sufficient variety that I don't think anything we worked on in Operations hasn't been most enjoyable, because everything involves some subset of change. As I said, when we started this thing we were in an incredible era of change.

ROSS-NAZZAL: Were you ramping up hiring in Operations at that point?

KRANZ: It's like everything else in life. We were the last ones to have the money to start building up because the program office always needed the money to build the spacecraft. So once it looks like you have a real schedule, you have a real spacecraft, right on down the line, then the money started coming our way.

One thing I had hoped was that we would have been able to make significant modifications to the Mission Control [Center] but basically that wasn't in the cards. We got the job done. It was only almost 10 years later that we got enough money to actually start making changes to build a 21st century Mission Control Center. Sometimes doing it the hard way is the best way, because the people have to rely more upon themselves, their own resources, their own knowledge, etc., as opposed to trying to add a whole bunch of sophistication in at the early stage of a program. So I think it worked out fine.

ROSS-NAZZAL: Would you tell us about that update that was made to the facility 10 years later?

KRANZ: That's so far downstream here. We'll cover that in a later time.

ROSS-NAZZAL: Okay. Tell us about your recollections of STS-1 and the selection of those flight directors and why you made those decisions.

KRANZ: Earlier I talked about succession. This has always been a requirement in Mission Operations, because we knew our flight directors would become very valuable to the program. We expected Glynn [S.] Lunney to leave after Apollo. We expected Gerry [Gerald D.] Griffin to leave after Apollo. I had been given a whole new set of responsibilities so I was no longer a flight director. So we had to start building our next generation flight directors while we still had the training experiences for Apollo. In the final three missions for Apollo, we brought on Don Puddy, Phil [Philip C.] Shaffer. Milt [Milton] Windler had already flown Apollo, but he would

go over there, Puddy, Shaffer, Neil [B.] Hutchinson, and Chuck [Charles R.] Lewis were the five that we selected there.

We looked for opportunities during the Shuttle Program to bring them on board. We basically selected the last three missions. This provided them the background they needed and us the confidence that they had the leadership potential, the team building potential. They had the good track record from the standpoint of decisions that they would be able to carry the transition. They would be able to transition our teams and people and mission from the end of Apollo into the Soyuz. The subset of those into the ALT with Don Puddy, and then basically use them as the cadre for the Shuttle Program. We assured continuity over this five-year period in here from the completion of the [Apollo] Program into the Skylab through ASTP [Apollo-Soyuz Test Project] in there—so basically I didn't have much concern there.

The key thing was to make sure that we had enough lead controllers. We were fortunate that virtually all the people we needed stayed with us. We always had a plan for succession, and we always had good people capable of stepping in as other people moved into other responsibilities.

The selection of the people for each one of the mission phases was not too difficult. Because the launch phase involved trajectories, you're going to use a very strong trajectory-oriented individual. Neil Hutchinson covered that part of the job very well because he'd worked both down in "the Trench" in mission control as well as one of the systems guys. Don Puddy covered the reentry part of the mission in there. Milt Windler and Chuck Lewis became the orbital flight directors. Phil Shaffer also carried and moved into the launch phase. So it was just common sense based on the background they had.

The early years, launching [STS-1], was interesting from my standpoint, because I had moved from the flight director's console into the Flight Operations Directorate console sitting right behind my flight director. This flight operations director is an interesting position. If everything's going normal you don't do anything, but generally that isn't the case. The flight operations director's job is to keep the outside world off the back of the flight director, so the flight director can do his job. This may involve simple things like you got some people in the viewing room, or you got folks up there who don't like the way the team is going, or now they finally have looked, on launch day, at the mission rules, say, "Oh my God you mean to say we're going to shut down the launch if we lose one computer," something like that. All of a sudden they're aware of that. The flight operations director has to go back and hold their hand and convince them that this team here has studied this and basically you ought to have confidence in the team. It's to hold the hands of the people who are now faced with we're going to really launch this thing.

One of the real challenges was again our Administrator, who shouldn't even be involved in this thing. We had one of the Mission Control Center computers go belly up right when we were in the terminal countdown, last few minute and a half of the countdown for the first Shuttle launch. Basically Neil turned around and says, "You want to go?"

I said, "We're go." Our Administrator had read the same rule, but he didn't read the other rule that says we want to apply judgment in this thing here. Times being equal, when you shut down a firing circuit, you're getting ready to launch things, the one thing anybody who's ever had hardware experience gets worried about is—this is the first time you're doing this—is such things as relay races. If you're in the middle of a critical thing and all of a sudden you try to abort this, is everything going to work out perfect there? Is all the system going to be safe?

Are you going to have problems to resolve those? There's some point where each flight director has his own cutoff point where he says, "I'm going to go on my own judgment right now and mission rules be damned." That is always in the final seconds of this launch countdown. You're worried that you go to tell somebody this, he may not hear it or only part of the team hears it. So this thing here has to work perfectly in these last few seconds.

Well, Mr. Beggs got interested in why we decided to go on this thing. It wasn't the only time. We had enormous involvement from Headquarters in at least two missions that I was directly involved in. It was just part of the transition from people who had hands-on experience and trusted the rest of the team to do their job to a group of people that were much more aloof and remote that had never been involved in the hands-on operation before. Anyway, someday that'll make a good book.

ROSS-NAZZAL: Absolutely. Part two.

KRANZ: I don't know who's going to write it. Go ahead.

ROSS-NAZZAL: Tell us about some of the other missions that you were involved in when you were on console, or some of the missions that you were involved with the flight readiness reviews and all those other activities that you might have been involved with.

KRANZ: I'll go back. This is probably backtracking. This is going to mess up your continuity here. At the time that the Shuttle requirements were being levied upon the programs to build them, there was no requirement for EVA [Extravehicular Activity]. This for us operators, we

just say, “How in the hell did we ever get to a point in a program where there was no requirement to have an EVA capability for the Shuttle?” EVA capability is very expensive, because you need an airlock. You need a way to get into the bay. You need all these things, but none of these things existed in the Shuttle design. It was a real battle.

We worked against Aaron Cohen’s own interests, because we always would come up with a mission rule that says, “Well, we’ve got to have these payload bay doors latched for entry. If all these latches you got don’t work, you’re not going to have a safe entry.” So we kept finding rationales to build this. Finally we would establish the ability to at least get out into the payload bay. Now the majority of payloads were so big that they completely filled the bay so we had to come up with now a way to get from the front of the bay to the back end of the bay. Right along the edge of the bay, you see this slidewire. Boy, you can’t believe the amount of arguing and hassling to get just that simple bracket in the front and bracket in the back, where a crew could tether onto that thing and go all the way down the length of the bay without worrying about being separated from it.

So it was the evolution of the EVA capabilities was probably the most difficult. Yet to me it was the most logical. We had a guy by the name of Bill [William D.] Reeves who became an excellent flight director who carried that ball all the way through to make sure that proper EVA capabilities were put in there.

Now I take a look at it today, and every mission is EVA. It’s got something to do. They’re repairing this or catching this, right down the line. But at the time we started into the design of the spacecraft no EVA requirements existed. I don’t know how we got into that. That was just something that I thought would be good.

ROSS-NAZZAL: Why do you think that was the case?

KRANZ: People just hadn't visualized what the Shuttle would ultimately do. They talked about we're going to go up there and deploy all these satellites. We're going to do this, that, right on down the line. They never really had started to address really this repair-related issue. We're going to bring something back. We're going to repair it. Then we're going to redeploy it like we did the Hubble [Space Telescope]. This was interesting time.

One of the things that was interesting throughout this entire process as we moved into the flight phase was introducing—I mentioned introducing women. We had several women come into the team at this time. We had Jenny [M.] Howard become a booster. Linda [P. Patterson] moved into the guidance, navigation and control. We had two or three others in there. It always surprised me that the initial ones selected the most difficult, most time-critical jobs.

I think this was part of the cockiness that you had to have as a woman in breaking into the ranks of this all-male team and saying, "Yes, I can do it." Jenny Howard was one that decided she wanted to be a booster. Booster engineers in the early programs, their decision timeframe is on the order of seconds. No minutes timeframe for them.

Jenny decided that yes she wanted to be one of these booster engineers. Now the job is only minutes long actually during powered flight then it's all over. At this time they put accelerometers on the engines because they were worried about this. These engines are consuming about five tons of propellant a second during powered flight. What they wanted to do is if we had instability—this fuel coming down this long stack from the tanks—[it] would create an oscillation, we called it pogo. Pogo would very rapidly become destructive. So basically they

had accelerometers down on the engines. If they saw that they would basically shut the engine down.

Well, this was a tough tradeoff, because if you shut the engine down at the wrong time during powered flight, you end up with no abort option. So this is one of the things that was always a tradeoff between what operators thought and what engineers thought. Our concern was that having these sensors in each one of the engines could put us actually with just—I won't say a minor problem—it's a major problem, but one that was manageable. Could turn this into a catastrophic problem with no way out.

Well, Jenny Howard was booster engineer. I forget. It was one of the very early missions. Basically she'd been watching the engines all through the early powered flight. All of a sudden one of these guys shut down. She didn't see any reason for it to shut down. And pure guts poker, she decided she'd inhibit the shutdown sensors on the other two engines, and for that decision she got an, I think, NASA Exceptional Service [Award], whatever it was, nice award.

This was one of the first of the ladies that entered into the mission control teams. Linda Patterson is the other one. She stayed with us all the way until just a couple years ago, really really a marvelous lady. I don't like to say "tough lady" because that gives the wrong connotation, but this woman was first-class. Linda Ham came up through the ranks, became flight director. In fact it was funny. I don't even know if this is appropriate. One of my supervisors decided that with these women coming into the organizations he had to write a dress code for the women. That went over in this world not very well. So I had several interesting challenges as the Director of Mission Operations to try to keep this to a dull roar. It was an interesting time. I would not trade this at all, very challenging.

We continued, however. We started seeing more and more and more management changes. One of the saddest I think—I don't know if Chris talked about this in his—was on the second Shuttle mission we were using fuel cells. We saw a high pH very shortly after we got in orbit in one of the fuel cells. The high pH indications would say that we had some kind of a membrane breakthrough, a membrane leakage, within the fuel cell that might allow catastrophic mixing of the hydrogen and oxygen within the fuel cell.

We had a mission rule, and the mission rule indicated that this was a come home. Headquarters became aware of what our plan was, and literally the Administrator and his staff got on the horn. I was back with Kraft at my console. Hutchinson was saying, "Hey, we need a decision. Are we coming home or not? Because we got to tell the crew what we intend to do."

Kraft finally told Beggs very straightforward, "We're coming home." I think to some extent that set a bit that Beggs wanted to replace Kraft. I think it was very unfortunate, because that was just one decision of many decisions that had a high Headquarters involvement in the missions. I had one that got me, and this is just the natural evolution of the mission. We always had a mission rule that indicated that we would have a backup deorbit capability in case one of the OMS [Orbital Maneuvering System] engines failed. We'd keep enough RCS [Reaction Control System] to do that.

Well, that was fine, until you finally used the RCS during the course of the mission. Then the mission rule falls out, and you got to rely upon OMS. I got called on the carpet to go up and visit Mr. Beggs to explain to him the natural evolution of the mission where you use your RCS to the point where that backup no longer exists. But this was a change that was setting the stage for a long period of time where we really did not have the kind of leadership at the top

level within the agency that I believe the agency deserved. Okay, where are we? I'm taking you all over the map here.

ROSS-NAZZAL: That's okay. You're giving us good information actually. It's all stuff we don't know. Tell us about working with DoD. That was quite different from your early experience.

KRANZ: We had a very, I won't say stormy marriage to begin with, but there were three things related. It was working with the DoD, working with the commercial customers, and working with the program office. Let me start back working with the program office first. Leonard [S.] Nicholson, at this time, had a role within the program office to establish the relationships. We had the customer relationship, which is entirely new, I'd almost say alien to us.

To a great extent we were our own customer for all the early missions. Then when we weren't we had the science people, the lunar people, in the back rooms, where they were very strongly welded into the teams in mission control.

So we had had this customer experience, but it was a very tight loop. Now we're talking about a multiplicity of customers and trying to set up some way that they could get their requirements introduced into the mission control room and the planning, etc., for doing this. We established the concept for what was called the payload officer, and we had to convince the program office as well as the customer that this guy would be an honest broker.

That was really a challenge because he was a member of the flight control team but he also had to fully represent the customer and the program office to the flight control team. So it was really difficult to establish that relationship. You can talk about it all day long, but it wasn't until we flew our first few missions that we started getting support from the customer community

and the program office community saying, "Yes, these guys are an honest broker." There were times when we would have significant disagreements within mission control as to which way to go where you have one guy saying, "This is what I, representing my customer, want to do," and the other guy saying, "Doesn't make sense because this is the best use of the system and the crew time.

Eventually this thing here ironed out because this person called the payload specialist started becoming more and more oriented towards customer requirements so that we now had a way to exert influence upon the pilot and commander, the astronaut mentality, to the point where we really did become honest brokers both from a crew standpoint as well as a controller standpoint. But again this is the kind of thing you can talk about all day long, and we did; many, many, many discussions and meetings and everything else. It was only when you finally tried to put these pieces together you got some experience under your belt.

I think this set a stage that a lot of times we talk too much instead of setting up a situation where you get the experience in order to make the right calls. One of the guys that was very instrumental in the payload officer business was Mel [Melvin F.] Brooks, who was my deputy. He basically had come up with the concept of this payload specialist that they carried on board the spacecraft. He became our representative to ESA. He went over to Noordwijk [Netherlands], I believe it was and became our representative to ESA. We not only had our own people in the States, but we had the European Space Agency. All these other people who just felt we were going to run all over them. We had to get some experience under our belt before this thing was really ironed out. It really was surprising how well it turned out. I believe that was probably one of the most satisfactory things. This entirely new thing.

Now the DoD was very interesting, because I had one of my young flight controllers, payload guys, come up, by the name of Rob [Robert M.] Kelso. He then became a flight director. Rob had a very interesting mannerism to speaking. I used to love to watch him. He would take a cup of coffee. He'd always fill it just about full to the brim, and he'd be talking to you. Pretty soon you'd get so distracted by his arm waving this coffee around. You thought he was going to spill the coffee. He could sell you on some topic without you knowing it. So it was real interesting. He had this skill—elocution I guess is the word. Basically he had a solid agreement on understanding and where he wanted to go and how he wanted to get there.

He was visceral in his support for his customer. There was no question he was customer-oriented. He was the guy that I selected to go start working the DoD thing. He set up such an arrangement that when *Challenger* [STS-51L] came along—we'll talk about that maybe next—and we lost our DoD customers, we really broke a relationship with them that was first class. We had a working relationship. We had a team in place that handled the DoD. The classified aspect of the operation was alien to mission control: securing buildings, securing facilities, having everybody go all through these loops. The thing worked out. By the time that we had flown a couple missions we had no problem.

The greatest problem we had with the DoD—it wasn't related to one of the missions, it was mainly because we were using their IUS [Inertial Upper Stage] for deploying the TDRS [Tracking and Data Relay Satellite]—was to set a solid relationship between ourselves and their support facility out on the West Coast. The solution was send some people out there to work with them to iron out our difficulties. By the time we got ready for our second TDRS deployment we were pretty much on the same page.

This was just a radical way of doing business that relied upon the goodwill of all the parties. If you could get that goodwill you could get the job done. It worked out pretty well. There were some rough edges, but they got smoothed out. It was amazing to see the DoD guys party with the flight control team and their contractors, etc., just like we'd worked together for a decade. Here we'd worked together only for about 18 months to fly one of their missions. I think we all had more problems with Headquarters than we had with any of the Field Centers or any of the customers.

We were really on a roll. I believe in metrics, and everybody hated what they called my green sheets. All the way through the space program from late Gemini all the way through Apollo, I had my controllers log how they spent their time, every product. I knew to within maybe 100 man-hours what it took to do everything that we did. Therefore I had confidence in establishing schedules that were aggressive. Or if we were given schedules that were impossible I had the confidence that I could shoot it down based on cold logic and metrics.

The metrics as we were approaching *Challenger*, 51L, indicated that we were borrowing resources from downstream missions. There was going to be no recovery. Shortly after *Challenger* we had the Centaur payload, if I remember right. This was a high-risk mission, high-risk payload. We not only were borrowing resources from downstream missions, we were starting to borrow resources from that Centaur stage there.

I knew that soon some very difficult decisions would have to be made on flight rate, because we were in the process of stepping up. This was really my principal concern as we approached launch day for 51L. Walked into the control room that day. I was absolutely astounded to see the video on the launch pad and see the ice that was just hanging down from the entire launch complex. Ice team was out doing its work. As I said, I was the flight operations

director, in the process of handing over to Tommy [Thomas W.] Holloway I believe. I also had a room, because we were still in the process of building up staff. I had a temporary building being established over—I'm trying to remember what the road is. It's a temporary building that we put in there, moving all the flight planning. We were getting ready to move into it. So I decided that I'd walk over there and take a look at it before we opened it up.

I came back, and I was astounded that they had made the decision to continue the count with all the ice there. To my knowledge, I never remember any significant discussion relative to the ice and any concern about the SRBs. We were more worried about ice coming off and impacting the Shuttle and doing damage to the thermal protection system.

But, they launched. The only place we had TVs in the ops room were up at my console and over at PAO [Public Affairs Office]. Everybody else could not watch launch TV because we felt it was a distraction. I always looked at the booster displays. Basically gave me how the engines were doing, because that's the key to early flight.

I heard the throttle up call. Just shortly thereafter, you just saw this burst of white over on the right-hand side on the TV. I'd seen rockets blow up when we were down at the Cape [Canaveral, Florida] at Project Mercury. Without any doubt I knew that we had an explosion and that the crew more than likely was lost, no survivability for the space system.

It was amazing how long it took for this dawn, this realization, to start appearing on the faces of the controllers down there. Went down to the procedures officer and had him pull out—we have a set of procedures that we use in mission control when we have a mission failure, mission catastrophe, and [it] requires everybody to terminate all outside phone conversations, to secure their logs. Do all these things. So we started that thing there.

So that was the key. But that was not, I'd say, unexpected. I think everybody who grew up in the early years recognized the risks of the work that we do. The difficulties we had was in having our Headquarters folks and the American public recognize the risks we did, because now as a result of that we started making several dumb decisions. Probably the greatest dumb decision that we made was to allow Congress to drive us to a position where we would never do anything with the Shuttle that we could do with an unmanned vehicle, which eliminated all of our commercial launches, PAMs [Payload Assist Modules] that we were launching out of the payload bay. So we got out of the commercial launch business, and we were getting pretty damn good at it.

We also cleared off all the DoD. The entire economic basis for the Shuttle Program just disappeared, and we became our own customer. That I think was one of the real leads now that brought us to the point where we shut the Shuttle Program down as a result of bad decisions we allowed Congress to make. Within our own system, we supported that kind of a decision because we allowed Congress and the American public to believe that we could make the Shuttle significantly safer by a series of what I'd say were placebo changes: providing bailout capabilities, carrying parachutes, doing an enormous amount of training for the crew to jump out of the Shuttle.

I think that was where we wrote the epitaph, unknowingly, for the Shuttle Program. I think the crews would have kept flying it. We would have kept flying it. What we did not have were the leadership that we needed within our own Center and within Headquarters to fight that battle and convince the public that this was a business worth continuing.

This was also a timeframe where we saw the influence of the media start to hammer away at public opinion. CNN [Cable News Network] was just coming online. You now started having

this minute-by-minute news. John Holliman [of CNN]—he was one of the guys that when they went [into] Baghdad, [as the Americans were] driving the Iraqis out of Kuwait. He had a long personal discussion with Dick [Richard H.] Truly in the recovery from this thing here that you got to stop this direction that you're going, he said, because it's going to be the end of your programs. You have to convince the people that the risks of this business are outweighed by the gains. You have to convince the people, and we never did. Anyway, that's off track.

ROSS-NAZZAL: What did MOD [Mission Operations Directorate] do during the flight hiatus as changes were being made to the Shuttle?

KRANZ: Basically we picked up tracking. We did pretty much what we had done in previous programs. Arnie [Arnold D.] Aldrich was a marvelous engineer. He was one of my branch chiefs. He was the guy that on Apollo 13 I used to track all the procedures. Arnie Aldrich became the guy tracking all the changes from the program office and trying to identify what we could do to address these. So he became our node in responding to and setting up the return to flight activity.

ROSS-NAZZAL: Did you make any changes at all to Operations, or any of the procedures that you had established?

KRANZ: Well, the changes in Operations were all subtle. There wasn't anything that was visible. Operations by that time had matured. The only thing that would help us any further was a few years later, about five, six years later, when engineering workstations became readily

available, and we could assist the controller with some pretty sophisticated software to help him rapidly assess not what are you going to do, but what is the problem. Basically identify in a clearer, more recognizable, more timely sense what is the problem.

The majority of the controllers if they know what the problem is will pick the right path. What you got to do is figure out what is the problem. This was one of the things that we learned back on Apollo 13, that it was really identify what was the problem. We spent almost 15 minutes before we finally concluded we had an oxygen tank go south on us. If we'd had today's technology we'd have picked that up literally in seconds. So what is the problem? Then you can figure out what are you going to do about it, which direction you're going to go.

ROSS-NAZZAL: Was this part of that change that you had talked about earlier, in making changes to the facility itself?

KRANZ: It came about—I mentioned John Muratore earlier as an absolutely brilliant young man. One day he and I went to the restroom, and we were in the middle of a long budget battle. He had sat through and listened to some of these things. He says, “If you'll give me a couple million dollars, I will set up a demonstration facility that will show you how to save 200 M&O [Maintenance and Operations] people. That will pay back that investment in less than a year.”

So I said, “John, you're on.” So I found him some money. Well, he came up with a concept for the new mission control: engineering workstation-based where a good portion of the programming [is] done by the controllers. If you remember in the early days you used to put computers down on the bottom floor, because they required a lot of care and maintenance and servicing, right on down the line. That creates all kinds of dust. Basically this is the first place

in JSC where we moved all the computers to the top floor. It's a lights out environment up there. Basically he came up with that concept. It was interesting.

A month later, after the program was kicked off and running, he did an interview and talked about our discussion in the restroom in *Rolling Stone* magazine. He was the kind of guy that we've always been able to produce, the kind of radical thinker that kept us ahead of the power curve. Very interesting.

ROSS-NAZZAL: What are your recollections of that first return to flight? Anything stand out from that mission [STS-26]?

KRANZ: Any time you launch a crew, you have to admire the courage of that crew, the people being willing to step into the breach, to allow us to progress as a nation. Risk is the price of progress. If we want to keep moving forward, risk has to be an essential component. I go back into my experience back in the '50s. I was a fighter pilot for high-performance airplanes. I went out to Holloman Air Force Base [New Mexico] as a flight test engineer. At that time you had Joe [Joseph W.] Kittinger in [Project] Man High jumping out of a balloon from 102,000 feet and freefalling, exceeding the speed of sound during his free fall, without being in an airplane. He was addressing the issues of physiological effects of free fall. After Kittinger, you had John Paul Stapp riding rocket sleds up to 40 G and literally being blind for months as a result of the deceleration forces, hemorrhaging within his eyeballs. This was the kind of people who were stepping forward to allow these great breakthroughs that we then started following up when we put Alan [B.] Shepard out and John [H.] Glenn. John Glenn, when we flew him on the sixth

Atlas, two of the previous five had blown up so you really have to accept risk in order to move forward.

You have this new baby down there. It's a risk as they take their first steps they're going to fall and bang their head or something like this. But risk is what allows us to keep moving forward as a nation, as a people. Every time you launch, I always admire those people willing to step forward and accept this risk. A lot of times I don't like them, but I still respect them. Interesting business.

The same thing with my controllers. They make their decisions. If they're wrong they got to live with that wrong decision for the rest of their lives.

ROSS-NAZZAL: While you were in charge of MOD there was a consolidation of contracts. The STS [Space Transportation System] Operations Contract, can you talk about that a little bit?

KRANZ: That's another one you could write a book on. I'm trying to remember the guy who came up with it. Lyn [Lynwood C.] Dunseith and several of the others. I think Dunseith had died by that time. Bob [Robert E.] Ernull I think was one of the ones that was associated with it. Basically a group of people got together and said look, we got to reduce costs. The way to do this is reduce cost of operating our facilities. Now at this time when we consolidated I think I had 27 different contracts and 24 different contractors, which results in a very high overhead from the standpoint of management.

It also results in relatively long lines of communication. The proposal was sent forth that we should establish that consolidated contract. This would end up with one prime [contractor] and two subs. This sounded very good to me. It sounded like the right thing to do. But now the

question is when and how are you going to do that. I didn't know I would become a part of this thing here. I thought somebody else would be managing this thing.

But all of a sudden I found out that no, we're not only going to accomplish this contract change, we're going to give it to Kranz, and he's going to have a consolidated organization. I was again fortunate. I've been blessed all my life with good people. I had a guy by the name of Jim [James D.] Shannon. There's a couple out there, I wish I could remember their names that showed up on the scene there, that basically helped Jim out. The contract consolidation came about, the bidding, the review of the proposals, everything else was relatively smooth considering what you were trying to do.

The implementation of the contract came about again quite easily with one major exception. Because what do you do? Most of the people are expected to just change badges. You're just eliminating a whole bunch of management overhead. The only mistake they made, however, was that the people who had been doing the trajectory design were very loyal to McDonnell Aircraft. We assumed in all of our planning that we would be able to have these people swap badges and be picked up under this new contractor we were getting. Well, the trajectory design is one of the core elements of operations. If we couldn't get critical mass there, we wouldn't be able to consolidate them into this larger operation. We'd have to handle them as a separate contract under this.

Well, about this time, the *Challenger* accident occurred. So now it's a question of we got this whole ball in motion. But then what you have to do is you have to stretch out some of the contracts. You have to address this McDonnell issue. You have to address the facilities issue you got. So this was probably one of the most difficult time periods we'd ever had because we were trying to recover from the Shuttle, get back on track, bring this new contractor on board,

have the same confidence in the teams and the management, everything that was being put in place, and above all as part of this contract we also picked up the flight software, what's called the day of launch I-loads. That was something that again I'd never had any major responsibilities in before. This was again a place where John Muratore shows up. He's my go-to guy for an awful lot of things.

He set up a team to facilitate this transition. The key thing was eventually we had to set up separate contract provisions for the McDonnell people until we were able to get them to come over, bringing this team back up, and getting certification, etc. Now at the same time, I probably shouldn't talk about this. I had a major lawsuit on my hands from some of the people that were involved in this transition, and I think I'm just going to leave it with that. So that posed some challenges also.

ROSS-NAZZAL: We're getting close to time. Would you like to review your notes? I had a couple more questions, but I don't want to eat up your whole day.

KRANZ: We didn't talk about—this might be some later date or something like this. We were also on the cusp of a new technology with the Shuttle design, because now we were moving away from analog systems, into total digital, to the fly-by-wire. You had to have the kinds of redundancies, confidence in the flight system. It was very large flight system, it's an airplane that has to fly like a spaceship, which has to fly like an airplane. You had to have the confidence that you have from the standpoint of a commercial airline operation. In fact it had to be even better. Probably better people to talk about that. I think that's pretty much [all]. I think you've got it. What are your questions?

ROSS-NAZZAL: Well, one thing I did want to ask you was to go back before *Challenger*. There was a lot of changing going on at that time in terms of the crew manifest and the payloads and things like that. What impact did that have on MOD and trying to do flight planning and trajectories and all those sort of things?

KRANZ: I really can't be specific about that, because as I said, I had the metrics. The metrics said we were in trouble. So I think that might have aggravated to some extent, but I don't think it would have aggravated this looming mountain of problems that we were faced with where we were borrowing resources from downstream missions. I can't remember anything specific about that.

ROSS-NAZZAL: The only other thing I wanted to ask was about working with the Germans. We had the [STS]-61A flight, and you were working with their German Space Center. Can you talk about that? Because for so long it had just been mission control, and now you have another Center. You obviously had Marshall too.

KRANZ: As I said we were on the cusp of many new technologies. The technology of teleoperations was in its infancy at that time, but it was something that had to be done. You had to start looking at remote operations. To some extent we had piloted some of these remote operations from what we called a Spacecraft Analysis Team. Every time we would fly we would have a team in place out on the West Coast listening to our communications, capable of responding to questions. We'd have some data, limited, but some data going up to Headquarters.

They'd be looking at the mission. So basically it was now to the point of technology made remote operations feasible. Why not do it? So it was a question of more developing the confidence in the people that would be operating out there and the challenge of finding ways to communicate effectively. The mission still was under the control of Johnson from the standpoint of the overall flight planning, right down the line, but you had to be able to accommodate the requirements of these remote facilities. To a great extent it turned out to be a lot easier than most of us thought.

Again go back to the ESA thing. This goes into Mel [Melvin F.] Brooks, because he was over there throughout this entire period of time. If I remember right, I think they set up their facility at Darmstadt [Germany]; their headquarters is at Noordwijk for ESA, but I think the control facility they had was at Darmstadt. Basically he was in the facility so I had my own people. By now he had changed badges. He was working for ESA full-time. I had the confidence in him. Teleoperations and the remote operations was something that was more political than technical. It was really a question of establishing the protocols that would solve the politics of the problem and then turn it over to the technical people to work. In almost all cases, once you got past the political boundaries, everybody wanted to have prerogatives; once you got past that then the technical part of things solved itself pretty quickly.

It happened that we grew into it by necessity. The real problem is when we were operating at JSC here with Nicholson's guys, because he was overly protective of the customer, where we just wanted to work with the customer directly. Once we had enough mission experience under our belts, it took care of itself. I can't remember any major problem that occurred beyond this getting used to working with each other. Once we started working, everything worked out.

ROSS-NAZZAL: Well, I think we have hit the time that we've agreed upon. So I thank you very much for your time today.

[End of interview]