

---

# COLUMBIA

## ACCIDENT INVESTIGATION BOARD

---



**Note:** Volumes II – VI contain a number of conclusions and recommendations, several of which were adopted by the Board in Volume I. The other conclusions and recommendations drawn in Volumes II – VI do not necessarily reflect the opinion of the Board, but are included for the record. When there is conflict, Volume I takes precedence.

---

REPORT VOLUME VI  
OCTOBER 2003

---

### On the Front Cover



*This was the crew patch for STS-107. The central element of the patch was the microgravity symbol,  $\mu g$ , flowing into the rays of the Astronaut symbol. The orbital inclination was portrayed by the 39-degree angle of the Earth's horizon to the Astronaut symbol. The sunrise was representative of the numerous science experiments that were the dawn of a new era for continued microgravity research on the International Space Station and beyond. The breadth of science conducted on this mission had widespread benefits to life on Earth and the continued exploration of space, illustrated by the Earth and stars. The constellation Columba (the dove) was chosen to symbolize peace on Earth and the Space Shuttle Columbia. In addition, the seven stars represent the STS-107 crew members, as well as honoring the original Mercury 7 astronauts who paved the way to make research in space possible. The Israeli flag represented the first person from that country to fly on the Space Shuttle.*



### On the Back Cover

*This emblem memorializes the three U.S. human space flight accidents – Apollo 1, Challenger, and Columbia. The words across the top translate to: “To The Stars, Despite Adversity – Always Explore”*

The Board would like to acknowledge the hard work and effort of the following individuals in the production of Volumes II – VI.

Maj. Gen. John L. Barry	Executive Director to the Chairman
Dennis R. Jenkins	Investigator and Liaison to the Board
Lt. Col. Donald J. White	Technical Editor
Lt. Col. Patrick A. Goodman	Technical Editor
Joshua M. Limbaugh	Layout Artist
Joseph A. Reid	Graphic Designer
Christine F. Cole	Administrative Assistant
Jana T. Schultz	Administrative Assistant
Lester A. Reingold	Lead Editor
Christopher M. Kirchoff	Editor
Ariel H. Simon	Assistant Editor

Limited First Printing, October 2003, by the  
Columbia Accident Investigation Board

Subsequent Printing and Distribution by the  
National Aeronautics and Space Administration  
and the  
Government Printing Office  
Washington, D.C.

## VOLUME I

PART ONE	THE ACCIDENT
Chapter 1	The Evolution of the Space Shuttle Program
Chapter 2	<i>Columbia's</i> Final Flight
Chapter 3	Accident Analysis
Chapter 4	Other Factors Considered
PART TWO	WHY THE ACCIDENT OCCURRED
Chapter 5	From <i>Challenger</i> to <i>Columbia</i>
Chapter 6	Decision Making at NASA
Chapter 7	The Accident's Organizational Causes
Chapter 8	History as Cause: <i>Columbia</i> and <i>Challenger</i>
PART THREE	A LOOK AHEAD
Chapter 9	Implications for the Future of Human Space Flight
Chapter 10	Other Significant Observations
Chapter 11	Recommendations
PART FOUR	APPENDICES
Appendix A	The Investigation
Appendix B	Board Member Biographies
Appendix C	Board Staff

## VOLUME II

	CAIB TECHNICAL DOCUMENTS CITED IN THE REPORT
	Reader's Guide to Volume II
Appendix D.a	Supplement to the Report
Appendix D.b	Corrections to Volume I of the Report
Appendix D.1	STS-107 Training Investigation
Appendix D.2	Payload Operations Checklist 3
Appendix D.3	Fault Tree Closure Summary
Appendix D.4	Fault Tree Elements – Not Closed
Appendix D.5	Space Weather Conditions
Appendix D.6	Payload and Payload Integration
Appendix D.7	Working Scenario
Appendix D.8	Debris Transport Analysis
Appendix D.9	Data Review and Timeline Reconstruction Report
Appendix D.10	Debris Recovery
Appendix D.11	STS-107 Columbia Reconstruction Report
Appendix D.12	Impact Modeling
Appendix D.13	STS-107 In-Flight Options Assessment
Appendix D.14	Orbiter Major Modification (OMM) Review
Appendix D.15	Maintenance, Material, and Management Inputs
Appendix D.16	Public Safety Analysis
Appendix D.17	MER Manager's Tiger Team Checklist
Appendix D.18	Past Reports Review
Appendix D.19	Qualification and Interpretation of Sensor Data from STS-107
Appendix D.20	Bolt Catcher Debris Analysis

## VOLUME III

### OTHER TECHNICAL DOCUMENTS

	Reader's Guide to Volume III
Appendix E.1	CoFR Endorsements
Appendix E.2	STS-107 Image Analysis Team Final Report
Appendix E.3	An Assessment of Potential Material Candidates for the "Flight Day 2" Radar Object Observed during the NASA Mission STS-107
Appendix E.4	Columbia Early Sighting Assessment Team Final Report

## VOLUME IV

### OTHER TECHNICAL DOCUMENTS

	Reader's Guide to Volume IV
Appendix F.1	Water Absorption by Foam
Appendix F.2	Follow the TPS
Appendix F.3	MADS Sensor Data
Appendix F.4	ET Cryoinsulation
Appendix F.5	Space Shuttle STS-107 Columbia Accident Investigation, External Tank Working Group Final Report – Volume 1

## VOLUME V

### OTHER SIGNIFICANT DOCUMENTS

	Reader's Guide to Volume V
Appendix G.1	Requirements and Procedures for Certification of Flight Readiness
Appendix G.2	Appendix R, Space Shuttle Program Contingency Action Plan
Appendix G.3	CAIB Charter, with Revisions
Appendix G.4	Group 1 Matrix Brief on Maintenance, Material, and Management
Appendix G.5	Vehicle Data Mapping (VDM) Team Final Report, Jun 13, 2003
Appendix G.6	SRB Working Group Presentation to CAIB
Appendix G.7	Starfire Team Final Report, Jun 3, 2003
Appendix G.8	Using the Data and Observations from Flight STS-107... Exec Summary
Appendix G.9	Contracts, Incentives, and Safety/Technical Excellence
Appendix G.10	Detailed Summaries: Rogers Commission Report, ASAP Report, SIAT Report
Appendix G.11	Foam Application and Production Chart
Appendix G.12	Crew Survivability Report
Appendix G.13	Aero/Aerothermal/Thermal/Structures Team Final Report, Aug 6, 2003

## VOLUME VI

### TRANSCRIPTS OF BOARD PUBLIC HEARINGS

	Reader's Guide to Volume VI	5
Appendix H.1	March 6, 2003 Houston, Texas	7
Appendix H.2	March 17, 2003 Houston, Texas	41
Appendix H.3	March 18, 2003 Houston, Texas	71
Appendix H.4	March 25, 2003 Cape Canaveral, Florida	105
Appendix H.5	March 26, 2003 Cape Canaveral, Florida	133
Appendix H.6	April 7, 2003 Houston, Texas	157
Appendix H.7	April 8, 2003 Houston, Texas	191
Appendix H.8	April 23, 2003 Houston, Texas	219
Appendix H.9	May 6, 2003 Houston, Texas	275
Appendix H.10	June 12, 2003 Washington, DC	309



# Volume VI

## Appendix H

### Transcripts of Board Public Hearings Reader's Guide

In the course of its inquiry into the February 1, 2003 destruction of the Space Shuttle *Columbia*, the Columbia Accident Investigation Board conducted a series of public hearings at Houston, Texas; Cape Canaveral, Florida; and Washington, DC. Testimony from these hearings was recorded and then transcribed. This appendix, Volume VI of the Report, is a compilation of those transcripts. The transcripts are also contained on the DVD disc in the back of Volume II. The video recordings of these hearings are included in the records of the CAIB, held at the National Archives and Records Administration.

**THIS PAGE INTENTIONALLY LEFT BLANK**



## March 6, 2003 Houston, Texas

### **Columbia Accident Investigation Board Public Hearing** *Thursday, March 6, 2003*

*10:00 a.m.*  
*Bayou Theatre*  
*University of Houston at Clear Lake*  
*Bay Area Boulevard*  
*Houston, Texas*

#### **Board Members Present:**

Admiral Hal Gehman  
Rear Admiral Stephen Turcotte  
Major General John Barry  
Major General Kenneth Hess  
Dr. James N. Hallock  
Brigadier General Duane Deal  
Mr. Roger E. Tetrault  
Dr. Sheila Widnall

#### **Witnesses Testifying:**

General Jeff Howell  
Mr. Ron Dittmore  
Mr. Keith Chong  
Mr. Harry McDonald

**ADM. GEHMAN:** Good morning, ladies and gentlemen. The first public hearing of the Columbia Accident Investigation Board is hereby in session. We are going to begin our review this morning by talking to two officials of NASA who work here at JSC. We're going to be talking about organizational and lines-of-responsibility kinds of matters so we have a clear understanding of who does what and how you get it done and who answers to whom.

We're delighted to be able to start right at the top here at JSC with the Center Director, General Howell, Jeff Howell.

Thank you very much for taking time to be here. We also

are aware that you've got duties that are going to call you away here; and those duties, of course, are related to this accident, for which we are understanding and appreciative.

Before we begin, the way we'll conduct this public hearing is Jeff Howell, Director Howell, will make an opening statement, which we'll be delighted to listen to. Then we will just simply ask questions as the Board sees fit.

Before we begin, though, Mr. Howell, let me first ask you to affirm that the information that you will provide to this Board at this hearing will be accurate and complete to the best of your current knowledge and belief.

**THE WITNESS:** I so affirm.

**ADM. GEHMAN:** All right, sir. The floor is yours.

JEFF HOWELL, having been first duly affirmed, testified as follows:

**THE WITNESS:** Thank you, Admiral. I'm pleased to appear before the Columbia Accident Investigation Board. It's now 33 days after the tragic loss of the courageous crew of Space Shuttle *Columbia*. We are deeply appreciative of the efforts of the Board to determine what caused the loss of *Columbia* and its crew, and we pledge to continue to cooperate and support your efforts in every possible way.

I'd like to begin by describing Johnson Space Center's role in our nation's space program. Originally named the Manned Spacecraft Center, JSC has served as a focal point for human space exploration since the early 1960s. The core capabilities resident at JSC since the beginning and continuing today consist of the design, development, and test of human spacecraft and human robotics interfaces; planning, execution, and control of human spacecraft; selection, training, and assignment of astronaut crew members; extravehicular planning of hardware

development and training; life science research related to human space flight and associated biomedical research; the program management of large-scale human space flight hardware development programs; the study and curation of astro-materials; and last but not least, the safety, reliability, and quality assurance expertise to support all of these activities.

Within this context, as the director of the Johnson Space Center, I am responsible for providing the Shuttle Program with the institutional support needed to execute the Space Station Program's mission. The center is accountable for the hardware and software it delivers to the program as well as the quality and technical content of the analysis products it delivers to the program. Center management works closely with the Space Station Program manager, Ron Dittmore; and I am regularly apprized of program status and issues, as well as personnel and other matters.

I will be happy to discuss my understanding of these roles and relationships. Thank you, sir.

**ADM. GEHMAN:** Thank you very much. I'll ask the first question since I'm the chairman. Would you describe for us the lines of authority and chain of command, as we say in the military, lines of authority that starts with Mr. O'Keefe, a couple of layers above you, one layer above you, and perhaps one layer or two layers below you. Describe it; but then, if you would, expand it to if there are any branches or sequels -- for example, if the money is done differently than hiring and firing or something.

**THE WITNESS:** Of course, under Mr. O'Keefe is his Deputy Administrator, Fred Gregory; and under the two of them, he has his enterprise Associate Administrators. Code M, which is the Office of Space Flight, is headed by Bill Readdy. He is my boss. I'm one of the Office of Space Flight Center Directors. We have four -- myself, Marshall, Kennedy, and Stennis. As the Center Director below me, I have an immediate staff of direct reports -- you know, Legal, HR, that type -- plus I have directors of our major activities, engineering, mission operations division, the flight crew operations, our extravehicular activities, space and life sciences, and then safety and mission assurance -- safety, reliability, and quality assurance.

So those are my major activities, and each of them has a director. Under them are their branch managers and so on. So the largest of those directors is our engineering and then our flight crew operations division. Those are the two largest ones I have.

**ADM. GEHMAN:** And Mr. Readdy also has various projects, a direct report to him also; and we're going to hear from one of those projects later.

**THE WITNESS:** Correct.

**ADM. GEHMAN:** So that means, then, the way the wiring diagram works out, that the projects and the centers operate in parallel to each other. Is that a safe way to say that?

**THE WITNESS:** That's correct. Of course, under him he has an Associate Administrator for these programs, General Mike Kostelnik, and he has both the Shuttle and Space Station Programs under him. So he's the direct line of authority to Mr. Dittmore. However, you know, down at our level, Ron Dittmore and I are literally joined at the hip in the way we function because a big portion of my center personnel support his activities and we are intertwined in a very complex organization in that regard.

**ADM. GEHMAN:** Thank you very much.

General Barry, you want to lead off since we're talking about Shuttle support?

**GEN. BARRY:** Sure. Could you go into more detail. A two-part question really. Responsibilities of the astronaut office in regard to your responsibilities. And then could you outline your role before and after the *Columbia* mishap.

**THE WITNESS:** Certainly. The astronaut office, the actual office is called Flight Crew Operations Directorate, and Bob Cabana is the head of that. Under him he has several different divisions; but the major one is the flight crew office, the astronaut office. So he is charged under me to recruit and select and then train our astronauts to get up to a level where they are designated astronauts. They go through a very vigorous almost two-year training program to qualify to go on to become a crew of either a Shuttle or a Station. So he's charged with that responsibility.

Under him are several activities to do that. He has, you know, an aviation division where he has aircraft that our military air crew have to stay current in, and he has the training aircraft for the astronaut pilots that simulate a reentry of a Shuttle. They have that type of capability, all those things. I am responsible for all of this. He is accountable. He does this for me in that regard. Does that answer your question?

**GEN. BARRY:** That's something I think few people understand, the difference between Ron Dittmore's responsibilities and your responsibilities for the astronauts.

**THE WITNESS:** Now, Bob, you know, has to make sure, has to ensure that his astronauts are ready to perform their functions for Ron as members of a Shuttle crew. We share responsibility in that with our mission operations director, though, because under the mission operations director they're the ones who actually design the missions and build the whole milestone of activities to prepare for the missions and to conduct the missions. So the astronauts actually are trained by members of our Mission Operations Division. That's where they get their specific training for the missions they fly on.

So the MOD under John Harpold is really the directorate of mine that does that function for them. So it's the next step beyond being an astronaut now to train for a mission. You're basically directed and under the auspices of the Mission Operations Division in planning the mission, and they're the same ones who control them when they're in

space.

**GEN. BARRY:** The second part of the question is could you explain your responsibilities so the Board understands what is the Center Director's role insofar as the Shuttle mission is concerned, what were you doing before, and just kind of a general outline of the responsibility that would be on any normal launch.

**THE WITNESS:** I don't have any direct responsibility over the Shuttle Program or the missions themselves. However, as I said before, we're so intertwined with our activities that I have members of my staff and members of my organization who support all of their activities. So I have a responsibility to make sure that they do their jobs correctly. Also as part of the budget process, we have activities that are defined by the program that they assign to us and, of course, we work out a budget with them and we are given tasks that we have to perform in support of the program. And, of course, I'm responsible for making sure that it -- it could be hardware products coming out of engineering, it could be software, and also the activities out of MOD. And I'm responsible to make sure those are done correctly. So that's the type of oversight I have in that regard.

Now, on a higher level, I'm also a member of the Office of Space Flight Management Council; and that is under Mr. Readdy. The members are the Center Directors and his Deputy or Associate Administrator, Mr. Kostelnik. We gather on a regular basis to discuss policy, discuss issues, and we all have a voice in that regard. That's another indirect oversight that we have in influencing what might occur or not occur in the Shuttle Program.

I am also a member of the Flight Readiness Review. We meet approximately two weeks prior to every Shuttle mission; and we have a very formal, extensive, comprehensive review of every aspect of the mission. I am a voting member of that Board. I sit at the table at the FRR that is chaired by Mr. Readdy and as a voting member, I can participate in questions and answers of any of the people who brief it and also I have a vote as more of, I guess, on the level of a Board of directors and I sign the certificate for flight. So I do have that type of oversight on a personal level, direct level.

**GEN. BARRY:** Thank you.

**ADM. GEHMAN:** Ken, do you want to be recognized?

**GEN. HESS:** One of the constant things that we see and hear about is talking about the debate about enough resources and staffing to conduct the mission that we have here. You laid out for us a pretty articulate description of a very complex, highly matrixed organization. Could you go into your personal feelings about staffing and resources?

**THE WITNESS:** I think we're in good shape. The majority of our people who work at the Johnson Space Center are contract employees. Just to let you know, on site on a daily basis, we have about 10,000 people working here

every day. 3,000 are civil servants; the other seven are contracted people. Even in the surrounding area for support of our activities, another 6,000 or so contractors who support our activities. So it's truly a team effort. When I look at that team that we have right now, I am very pleased. I think we have a very highly qualified, gifted, dedicated, and committed team of men and women who support our activities and get the job done.

If I have a concern, it's always the balance between civil service and contractors. What's a critical mass of civil servants necessary to ensure that we have the proper skills to oversee our contractor activity. I am very confident that we have that at this time. The issue, of course, always is, within our 3,000 civil servants, our skill level, our experience level. We're in great shape right now. However, I have a concern because a very large number of our civil servants are at the age where they may retire in the next several years. So I have that challenge in the future ahead of me; but as we speak right now, I am very confident in the capabilities and skill levels of our people and our ability to support the Shuttle Program.

**GEN. HESS:** As a follow-up, you mentioned that one of the direct reports you have is for the safety and mission assurance area. Could you explain to us how that functions and how that works in parallel during the flight readiness process?

**THE WITNESS:** Once more, it is complex; but I think it's very effective. Every activity that supports our human space flight program, each one of my directorates, each one of our contractors, United Space Alliance, Lockheed, Boeing and so on, they all have quality assurance, safety people and the like because everybody is totally intent on making this a safe activity at all levels and all the way to the end. However, because of the critical nature of our activity of having people exposed to this environment, I think it's imperative upon me to have a separate organization, a safety, reliability and quality assurance organization that is an added dimension for oversight to ensure that everybody's really doing their jobs and taking care of business.

There are several facets to this. One is we actually use them to support the program and have actual activities with the review boards and a report of the program team being with them and participating in the design and development, just to ensure that, from our point of view, everything is done according to Hoyle. But another aspect of it is I retain the right, since the astronauts belong to me, I have the right to have my own oversight in activities to ensure that everything is done to reduce the risk to the men and women who go in those machines, as well as the men and women who work with those machines. So that is another aspect of that organization. They work for me directly to do that.

So there's a combination. They work in concert with the program to assist them in what they do, but they also have the right to come to me with any kind of concerns about anything that might be going on and I can take that directly to Mr. Readdy or whomever.

**GEN. HESS:** Thank you very much.

**MR. TETRAULT:** Sir, did the Shuttle Program manager ever report directly to the Johnson Space Center?

**THE WITNESS:** At this time, no. He did.

**MR. TETRAULT:** Yes. And how long ago was that?

**THE WITNESS:** Just less than a year ago. I became the Center Director on 1 April of last year. So I've not been here quite a year; but right after Mr. O'Keefe became the Administrator, the decision was made to take the two major programs in Code M, both the Shuttle and Station, and move them under the direct leadership of the Johnson Space Center director and up to the Deputy Associate Administrator for space flights. So this was, I think, a result of the Young Committee's suggestions and recommendations. So that decision was made and we went through a transition period. The transition period had begun when I arrived in April, and by summer we had moved the total responsibility for those programs under General Kostelnik. So it's been fairly recently. If you look over the long term in the history of NASA, this authority has been moved back and forth from the center to the headquarters a couple of times, I believe; but this was the last iteration of that.

**MR. TETRAULT:** Thank you.

**DR. HALLOCK:** As I understand the Shuttle Program, there are four centers that really are very much involved with it -- your own, Kennedy, Marshall, and Stennis. I'm just curious what kind of interactions you have at your level with these other groups.

**THE WITNESS:** With the other centers?

**DR. HALLOCK:** Yes.

**THE WITNESS:** We communicate quite regularly. I think sometimes, given what the issues are, I might be communicating every day with Roy Bridges at Kennedy or Art Stephenson at Marshall. Other times we'll go a week or so without talking to each other. So really at our level we sort of hit the hot buttons and talk to each other over major issues.

At a lower level, we have a continuous liaison, communications and actual integrated work with the other centers with our engineers. We actually have a virtual engineering capability with Marshall where our engineers and their engineers sit down together and work out problems together on a regular basis. Our relationship with Kennedy is very close because, of course, that's where they process the vehicles and work with them and our astronauts are over there on a continuous basis for training and for familiarization. So below me, at a lower directorate level, there is a continuous flow of information and activity among the centers where they work with each other on a continual basis.

**MS. WIDNALL:** I actually have two questions. One is just a point of information. Who does the Mission Ops Directorate report to?

**THE WITNESS:** The Mission Operations Directorate reports to me.

**DR. WIDNALL:** Okay. So that report's to you.

The second question is that you spoke about the safety and mission assurance organization that works for you which, as I understand your description, is basically supposed to provide an independent assessment. Could you give me some examples of major program or mission changes that have occurred as a result of recommendations brought forward by the safety and mission assurance organization. Of course, I put in the word "major." I have no idea what major means; but if you can answer it now, I guess I would be interested if you could supply some examples for the record.

**THE WITNESS:** Right at this moment, I really don't have an example.

**DR. WIDNALL:** I understand.

**THE WITNESS:** I'll be happy to do that. Another aspect, just because of my capability of having leverage in these things, a lot of issues that they raise are worked out with the programs at a lower level. So it's a rare occasion when they would actually come to me.

I probably can't say it sufficiently, how important safety is to every person who works at that center. It's a way of life. You can say it's No. 1 first; but really if we were fish, it's the ocean we swim in. It's an attitude. So anytime anybody raises that flag at any level, it gets people's attention very quickly and people are going to take care of it. So since I have been the director, I don't really have an example. I do know that those things have happened in the past, and I'll be happy to get some examples.

**DR. WIDNALL:** I would be very interested.

**GEN. BARRY:** If I could have a follow-up question on your discussion about civil service. Since 1993, according to a report that we've got -- and I think you participated in this and I'd like your comment on it, the concept of privatization of the Space Station Program. One of the things that was stated in here is that since 1993, 50 percent of the civil service work force has been reduced at NASA. The specific wording is: "The NASA Space Station Program civil service work force has been reduced nearly 0 percent, resulting in significant loss of skills and experience." It says: "NASA's skill base continues to erode as more functions transition to the Space Flight Operations Contract." Now, some of that affects you obviously here. Could you give us some more information on your views on that and maybe some insight on your participation in this report.

**THE WITNESS:** I did not have any participation in that

report. I think it goes back to my answer that I am very comfortable with the balance of civil servants versus contractors that we have at this time, and that has been a change from ten years ago. It has been a move toward contractors, increasing numbers doing functions that were done by civil servants in the days before.

I do have a concern for the future of, you know, once more, what is the critical mass necessary of civil servants in all the different disciplines that we participate with the programs to ensure that we have enough numbers to grow civil servants up to the expertise they need and so that we can have proper oversight on the civil service level. So at this time I'm very comfortable with it. I am very concerned about going any lower on our civil servants. However, I think it needs more study. I'm not saying we won't, but this is something that we need to really take a hard look at for the future.

**ADM. GEHMAN:** General Howell, we'll take turns here. You mentioned before in your description of your work force -- engineers, for example, the engineering department -- which are largely matrixed in support of a major project that you have here. Would you describe for us how that works as a practical matter? What I mean is if there's an engineering problem that must be solved or if one of the project people says I need more help here, I need more help there, who decides where the engineers work and how do you get reimbursed for that?

**THE WITNESS:** I guess it's a family matter, is the best way to put it. One of the extraordinary blessings we have here is that we have both the Shuttle and Station Programs located here and we support them with our Engineering Directorate and our other MOD and what have you. So every year they come out with guidelines on what type of support they want and we tell them what it's going to take to do it and we work out a budget. So we have a force of engineers -- we have two types. Each program actually has certain people who are assigned to them full time. For instance, in the Shuttle Program I have 700 plus full-time equivalent civil servants who work for the Shuttle. Now, I don't have the number for you; I'd have to get it for you. Not all 700 of them are full time. There are a certain number of those people are full time and the other number are matrixed work from several people who will take up one full-time equivalent. We have the same arrangement with the Station. We budget with them and work out an agreement on what type of work and what it will take to do it and I agree to the budget and then we go forward. And the budgets actually belong to the programs. So we make an agreement.

When something occurs, because of the family -- for instance, when we had the flow liner cracks, we went to full court press to figure out what had caused that, to do the metallurgy of that, all the what-ifs. So we set up a series of tiger teams to help analyze and come to agreement on what it took to fix that problem. I would say very easily that I took about 150, at least 150 engineers who were not part of the Shuttle Program who came to address that problem and work full time for several weeks to take care of that. Now,

some of them came from our training people. Some came from Station on a loan. A legacy of Johnson Space Center is that, you know, you come on and you stay on when you get a problem and everybody turns to do it. Everybody knows that that's the way we do it. How we work that out in the budget, I'll have to bring John Beall, my financial guy, in to tell you. I don't know, but we get it done and it is paid for. And there's such great cooperation between the programs that they're willing to, you know, do what it takes to help each other in that regard. I'll have to get you more specifics on really the details of how we do that.

**ADM. GEHMAN:** Good. I, for one, would be interested to know how that works out, not so much because I'm really interested in the accounting part of it but I am interested in the lines of authority considered. In other words, the cracks in the piping is a good example; and I certainly can appreciate the energy with which JSC attacks something like that, because it stopped the program for a period of months. I would like to know better whether or not that tiger team, for example, as you described it, was working independently, whether it was working for you, or whether it was working for the project manager.

**THE WITNESS:** They were working for the project manager. They asked for help. We offered what we could do to help them. They agreed to that, and those people worked for them. Ron Dittmore was in charge of that operation. We just provided him with a lot of expertise that he didn't normally have to help him solve that problem. Once more, though, I feel a responsibility that those people did the correct thing and came up with the correct analysis and testing. So I have something in this. However, they did belong to Ron Dittmore in that regard.

**ADM. GEHMAN:** I hate to jump around subjects here, but you said that you and other Center Directors, of course, are part of the COFR process, as I understand, the Certificate Of Flight Readiness?

**THE WITNESS:** Yes.

**ADM. GEHMAN:** And you actually sign on it. When you do that, of course, you are expressing your overall satisfaction in your sphere of knowledge, that you're ready to go; but except for that generality, what interests are you actually representing? Are you representing the interests of the astronauts? Are you representing the interests of the engineering department and the flight directors? More? Less? Have I overstated it? Would you characterize that?

**THE WITNESS:** Not at all. That's a very somber signing. It's very important. In my mind, I am representing every JSC person who has been involved in that, my confidence in them. It's also as a member of the management council for Bill Readdy. I feel that I am actually affirming everything that's gone on that I don't really have control over either. So I think I'm signing for the entire Office of Space Flight as a member of that Board with my approval.

Let me say, though, before I go to that FRR, every one of my directorates who are involved in the Shuttle

preparation, MOD, the operations directorate, SR&QA, our flight crew operations directorate, engineering -- they all have their own separate FRRs where they go over every detail, every piece of paper that's been processed and every action that's been taken so that they are satisfied in their own mind that this thing is ready to go. Then they come brief me. I don't have a formal FRR per se, but we have a meeting and I am given a thorough briefing by all those heads so I can be confident when I go in that FRR that I can make that vote. They also raise, you know, issues that have come before, how they've been mitigated, and any issue that might be briefed at the FRR. So I am fully aware what issues might be raised and I'm ready to go be a participant in that.

**ADM. TURCOTTE:** Sir, following along the lines you described about the matrixed organization that is NASA and alluding to a little bit of Major John Barry's comments earlier about privatization of the process and then the recent organizational changes. As in any matrixed organization, one authority has lines of responsibility; and, more importantly, lines of resource flow in different directions. Are you in a better position now than you were a couple of years ago, as a result of the changes, in order to leverage that matrixed organization to get the work done that you need to do as both, 1, a director and, 2, as a signer on the COFR?

**THE WITNESS:** That's a good question. I don't know if I can answer it because I am a newbie. All I know is what I know since I've been there. Being a former commander in the Marine Corps, I'd like to be in charge of the whole thing. I am very comfortable with the way that it's organized.

Now, I think it was very timely, you know, if I can put on a NASA hat, a Sean O'Keefe hat, and look at why they decided to change that authority directly up to the office, when you look at what we're going to do in the future, looking at the SLI program that's going to come up, the orbital space plane, all those things are going to have to be intertwined and decisions are going to have to be made with all those things affecting each other. I think it's to NASA's advantage to have the heads of those programs up in Washington where all that can be worked together. So I think it was a very wise move, frankly, if I'm sitting in Sean O'Keefe's chair; and I'm very comfortable, because of the relationship I have with both him and with Bill Raddy and Mike Kostelnik, that any issues I might have on budget or what have you, I get a fair hearing and we get it resolved. So I really am very comfortable with our organization the way it is now.

The privatization, you know, the SFOC contract, I guess, was sort of a move in that direction. The organization I have now is what I inherited almost a year ago. So nothing has changed in that regard, and I'm very comfortable with the organization we have now.

**GEN. BARRY:** Sir, a lot of changes have occurred here at NASA during the last two or three years. You cited one of the Center Director responsibilities being shifted. The other

one is the movement of the contractor support from Huntington Beach to JSC. Could you comment a little bit about that and your concerns, if any, about that move, particularly with regards to expertise, qualifications of the folks, and has that strengthened you. Advantages and disadvantages.

**THE WITNESS:** I think the move was really a very wise move by Boeing to get more central and get closer to the customer with the people who need to serve them. There is a concern, though, that he left a lot of expertise back in California. A lot of people didn't want to move. Mike Mott and I have had a lot of discussions about that. He's assured me that he is bringing in the right kind of expertise, that we can be confident in his products and what he's got to do. So I think what he did was the right thing to do.

There is friction and a hiccup anytime you do something like that. Things at first are not quite as good as they were before. But I think he has a very excellent plan to get back on step and be just as strong as he was and actually better because he's going to have a more centralized organization that can respond a lot quicker to the needs of the program.

**GEN. BARRY:** Just a follow-up. Did you have any involvement that you comment on and give us some help in trying to understand? I know we talked a little bit about this with Mr. Dittmore. When the OMM was moved from Palmdale to KSC, were you involved in that decision advice-wise with providing some counsel?

**THE WITNESS:** No, I really wasn't. That decision was made before I became the Center Director. So I had no involvement in it.

**DR. WIDNALL:** Could you describe your role in the issues like the resolution of in-flight anomalies, the design or material waivers that need to be granted, what I would refer to as escapements, which basically means approving hardware that for one reason or another just does not meet spec or a situation where something happened on a flight that maybe shouldn't happen, is not understood? Could you describe your role in that and then also indicate whether there is a formal process for resolution of those anomalies, in the general sense of anomaly?

**THE WITNESS:** We have a Mission Management Team which is tasked with, on a daily basis, having oversight over the mission and taking care of anomalies and mitigating any kind of problems they might have while they are on a mission or in space. I am not involved in that directly. However, I have several of my direct reports from engineering, from MOD, and other of my directors are on that team. So I have a sense of responsibility to make sure we have the right people on that team, but those are really experts at what they do. It's a very robust organization.

The MMT, you'll have a table and I'm not sure how many, let's say a dozen people at the table, but I assure you behind each one of those people are at least a dozen other engineers dedicated to help them resolve whatever issues they have. This is really serious business, and we commit a

very robust engineering and operations team anytime we have a mission ongoing. It's at an expert technical level of our best technicians who do that. So I am not a part of that. I certainly don't have the qualities to be a part of that, but I feel responsible to make sure we have the right people.

**DR. WIDNALL:** Well, I'm not just talking about what happens in flight. I'm also talking about as the vehicle is certified as being ready for flight and some of the issues of hardware that doesn't quite for one reason or another meet some original specification and there's a waiver granted of some sort.

**THE WITNESS:** Well, because of our involvement with the program and participation in almost every aspect of these activities, I have people who are involved in all of those issues. I get regular briefings about that. Anytime there are any issues like that, I'm aware of them. And Ron Dittmore and I tag up every week and we'll discuss these things together. If I have any concerns, I'll let him know those things. So we work -- I am continuously apprized of any anomalies or issues that might be going on in preparation for a mission or anything like that.

**DR. WIDNALL:** But you're not part of a formal sign-on process?

**THE WITNESS:** No, I'm not. I'm not on that decision.

**GEN. HESS:** General, you've done a very good job this morning explaining to us how this highly complex organization comes together and talked a little bit about the structure and resources that we have. My question would be that here next year the Space Station is supposed to be core complete. I'd like you to talk to the Board a little bit about stresses to maintain schedule and impacts that you see in the future.

**THE WITNESS:** Well, we have been at Johnson -- I have to be very careful because I have been accused of being too success oriented, and that's sort of the nature of the beast at our center. One thing we have going for us, though, is we have an administrator who is just beating upon us how important safety is and that should be our first primary consideration in everything we do. He starts every meeting saying that and he ends every meeting saying that. We are very eager and excited about getting this Station assembled and the missions -- I better be careful; I'll get carried away.

You know, the complexity of these assembly missions is astounding. For me, watching how our people with the program put these things together and with the other centers and take this very huge, complex machinery up into space, get it connected and operating -- it's phenomenal. I think it's one of greatest achievements in the history of humankind, frankly. That's my opinion. So I'm excited about that, and we're eager to get on with it and get that done.

However, we understand the stakes and we are not going to do anything to impress anybody to put aside any kind of quality assurance or safety issue. I think that was very

evident. You know, our administrator declared that we're going to have core complete by February of '04. We wanted to make that happen. However, we had a flow liner crack and we came to parade rest until we got that done. That was several weeks or a month. Then we had the BSTRA ball issue. Stopped. Never a peep or a complaint from our administrator or higher headquarters. They understood that those things have to be resolved before we're going to commit people to flight. So I'm just very comfortable with the attitude of our whole organization, from the top person down, of what is really important and what our priorities are.

**ADM. GEHMAN:** General Howell, I would with some degree of hesitancy speak for the Board here in which the general impression of the Board as we have traveled to all of the centers involved in the manned space flight, walked on the production floors and crawled over them and met with all levels of NASA and contractor employees that the Board generally agrees with your assessment of safety, what I would call tactical safety. If somebody finds something wrong, there's no pressure or hesitation to go fix it; but critics of NASA, while admitting that you have a very enviable and rigorous and mature safety program, also sometimes say that NASA misses the big safety issues -- that is, that the process of repeatedly fixing things and then certifying the fix to make sure that it's better than original, that sometimes you tend to miss the trends that you shouldn't have ever had to address that problem at all, that whatever it is that you're working on was not designed to fail and the fact that you're working on it is telling another story. Would you just give me your views of whether or not this is not well-informed advice or how you satisfy yourself that you've got the eye open not only for the snake that's right at your ankle but what's over the hill? I know it's a hard question to get at, but I would just like your personal views of whether or not these critics are telling us something.

**THE WITNESS:** On a daily basis when I have a chance, I've got such great team, we sort of gather together at the end of the day over a cup of coffee to talk about things; and we discuss these types of things. I think if the critics will look at us, you know, one thing is we are tactical because we're trying to support the programs and get their mission accomplished. So we focus on that, and I agree we're taking care of business today. At the same time I think people might fail to recognize that we have set up at NASA headquarters and we have people on teams right now, as we speak, working on future spacecraft, on modifications. You know, Mike Kostelnik has a very energized activity going on now, looking at what it would take to have a service life extension for the Shuttle to take care of these things that might be popping up that we didn't know about, safety modifications and reliability modifications we might do to this vehicle to keep it going to service the Station, because we realize our predictions are the Station, to be viable, is going to need a machine to carry a lot of stuff up there. And that's what the Shuttle does better than anything else that we've come up with. These are not things that are on the headlines. These are things that working groups are working on and, until we make decisions, they're not going

to be in the press or in Aviation Week; but I assure you that there are some very good minds working on this. Some of our best talent from my center are up at headquarters working on these types of activities as we speak. We're working on an architecture for the future. So not only Shuttle people looking at what we can do to our present machine but the next machines to be better. We're also looking at what we'll be doing 20 years from now. So I would hate to think that people are claiming that we're too shortsighted.

As far as safety goes, you know if we had 200 more quality assurance people who could look over the shoulder of everybody, maybe we would be safer. There's that balance. As you know, on sailing ships, if you keep all of the ships in the harbor, you're not going to lose any of them. So you always have that terrible dilemma in a position of authority of how much is enough, are we ready to go. I think we have some very serious people and very well-educated and qualified people making these decisions, and I feel very fortunate to be on this team.

**ADM. GEHMAN:** Just a few more questions.

**GEN. BARRY:** Sir, if you could just comment and have an opportunity to talk about the budget. I know you've only been on the job for about a year or so but, you know, how it's transcended in your mind and what's the prospect for the future, particularly in any budget distinctions between the Shuttle and the Space Station that you might be able to comment on.

**THE WITNESS:** Right before I got here -- see, I can cast this stone because I wasn't here -- it was obvious to many people that our budget at NASA had gotten in disarray and it was very difficult for us to really identify what it cost to do things, to get things done. That was one of the first chores that Sean O'Keefe did when he got in here was to pin us down as an organization and find out exactly what it would take to achieve things that we said we were going to take and what it was going to cost to do those things and then to say do we have the budget to do those things. So we had to cut some things out because we really didn't have the money to pay for some things that we said we were going to do. That's just flat not good business. You can't do that at your household, and you can't do it at NASA either.

So he brought budgetary discipline to NASA. He came under a lot of criticism by people because he said I don't need any more money right now, I just want to see how I can spend the money I have. I think we have come through that and I think if you look at the President's budget submission, he actually modified it to ensure that the Shuttle and the Station both would have the adequate funding over the next couple of years to accomplish the missions that we've set out for them over the next several years.

Now, I think as we go forward, we are going to be in a lot better posture to predict proper budgetary accounts towards these things so that we will have credibility when we say we need this much for this and this much for that. I think

we are in good shape because he adjusted. We were concerned over the next couple of years that we were really going to have adequate funding for both Shuttle and Station operations that we had projected; and he adjusted, within NASA, funds from other programs to ensure we could do that. So I think we are in good shape.

**MR. TETRAULT:** I have a continuing question on the budget, just to be sure I understand it. It was my understanding that the budget or at least the budget for the Shuttle and the Space Station are on a project basis with the engineers or Johnson engineers. So there must be some transfer of funds obviously that goes back and forth between the projects and the center. So that's my first question.

My second question is that it's also my understanding NASA is going to a full costing basis, which they haven't done before. I would like your ideas on what kind of a difference that's going to make in terms of how you operate.

**THE WITNESS:** The first question first. We have an institution with a certain number of engineers and we forecast a certain number of them will be working for the different programs and their budgets pay for their services for those people. However, there is a pool of talent in the different disciplines we have that is funded by institutional money. So I actually have an institutional budget that is separate from the program funding so that I can maintain certain core capabilities that would stand the give-and-take and the ups and downs of utilization or not. So that's sort of my buffer to ensure that I can maintain a certain skill level, whether or not the program needs them today or not, when they're going to need them tomorrow. So it's that kind of give-and-take that goes on. I don't know if I can be more specific than that.

However, a lot of budget decisions are made on what you did last year and the year before and what you project. So that's the type of -- you know, we match our full-time equivalents, our civil servants. Then, of course, the program, the contractors have to do the same thing with their own businesses, what's going to be needed by the programs. Then we have to bargain with them over what we need to do to do the task that's given us. Then they give us the money that's for that. Does that help on that at all?

**MR. TETRAULT:** Yes. It confirms what I thought.

**THE WITNESS:** On the other aspect, full cost accounting, that's going to be a great new adventure for Johnson Space Center and for all of NASA; and we are going to roll into that into our next budget year. I, frankly, am learning about it as quickly as I can, and I would hate to try to tell you what I know about it right now because I'm very ignorant. So I'm afraid I can't really answer that question for you.

**ADM. GEHMAN:** Thank you, General Howell. I've got one last question, and then we'll let you get on to your travel. As you have indicated, over the years a great majority of the work that's done on the space flight

programs is now done by contractors, most of it under a great omnibus contract with this USA Alliance, this SFOC contract. What's the NASA mechanism for determining contractors' performance? Is there a board or a committee? Who decides whether they get bonuses or penalties and things like that?

**THE WITNESS:** Each of the contracts has a contract official who brings in and manages in the programs themselves, grade them on their performance. Of course, each contract is a little different, whether they get fee or whether it's fixed price or what have you. Each contract has a government official, usually with the program or project that they're contracted to, who actually grades them on their performance and determines their fee. Now, the fee determining goes up to the next level for approval. So we are involved in that because we have people on my staff, senior people who are actually reviewing officials to approve those determinations.

**ADM. GEHMAN:** So what you're telling me, it's really a series of smaller contracts?

**THE WITNESS:** Yes.

**ADM. GEHMAN:** It's a bunch of little contracts in each project; and does the center have a contract also, a support contract?

**THE WITNESS:** Yes, we do. We have several contractor people who do work for us on the center and we also have fee-determining officials and they are always reviewed. Of course, we have to get our headquarters to put a stamp of approval. So it's always the higher headquarters reviews things to make sure we made the right decision; and these folks, if they are upset about it, they can protest and have it reviewed.

**ADM. GEHMAN:** Thank you very much, General Howell. On behalf of the Board, we would like to thank you for rearranging your travel schedule to be here today. We would also like to thank you for the wonderful support that JSC has provided to us during the 2 1/2 or 3 weeks that we've been here in Houston. It has been wonderful and it continues. The Board is getting larger and we're digging deeper into your back yard and we appreciate your cooperation and the energy level with which all of your folks have supported us. I want to go on record in saying that. Thank you very much, and you are excused.

**THE WITNESS:** Thank you. We are at your service.

**ADM. GEHMAN:** Thank you very much.

Mr. Dittmore, if he's here, we're ready for him. If anybody needs a short, two-minute break, we will get started. I'm watching my clock.

(Recess taken)

**ADM. GEHMAN:** Our second witness this morning is Mr. Ron Dittmore, the Space Shuttle project manager. We'll

follow the same procedure we just did.

Ron, thank you very much for coming over here and helping us through this. I'll start off by asking you to affirm your intention to tell the truth here, which I don't think is in question. I'll ask the first question, and then we'll turn it open to the panel here to continue.

I understand that for television purposes we need to stop at 11:29 or something like that in order that the NASA television network can do something else and then we'll resume -- I mean, 11:45, I think, and then resume again at 12:30.

Mr. Dittmore, before we begin, let me ask you to affirm that the information you will provide to this Board at this hearing will be accurate and complete, to the best of your current knowledge and ability?

**THE WITNESS:** I so affirm.

RON DITTEMORE, having been first duly affirmed, testified as follows:

**ADM. GEHMAN:** I'll start off with the first question. Would you describe for the Board the lines of authority -- as we in the military call it, the chain of command -- but the line of authority, starting with Mr. O'Keefe and then down to yourself and then perhaps one or two below you.

**THE WITNESS:** It's almost easier --

**ADM. GEHMAN:** Excuse me, I apologize. We invite you to make an opening statement, if you would like to.

**THE WITNESS:** I'm okay to do it whichever way you would like.

**ADM. GEHMAN:** It's my procedural error. You were invited to make an opening statement. Then I'll ask my question.

**THE WITNESS:** Since you had invited me, I had prepared one.

**ADM. GEHMAN:** We would like to hear it.

**THE WITNESS:** First of all, let me say to Admiral Gehman and the Board that I am very pleased to be here and to discuss the Shuttle Program management topics that you informed me of. I mentioned to you privately but I'll do so again in public that I pledge our unwavering support to you and the Board through the conduct of this investigation.

As the manager of the Space Station Program, I direct all activities associated with the program, including the overall program and project management. That includes integration and operations, directing and controlling schedule, planning and execution of design, development, tests, production, and operations. I am responsible and accountable for program safety, technical and operational

performance, schedule, and costs. I report directly to Mr. Michael Kostelnik, the Deputy Associate Administrator for International Space Station and Space Station Programs, located at NASA headquarters in Washington, D.C. I meet regularly with Mr. Kostelnik, reporting daily to his support staff and apprizing them of topics of interest, issues, and concerns and general program status.

As you know, the Space Station Program office is located at the Johnson Space Center in Houston, Texas, where most of the program offices and staff reside. Additional program management reporting directly to me are located at the Marshall Space Flight Center in Huntsville, Alabama, and at the Kennedy Space Center in Florida.

I manage the Space Station Program through a combination of direct reports and matrix support at each of the human space flight centers, encompassing all the hardware and operational elements, including mission operations, flight crew operations and ground processes.

In the performance of these duties, I am strongly supported by the field center institutional management and support organizations. The relationship between the program and the field centers -- the field centers being the Johnson Space Center, the Marshall Space Flight Center, Kennedy Space Center, and the Stennis facility -- is outstanding, with exceptional human, physical, financial, technical, and other supporting resources provided as required to meet the highest expectations of safety and mission success.

I work closely with each of the human space flight Center Directors, Mr. Howell, Mr. Stephenson, Mr. Bridges, and Mr. Parsons, and their support organizations to accomplish the goals and objectives of the Space Station Program. I'm extremely appreciative of the work of the Columbia Accident Investigation Board and again commit to you our complete cooperation and all the resources at my disposal to aid you in your investigation.

**ADM. GEHMAN:** Thank you. You've already answered half of my question by describing the chain of command above you. Would you mention something about the direct reports under you, in particular if any of them are not located at JSC.

**THE WITNESS:** Let me go back and talk about those above me, just to make sure we're clear. I report directly to Mr. Kostelnik, who reports to Mr. Readdy, Office of Space Flight. Mr. Readdy reports directly to Mr. O'Keefe.

Starting at my level and working down, I have a management organization that is both direct reports and matrix support. Direct reports would include the vehicle engineering office, for example. That would be Mr. Ralph Roe. He would be accountable for the Orbiter itself as a vehicle, the software associated with the vehicle, the flight crew equipment, and the remote manipulator system, the arm that's physically located on the vehicle.

I have a manager for program integration, Ms. Linda Ham. She is accountable for basically the integration of the flight

products, the flight preparation, the activities associated with the mission control center, both preparing for flight, flight design, cargo engineering and integration within the program. She also is accountable for the conduct of the flight during a particular mission.

Another primary direct report is the manager for launch integration, located at the Kennedy Space Center. This particular individual is accountable to me for the processing activities that are conducted in Florida. I delegate to that individual what we call a noon Board chairmanship where he takes care of the day-to-day processing paperwork that needs to come to the program for approval to continue processing, whether it be additional work or testing or any sort of processing.

The person at Marshall that is a direct report to me is Mr. Alex McCool. He is the director of the Marshall projects office, and I hold Mr. McCool accountable to have oversight into the Marshall propulsion projects. That would be the managers for the External Tank and the solid rocket motor, the Solid Rocket Booster, and the Space Shuttle management.

**ADM. GEHMAN:** One last question from me before I pass it to the Board -- that's clear. Thank you very much. Does the money essentially follow the same line? That is, when you decide next year's budget or your budget request or however you do it, that request comes from your direct reports and your estimate of what you're going to need for the next year in the way of matrix support and then it goes up to Mr. Kostelnik to Mr. Readdy?

**THE WITNESS:** Yes. It's even broader than what I just mentioned because I just mentioned just a small part of the program. We'd go on and on for a little bit more if we went to every one of the project elements that is a matrix support to me. For instance, the Mission Operations Directorate that Mr. Howell talked about is a direct report to the Center Directorate but a matrix support to me. When I make a call for a budget request, then the Mission Operations Directorate would come forward to the program and submit to me their budget request for the upcoming year. The Flight Crew Operations Directorate, even though a direct report to the center, would come into the program with their budget request. And that occurs throughout the program, whether it's at the Johnson Space Center or the Marshall or Kennedy space centers.

I have a business manager that reports directly to me. Once we receive guidance from headquarters on the particulars associated with the budget, we pass that guidance down to each one of the projects and program elements, whether they're direct report or a matrix support. Then we conduct a series of reviews, intensive in nature, that goes right down to the nitty-gritty, if you want to think about it that way, of their budget requirements for the year. And we develop a budget request that, once I'm satisfied that we have sufficient data to justify that request, then I would take that report to Mr. Kostelnik.

**ADM. GEHMAN:** Then the ISS program manager's doing

the same thing?

**THE WITNESS:** Mirror image. In fact, the Station Program and my program will get together because there are some elements in our system where we share resources. They're very common in their function, and we would get together and make sure that we have the right split in appropriations.

**ADM. GEHMAN:** But the first time you meet a budget request then from the Center Director is when Mr. Kostelnik goes to Mr. Readdy?

**THE WITNESS:** I should tell you that even as I go forward to Mr. Kostelnik, one of the features that we like to do in the program is talk to the Center Directors and their staff before we go forward. We don't want to catch them in any surprise with the position the program's going to take. If we do have a position that the center feels strongly either pro or con, we want them to have the opportunity to talk to us before we go to headquarters. So I would utilize Mr. Hale in Florida to talk to Mr. Bridges; Mr. McCool at Marshall to talk to Mr. Stephenson; and we would transfer the information that we are considering to the Center directors and allow them any reclaim of activities or any positions that we are taking. We at least acknowledge the differences before we go to headquarters.

**ADM. GEHMAN:** Thank you very much.

**GEN. BARRY:** Mr. Dittmore, thanks very much for coming before the Board. I'd like to afford you an opportunity to comment on the number of changes that have occurred, particularly big decisional changes on management and responsibility. We could probably spend hours talking about this on an individual basis, but if you can give a sense to the Board about your background and decision-making made in a number of areas. Let me just cite them, if I may. One was the decision to move the OMM from Palmdale to KSC, almost within the same time frame was a decision to move contract support from Huntington Beach to JSC, then as you have commented a number of times publicly but also have mentioned about the issue of contractors insofar as oversight to insight. And I cited a report with General Howell about since 1993, in your report that you put out about the concept of privatization, where it said: "The NASA Space Station Program civil service work force has been reduced nearly 50 percent, resulting in significant loss of skills and experience. The NASA skill base continues to erode as more functions transition to the Space Flight Operations Contract." I also would like to caveat that in our trips and our visits to different Centers, we've been very impressed with a lot of the professionalism, specifically with contract and contract support. There is some concern by critics, however, as we look into this that maybe that was too much all at one time to go on. So if you could give a sense to the Board of the rationale of some of those decision-making processes.

**THE WITNESS:** There are three major topics in there that I certainly understood. One was the Orbiter maintenance

modification and the decision going from Palmdale to Florida. The other one was the transition of engineering from Huntington Beach to Texas and Florida. The third one would be in this privatization report.

Can you stop me when I start talking too long on these? 'Cause these are fairly meaty subjects and take a little bit of understanding as far as the background is concerned.

Let me just address the Orbiter maintenance modification first. It's not a new subject as far as us discussing where is the right location for that modification to take place. In the Nineties, I'm sure we did at least two or three studies. I'm familiar with a couple of studies that were internal to NASA in the '97 time frame, and certainly there was a study that was completed by the Inspector General's Office in 1998. All these studies were trying to understand where was the most cost-effective location for performing modifications or structural inspections on the Orbiter, what was the best location for the long term as far as the technical ability to maintain and sustain the Orbiter. Those types of questions, not to mention where was the best place as far as gaining the efficiencies that we were looking for in the future.

The study that was done in the late Nineties indicated that it was flight-rate dependent. If we had a flight rate that was greater than six flights per year and we desired to perform the modifications in Florida, we didn't have the necessary facilities to do that. The flight rate was going to be high enough that we needed the three Orbiter processing facilities that were in existence to just keep up with the flight rate and we couldn't afford to dedicate one to a maintenance period. The same report also indicated that if the flight rate were less than or equal to six a year, then Florida would be a viable option if the program so elected to consider that.

The conclusion at the time, because the flight rates were projected to be eight or so, was to leave the facility at Palmdale active and do our modifications there; and we moved and conducted the *Columbia* modifications in the Palmdale facility. The report also noted that if the assumptions changed, as I just rehearsed them at a high level, if they changed, they asked us to re-review the conclusions of the report.

Subsequent to the completion of the *Columbia* modification, we did just that. We went back and looked at the assumptions that were part of the report, saw that the flight rate was now six or less for the foreseeable future. In fact, even as you look at it now, we had flown two years with only four flights a year. We bumped up one year, I think, to six or seven; and we're flattening out to about a five steady state for the future. And we may bump up to six occasionally.

With that flight rate, we judged it was feasible to use the facilities in Florida as they existed today and that we did not have to provide additional facility. That's a significant finding because the cost of adding another facility and the timing of doing so was prohibitive.

We also looked at the work force. The Palmdale, just by nature of having the Palmdale facility out there and its entire function was modification, at the completion of a modification, we would essentially lay off the work force. So its methodology at Palmdale was to hire a large work force, complete the activity, and then lay off the work force for some period of months until it was time to do a subsequent modification, time for another vehicle to go to Palmdale, in which case you start the process all over again.

We were concerned that for the long term that the hiring-and-firing aspect of that facility would lose technical skills, would lose management knowledge, scheduling and planning knowledge, which we believe are extremely important when you're doing any type of overhaul activity on a very complex vehicle like the Orbiter.

We also looked at the Kennedy Space Center and recognized that we had migrated to a point where most of our technical expertise was in Florida. Day in and day out they're working on vehicles and they're scheduling, they're planning. It's just part of their everyday process. So that expertise was very strong in Florida, and it was a very stable work force.

So when we compared the two, Palmdale with the long-term turnover of people and losing some of the skills, that was a concern for us, and the fact that we were hiring and firing, comparing that to Kennedy with a very stable work force that we can maintain day in and day out who had the experience to work on the Orbiter, we opted for the long term for Florida because it looked to us in our judgment that that was the safest place to maintain the vehicle. The people most knowledgeable about the ins and outs of that Orbiter resided in Florida. Technically and from a safety point of view, we believe that's the right direction.

Looking at it from a cost standpoint, which wasn't our highest priority, but looking at it from a cost standpoint, we also believe there are significant synergies by allowing this activity to take place in Florida where they already have a large infrastructure associated with the overhead of operating a facility. So we can share some of that infrastructure with our modification period.

So those synergies effectively lowered the cost of the activity. So not only do we believe we can maintain a very superior technical work force, a stable work force over the long term, but we can provide synergies that will reduce the cost. So I'm safer and I have a reduced cost. It was hard for me to turn that down as an option.

So I recommended heavily that we move from Palmdale to Florida. Just as we have watched it over the last months, looking at the modification period for OV 103, it is coming along just wonderfully. They're on schedule. We don't see any technical issues, and we believe the cost is right in the ballpark of where we had predicted. So we're very happy with the activities so far in Florida.

I should mention it's not the first time that we had done a

structural inspection in Florida. We had done one previously in, I believe, the early nineties. So it wasn't the first time.

I'm going to stop there and see if I answered you on that.

**GEN. BARRY:** That's good.

**THE WITNESS:** All right. Let me go on to the Huntington Beach transition. I'm going to spend about the same amount of time, if that's okay. The Huntington Beach transition of engineering skill was really a United Space Alliance contractor initiative and that initiative was brought to us at NASA as an initiative to really get the engineering closer to the customer, to get the West Coast and East Coast closer together because there was a tight correlation and a tight lash-up between engineering design center and operating Centers in Houston and in Florida. For the long term, we also believe that the contractor believed that there would be efficiencies that would lower the overall cost.

Remember the lash-up is that United Space Alliance is the prime contractor. The engineering work force, the Boeing engineering work force at Huntington Beach is a subcontract to United Space Alliance. So they have that relationship. So United Space Alliance was bringing to NASA a proposal to not only move the engineering closer to where the action is but also, for the long-term synergy and efficiency of the program, let's move some of those folks into areas where the costs could be decreased over time.

Boeing took on the challenge to consolidate the engineering functions; and I must admit to you that when we first looked at this initiative and talked to both USA and Boeing, we recognized that this transition was our top program concern. We briefed this as a top program concern to our senior management at headquarters and we subsequently briefed the status as we moved into this activity of how we were coming along in the transition at a number of flight readiness reviews, because we wanted all the Center directors and the chairman of the FRR and our senior management to understand the progress we were making and the risks that we saw in the system as far as making this transition from Huntington Beach to Florida and Texas.

In order to mitigate these concerns, we put together a plan that involved a very formal process of planning, identifying critical skills, trying to capture the critical skills that we believed were the most important, training of individuals that were perhaps new to the program, and then a certification process. So that formal process of identification of the skills, training of new hires, and then certifying them is well documented. If you want to see that, I encourage you to look into that, but we put that in place because we were concerned about those that we could not capture and those that we were going to hire and make sure we had the right technical balance remaining to sustain the program.

I would say overall that the transition has been very successful. We have very high confidence in the technical

leadership that we were able to capture. We had NASA-USA-Boeing involvement. I met on a regular basis with the chief executive officer of United Space Alliance and also the general manager of Boeing Huntington Beach -- that would be Mr. Russ Turner and Mike Mott -- on a regular basis for some time. At the highest levels, we were reviewing the status of the transition. On a weekly basis all the senior management of Boeing and USA and the affected project offices, being the system integration office and the Orbiter office, met regularly to discuss the very details, by name, by individual, who was coming, who wasn't coming, critical skill, not critical skill, and the level or quality of people that were coming into the system, which was very important to us, especially since in the end we captured 24 percent of the incumbents out of Huntington Beach.

So effectively, if you looked at it on the surface, we had a large number of new people coming into our system. What was very gratifying to us was that the large numbers of new people weren't really new. They were people that were familiar with the Shuttle, familiar with Shuttle systems, had worked in the environment for 10 or 15 years, just happened to move from perhaps one company to another company. So we didn't get 70 percent fresh out of college, by no means. We got a large majority of very experienced individuals coming from different companies that had a lot of Shuttle foundation framework underneath them.

Even then, we still looked at the makeup of different groups of individuals. If we felt that we didn't have a sufficiently high number of experienced people in a particular group, we declared that group to be out of family. What out of family means to us is that it draws in additional expertise to look over their shoulder. An out-of-family group would require NASA and United Space Alliance technical expertise to validate products and to provide necessary oversight to make sure that we did not have any lapse in our technical ability to produce the products or in our analysis in response to any problems.

Some of the examples that were mentioned when General Howell spoke of over the last six months, the flow liner difficulty in the last July, involved the same lash-up of individuals -- some groups extremely well qualified, other groups requiring this out-of-family oversight. We found that this system worked well. The oversight provided just the necessary comfort that we needed and the skills, and we brought together the NASA expertise that still is available to us and the USA expertise to solve these very complex issues.

So overall the Huntington Beach transition has been a large success. It started out as a top concern, and it was organized and implemented in a way that managed the risk and resulted in a very strong work force. And I can't overstate the fact that it was a difficult activity all in all, moving a group of individuals, capturing only 24 percent, keeping your flight rate stable, and meeting the challenges of the problems that you face day to day. Just an excellent job by the management of NASA, USA, and Boeing to ensure a successful transition.

**GEN. BARRY:** Mr. Chairman, if I might cede the remaining part. We'll get to the privatization.

**THE WITNESS:** The privatization is going to go just like I just mentioned, that depth, if that's okay with the Board.

**GEN. HESS:** Mr. Dittmore, you gave us in your opening remarks some agree of description of your organization. I'm curious as to the SR&QA functions that are direct reports to you, the size of the organization, the scope of their responsibility.

**THE WITNESS:** I concentrate on safety and just that organizational responsibility all the time because it is our life blood. It is what keeps us safe. I need to give some background here also because to understand safety is more than just the word and just a high-level skimming the surface of what safety means.

You need to understand the relationships between in-line safety and independent assessment. It is a responsibility. For us in my program, the primary responsibility for safety is the in-line organizations. That is the design center reporting to a prime that reports to a project office that reports to a program office that reports to a flight readiness review. There is a primary path of accountability and responsibility, if you understand what I'm talking about. The design center is absolutely responsible for safety. The prime is responsible for safety. The project office is. I am. And we bring that to the flight readiness review.

It is very important that that primary path of safety is maintained in a robust fashion; and I watch that very, very carefully. There are ingredients of safety that are absolutely necessary, and these relate to the work force and relate to the skills that are important for us to consider. We have a term that we call checks and balances and healthy tension.

Checks and balances are making sure we have the right skills in the system, a safety officer that has the right background so that they can ask appropriate questions to challenge assumptions, technical results, et cetera. You have to have the right check and balance in the system.

Healthy tension is the way you set up an organization. There should be a healthy tension between an engineering design center and an operations center. The operator wants to use the hardware. The design center wants it used in a certain way. There should be a good healthy tension between the two of them to ask good questions, provide good technical answers; and if you set up your organization right, you have a very robust process and an ability to not let something slip through the cracks. All this is part of the primary path of safety. Appropriate checks and balances. Good, healthy tension.

Now, there's a second path that I think is also very, very important. It's a separate, independent organization. When you talk about safety, quality organizations, S&MA organizations that are outside of the program, I look at these organizations as being my secondary path of safety.

They watch, participate, and are involved in the activities of the direct path; but it's not the same people. It's a different contractor. It's a different set of NASA. So they are providing to me a separate, secondary, independent check. That's very important to me that I have someone that's looking over their shoulders and may not agree with the way the process has occurred or the way the technical answer has been achieved. I don't want the basis of both the primary and secondary path to be the same source. If it's the same source, I don't have value-added independent assessment.

So that's why I'm careful to tell you today that it's very important for me to have a primary path and then a secondary path that is an independent source. Different set of folks. Not the same contractor at the bottom. I don't want the same source. So when I talk about value-added independent assessment, that's what I mean. I mean a separate, independent assessment outside the program, outside the direct line. Then when they come to me -- and they do come to me, they sit on my boards and I ask them for their opinion -- I'm getting their opinion that is separate and distinct from my design primary path chain of command.

So when you talk about the organization for SR&QA, it's very important that we understand the primary path of safety that is direct accountability to me and a secondary path that's value-added independent assessment that is involved in our program. And we take both these paths forward to the flight readiness review.

**GEN. HESS:** Thank you.

**GEN. BARRY:** Next question won't be quite as cumbersome, but it may be. Let me ask the question on aging spacecraft in an R&D environment. We're entering an area here we've never really been in. Our space program, as glorious and as successful as it has been, really has been with vehicles that we've been able to use and then basically not use again. The Space Shuttle, of course, is the first one that now is, since the *Columbia* flew in 1981, over 20 years. Can you comment on the approach and significance of this new era that we're entering, if you could describe it that way? The Board's described it as aging spacecraft in an R&D environment, not an operational environment but an R&D environment.

**THE WITNESS:** I think we're in a mixture of R&D and operations. We like to say that we're operating the fleet of Shuttles. In a sense we are, because we have a process that turns the crank and we're able to design missions, load payloads into a cargo bay, conduct missions in an operating sense with crew members who are trained, flight controllers who monitor people in the ground processing arena who process. In that sense we can call that operations because it is repeatable and it's fairly structured and its function is well known.

The R&D side of this is that we're flying vehicles -- we're blazing a new trail because we're flying vehicles that are, I would say, getting more experienced. They're getting a

number of flights on them, and they're being reused. Hardware is being subjected over and over again to the similar environments. So you have to be very careful to understand whether or not there are effects from reusing these vehicles -- back to materials, back to structure, back to subsystems.

To the best of our ability, we try to predict the interval for inspection, the interval for subsystem testing; and there's been pressure in the past and even today to decrease the amount of inspections that you do on these vehicles. It's very difficult for a design center who has the accountability to maintain and sustain these vehicles to want to back off on a level of inspection just so you can get more into an operational environment and turn them around faster.

So we have resisted and the design centers have resisted reducing the number of requirements from a processing point of view. The processors have to complete the requirements of the design center. So we have resisted backing off on the requirements the design center wants to pursue to maintain their insight into what you call the aging systems.

Our challenge is, as we effectively tear the vehicle apart in these maintenance periods, our challenge is to identify clues that either substantiate that we have the right amount of time between inspections or to give us a clue that says there's something happening here that we need to change or we need greater analysis or we need greater tests. And based on the experience over the last 20 years and looking at the vehicles and analyzing the results of tests and analysis, we're getting better at predicting that time interval. It was fairly arbitrary at the beginning. We said we needed to do a structural inspection, overall, every eight flights and three years. Structurally now we're looking at the structure and we're seeing that, because of the quality of the hardware from inspection to inspection, that perhaps I can even increase the interval on structural inspection in certain areas of the vehicle. There may be other areas of the vehicle where, because they're more exposed to the elements, I want to see them more often. So we look at all those different aspects both from a subsystem and structures. I just give you that by way of background to help you understand those are the areas that we really are trying to understand. And perhaps there's more that we do need to understand by way of tests and analysis as we continue to fly for another 20 years.

**ADM. GEHMAN:** Thank you, Mr. Dittmore.

Panel, our time is up. We're being governed partially by the broadcast of this hearing. We will continue with Mr. Dittmore at 12:30. We all have a couple more questions. So if you're still available, we'll resume at 12:30.

(Luncheon recess)

**ADM. GEHMAN:** All right. Members of the Board, we're back in session. Mr. Dittmore, if you're ready, we'll just resume right where we left off. I believe General Deal gets to go first since he wasn't here this morning.

**GEN. DEAL:** Mr. Dittmore, there has been some talk in the media and amongst people about potential trade-offs and budgetary trade-offs in the ISS program and the STS program. I'd appreciate your comment on that and giving us your views.

**THE WITNESS:** I think the first thing to note is that both the Shuttle and the Station are very complementary in that we work very closely together. I have a very strong relationship with Mr. Bill Gerstenmaier, who is the manager of the International Space Station Program; and that close relationship is necessary because, as I mentioned earlier, we share certain resources. The mission operations area, the flight crew operations, and even the space walk functions are common to both programs. We get together and make sure that when it comes to us spending our own resources individually as programs, we make sure that we have the right percentage split. Whether it's 50/50, 60/40, 20/80, we look at that and make sure we have the right appropriations between the two programs.

We also agree on who takes the lead. If the percentage of a particular activity is 80/20 in favor of Station, in many cases Bill and I will get together and I'll say, "Bill, why don't you take the lead? Because I'm basically a customer, you have more of an owner relationship here, we'll let you be the advocate for the budget and we'll just tag along." The opposite is also true. So there is a very strong relationship between the two of us and as we work those types of subjects together, we bring those forward to Mr. Kostelnik either to arbitrate where Bill and I can't get together -- which is very seldom -- or to bring Mr. Kostelnik up to speed on where we believe the right split is so that he can carry it forward in the budget process.

To date, there's no real sharing of budgets. There's no transfer from Shuttle to Station or Station to Shuttle. We both go forward with our requests for the given operating plan and the cycle that we're asked to present; and we compare notes to make sure that we are complementary, as I mentioned. So at this point, it seems to be working very well.

**ADM. GEHMAN:** Mr. Dittmore, one of the things we forgot to do in the introduction here, would you tell us how long you've been the project manager, when you came into office.

**THE WITNESS:** Just six weeks ago, I would just have said generally, but now in the last six weeks it has made it very acute and I can tell you to the date almost. I was made program manager in April 1999, almost four years.

**ADM. GEHMAN:** Thank you very much.

**DR. HALLOCK:** I have two very different questions. I've been looking at the responsibilities of people and so on. I was just curious, as you come to a countdown, what are the responsibilities that you have at that time, your role and/or decisions that you get involved in as you approach the countdown.

**THE WITNESS:** I think it's important to recognize that once we get to a time frame that is launch minus two days and inward toward the count, the management of the activities, the launch countdown itself is really handed over to the launch teams, the operating teams, and the management of the program is delegated from an operational point of view to the manager for launch integration. As I mentioned earlier, he is my direct report to me, located in Florida. That particular individual chairs the Mission Management Team, starting from L minus two days down to the count.

As we get into the countdown and we're all in the Launch Control Center, then the final go for launch is given by the Mission Management Team and specifically by the chairman of the Mission Management Team. That would be the manager for launch integration. He will provide to the launch director his approval or her approval to go ahead and proceed with the count. That is done just before we come out of the hold at T minus 9 minutes.

My relationship to the manager for launch integration during this time frame, because we're both located in the Launch Control Center but not in the same general area, we are tied together via a phone. If there's anything unusual, we communicate with each other; and if there's nothing going on, we communicate. So both positive and negative reporting, depending on what time frame we are in the launch count. And we're co-located sufficiently close to each other that if there's any reason I need to get up and walk over and talk face-to-face, that's easily done. So the relationship is a very tight communication loop.

Where I am located in the Launch Control Center is in the senior management area, and I'm sitting right next to Mr. Bill Readdy, the Associate Administrator for space flight. We have the Center Directors in this general area and if there's anything that would come up that involves the agency, if there's anything beyond the operations team involvement that requires a senior management discussion, we're all there together and can feed that information back to the manager for launch integration who's chairing the Mission Management Team, and that would get fed into the launch team or the mission team, ops team, whichever the case may be.

**DR. HALLOCK:** Thank you.

**ADM. GEHMAN:** Let me follow up on that. I want to get back to that exact relationship you just talked about, the Mission Management Team, the launch director, and yourself. You're all three sitting there and all three of you have some authority and some responsibility. Maybe you could go a little bit deeper into that. My understanding in layman's terms is that as long as the launch is going in accordance with the flight rules, if you can call them flight rules -- you probably call them launch rules -- then the launch director does his things and then if there's anything that's anomalous or different, then the Mission Management Team has to step in. Is that right?

**THE WITNESS:** You said it very well. The launch

director can make decisions within the framework provided to him within the launch rules, launch commit criteria. Anything outside the authority given to him within that launch commit criteria must go to the Mission Management Team.

**ADM. GEHMAN:** But you're sitting there listening to all this. Can you overrule the Mission Management Team chief, or what is your role?

**THE WITNESS:** The chairman of the Mission Management Team reports to me. I have assigned that individual to chair the Mission Management Team; and so our relationship is that if there's something that I feel uncomfortable with, I can certainly stop the count at any time. And I'm paying close enough attention to it so that I have that relationship and knowledge that if for whatever reason I don't feel the technical discussion has been appropriate or the work, that's there's open work that I think needs to be closed, then I have the authority to step right in and stop the count.

**ADM. GEHMAN:** Thank you very much, Mr. Dittmore.

**DR. HALLOCK:** My other question was: Over the last couple of weeks I've had the opportunity to talk to a lot of the people here at Johnson, a lot of the people that are working for you -- by the way, they have been very, very helpful. I have seen that they are just as determined to get to the bottom of everything that's going on as I think we are right here at this point. I'm just curious what you perceive as sort of the morale, if you will, of everybody at this time.

**THE WITNESS:** Well, I think the morale is generally pretty good considering the conditions we're operating under. It's been six weeks since we had an event that changed all our lives, and every day that goes by gets better as far as the work force is concerned. As I mentioned to some folks earlier, the best therapy that we can do is to be extremely engaged in solving this particular problem; and everybody wants to be engaged in this effort, without exception. Senior management to the technician wants to be involved in this effort. Not all of them need to be, but their waking moments, their thrust, their reason for coming to work is to help you as an investigation Board solve the problems so that they can implement whatever needs to be done to get us back to flying.

I would say the morale is good in that sense. There is an even more increased determination and a greater commitment to look very closely at the system, and they are determined to identify if there's any weakness. And it's broader than just what may be determined as the root cause. They're going to look to see if there's something else in the system that may have existed for many years but now that -- they will come back and make a recommendation to me that says they'd like to make some improvements. Even though it may have nothing to do with the root cause, I suspect that they're going to be very interested in making some recommendations that would improve the overall configuration of the system. So they're engaged, definitely;

and I hope you get the sense that there is an absolute 100 percent commitment on their part to support you in every activity.

**DR. HALLOCK:** I have been seeing that.

**DR. WIDNALL:** You know, following the *Challenger* accident, watching NASA as it moves forward in its organizational development, many observers have sort of commented that NASA is making a transition from an agency in which it's important to prove that it's safe to fly to one that needs to prove that it's not safe to fly. I don't know whether that's clear; but in other words, if you make a launch decision, rather than proving it's safe to do it, somebody has to come forward and prove that it's not safe in order to have it basically stopped.

A kind of corollary of that is the question of how do you take the bubbling and turmoil level of concern that clearly comes from your engineering workforce -- and we saw that -- and translate that into actionable programs, I guess, to resolve some of the uncertainty that's being expressed.

**THE WITNESS:** Well, my general observation is that we as a program are very zealous about making sure we are safe to fly, and I think our track record will defend that. Let me give you some examples.

We've had a number of different cases where we probably could have continued a launch and flown but decided not to because we didn't understand the events that transpired, we didn't feel comfortable with understanding the background, and we didn't think we had sufficient discussion to convince ourselves that we were safe to fly. And I think that is the right side of the equation to be on. We have scrubbed, we have taken timeouts, we have delayed 24, 48, whatever it takes for us to get comfortable; and I think we have a strong track record that will substantiate what I'm saying.

Last summer a particular technician identifies a very, very small, what is perceived to be inconsequential indicator in a flow line. That stopped the process. We didn't go into it and say, "Someone prove that we're unsafe." We went into it and said, "We have a crack in the flow liner. We're going to stop processing on all vehicles. We're going to inspect all vehicles and we're going to determine how big the problem is because unless we understand it, then how can we say we're safe to fly?" That's an example, and that delayed us on the order of six weeks and required a significant amount of effort across the program, both from the public side of the government, from private industry, from academia, to pull this together in a very concentrated effort.

Later on in the year we had other indications. As we were working on the *Discovery* OV 103 in its major modification period, we identified small indications on what we call the BSTR or ball strut tie rod assembly. All by itself it looked very, very small and inconsequential; and if I think there was an attitude to prove it's unsafe, it would have just been in the system, worked its way through paper. Not in this case. It's immediately notified to upper management that they believe there's something here that we should look at.

Again we stopped processing and we go prove to ourselves that we're safe to fly. Again, significant amount of time and resources to prove to ourselves that we are able to continue with flight preparation.

So I don't know where the comments come from, but I think the track record is there to defend ourselves ably that we are a program, an institution, and a culture that today proves that we're safe to fly rather than any other method.

**DR. WIDNALL:** The second part of this really was this question of how do you take these bubbling turmoil and comments of concerns that you verbalized and really translate those into action?

**THE WITNESS:** I think you have to cultivate a culture that allows everyone the opportunity to raise their hand and say they have a concern, to have the work force feel that no matter what position they are at in their organization that they can bring to management's attention an issue that they feel is a significant one that management ought to address from a safety-of-flight point of view. The culture and the process have to be there, and I believe that is true today in our culture and our process.

However, I must also state that we also cultivate a culture of second-guessing, challenge, checks and balances, as I mentioned earlier, and healthy tension. We want the people in our system to challenge the assumptions. We want them to challenge the results of technical analysis or tests, and we do not feel threatened at all by that challenge. In fact, we believe it is healthy for us; and so when I hear about people in the system that are challenging and talking about particular analysis, that's what I want them to do. I want that to be part of our culture; but I also want them, if they believe that they have an issue, I want them to raise their hand and bring it forward to management. If they don't, given that I believe the culture is there and established for them to do so, then I must conclude that they do not believe strongly enough to bring it to management's attention, that it is something that they are in this challenging stages and they are doing a what-if type of discussion, which we also want them to do, to cover any event. So all I can say is that we cultivate that culture both on openness -- anybody can come and walk in my office and say they've got a problem. Anybody can walk in any of our management, senior management's offices and say they have a problem, and we will listen to them. I'd be very disappointed if I found it to be otherwise.

**ADM. GEHMAN:** Thank you very much.

**MR. TETRAULT:** One of the unfortunate results of this accident is that there will be future delays of launches and that, as I understand, will, in fact, result in some cutbacks within the program. My question to you is: Are you concerned about the loss of capability particularly in the technician ranks as some of those cutbacks occur?

**THE WITNESS:** Well, at this stage in our investigation in supporting you, we have not discussed any cutbacks in our work force. Not only have we not discussed it, we have not

entertained it; and our work force is a part of our system. They're vibrant, they are creative, and we're going to need every one of the members of our work force to get us through this period of time. There are a number of activities that will be required to be completed, independent of the investigation, to get us back to a return-to-flight posture. I think the work force needs to understand that they are a part of this, they are a part of the return to flight, even though they might not be totally involved with the investigation and support of the Board.

So just to reinforce this message to the work force, we have not discussed or contemplated at this point any slowdown, any layoffs, or any reduction in our work force because we are aggressively trying to determine exactly what areas of emphasis, in addition to your investigation, we need to concentrate on to involve the work force in.

**ADM. GEHMAN:** Thank you very much.

**GEN. BARRY:** I'd like to afford you an opportunity to comment on this privatization report, if I may.

**THE WITNESS:** How much time do we have left?

**GEN. BARRY:** The point again, if I can restate it, is that since 1993 the Space Station Program's civil service workforce, it states in the report, was reduced nearly 50 percent, resulting in a lot of loss of skills and experience. In the same report it said in the previous five years, which would have been '96 to 2001, your program had approached contract consolidations; and there's a term in there, "oversight to insight," which it would be helpful to understand what that is, if you can spend some time on that one. During this transition which has gone on in this period of time, it states here that NASA's skills and experience will result in serious erosion of checks and balances critical to safety and mission success. The final statement I'll just read here, if I may, is: "Continued consolidation utilizing the existing approach results in a serious threat to safety and mission success. A different approach is required." So can you comment? I just want to afford you an opportunity to give us your insight on this report and what was meant by that.

**THE WITNESS:** I think you need to go back in time because the environment at the time that report was written is completely different than the environment that it is today. In the summer of 1999 -- and you've got to help me, General Barry, on my dates. The report was authored in September of --

**GEN. BARRY:** 2001.

**THE WITNESS:** Okay. So it's the summer of 2001. Thank you. There was an excitement in the air about talking about privatization, and what's interesting about that is there was no general agreement on what privatization really meant. So even by me putting out a report that says concept of privatization, it's debatable what that means. It was debatable in that summer what privatization meant. So you have to almost put yourself in that type of environment

where there was a large excitement about thinking about where are we going in the future, were we going to ask the government to step farther away from operations.

They had made a commitment in '95, '96, when we went to a space flight operations contract and had transitioned government functions over to the private sector. The government had already made a commitment to step back in many areas. In the summer of 2001, there was again this excitement going on in the system at the highest levels in our agency concerning should we do more; and in that environment, I was asked to develop some concepts.

The other important thing I think we need to understand is, from my point of view as a manager of the Shuttle Program, I look over the entire assets of the program -- work force, facilities, skills, everything associated with the program -- and I, on a regular basis, along with my team, try to understand are we safe to operate today, are we going to be safe to operate a year from now, are we safe to operate five years from now. And they may have different answers depending on where you are with your work force and where you're going with your tactical and strategic activities.

In the summer of 2001, we had some basic program concerns; and the concern is that we had had a large decrease in our civil servant population supporting the program over the previous decade. I think we mentioned in the report somewhere between 40 and 50 percent civil servants supporting the program, reduced 40 to 50 percent. That's a significant decrease and a significant loss of experience and knowledge.

Now, some of that, I believe, is justified because we were coming off a heavy emphasis on development and we were turning the gain down on development and moving toward this operational aspect. So we didn't need as many people supporting the program. However, you have to consider and you have to project where you turn the faucet off so these people stop leaving the program. As we looked at it, we were concerned that the faucet had not closed, it was still open, and we were still getting a drain of civil servants over time. In fact, there continues to be and has continued to be a discussion about outsourcing and competitive sourcing and moving more functions from the government to the private sector. Those types of discussions, and knowing that your civil servant staffing to support the program continues to decrease, causes me as a program manager and my management team to have concerns.

As I mentioned earlier when we talked about SR&QA and the in-line primary path of safety and the secondary path of safety, the way you relate skills and experience in this program is to look at the checks and balances that are available to you and a healthy tension that needs to take place. It all goes back to that. If I lose the skills and experience in my program over a period of time, then I am slowly affecting in a negative way the checks and balances that I believe are critical and the healthy tension that must take place to maintain the safety; and if I don't maintain this value-added independent assessment, then I'm

weakening my program's ability to fly safely in those three areas. I'm weakening independent assessment because I'm losing skills and knowledge that could be independent; I'm losing the ability to have knowledge to give me a healthy tension; and I'm losing the ability, with the loss of knowledge and experience, to have strong checks and balances.

So if I look into the future, project where I've been into the future, then I have a concern. If you looked at it, another way is I'm in a going-out-of-business mentality and I'm doing it slowly over time so that one year to the next it doesn't look like you're making much effect or having much influence but over three years or five years, if you don't project it carefully, you're going to get to that five-year point and you're going to ask yourself, "What have I done to myself?" And it won't be on my tenure as program manager, it will be the next program manager or the one after that that's going to look back and come find me and ask me what the heck I was doing that allowed this to happen. So I just give you that background because it's necessary to help you understand the concerns that I have about maintaining the right balance of work force to support this program on the government side and on the private sector side.

Along with that, to understand privatization, you have to understand that the role of the government has not changed. We are still accountable. I am still accountable for this program. Even though functions are being transitioned to the private sector, I am still accountable for everything that I had been accountable for five years ago; but I have less resources and perhaps less skill to do the same job. So if we want to still be accountable on the government side, then I have to help senior management understand the level of civil servant experience and skills necessary to operate the program.

That's really the foundation of that report. I wish, in hindsight, I had not called it privatization because it gets all mired up in somebody's definition of privatization, which someone can take a crack at that and we'll spend a year debating it. That was not our intent. Our intent really was to focus on the brain drain, the loss of skills and experience, to get everybody to focus on the checks and balances and the healthy tension and the organization that needs to exist to maintain flight safety. That's the basis of the report.

Now, I have to tell you also that as a team we worked for several months -- and I'm talking about my management team, my senior management in the program, along with some senior managers on the contractor side -- we got together and discussed these concerns that I just related to you. As a management team on the NASA side, our first option and our desirable option is to shore up where we believe the weaknesses are in the civil servant side. In other words, we believe we should be accountable, we accept that accountability, but I need the right resources in the right areas for the long term. I am safe to fly today. No question about that. I'm not talking about today. I'm not talking about next year. I'm talking about the trend and projection of where it's going to be unless we do the smart

tactical actions today.

Our first option was to take the necessary action to either reverse direction in some areas that we thought were too weak and had gotten weaker over time and/or shore up areas for the future that we knew were going to be sensitive. We did not believe that to be a credible option because of the environment at the time. That's why I say you have to put yourself in the environment at the time. The environment at the time was not bigger government for the sake of the Shuttle Program, it was try to get lean and mean, try to get efficient, try to reduce and still be safe. So we didn't think that first option was very credible, and we wanted to be realists about this proposition.

So our only other choice as a management team that we believed could be credible was to somehow merge the work force, the best and brightest on the government, the best and brightest in the private sector, and somehow put them together in such a way that it preserved the safety of the program for the long term. We did not say how to do that necessarily. We did not say that had to be all turned over to the private sector. There are a lot of different options that people can talk about. We kind of left it just that way. There are several options if you wanted to address it, if people wanted to address it in the future. We just left it from a program point of view that these are our major issues, these are our concerns. Whatever options that people like to address, these basic factors need to be considered.

So when you talk about that report, it needs to be understood in the vein of the concerns the program had in 2001 and still has today; and it's my responsibility to make sure that my successor, the people that follow me as program manager, either the next one or the one after, I have to take the actions necessary today to let them be able to manage a viable program 2 years, 5 years, 10 years, 15 years in the future. I know most of you have been involved in these types of projections. It's very difficult to project into the future and be right or convince people that you're right. It's just subjective and it's judgment. That's what we were trying to do with that report.

**GEN. BARRY:** Thank you.

**ADM. GEHMAN:** I'm going to close out here, Mr. Dittmore, with one or two questions that maybe we can go over quickly. The first one is certificates of flight readiness waivers. For the people in the audience, what I understand were the waivers I'm talking about, they go all the way back to the original production of the Orbiter and every time there's a repair done that's not to spec but it's a certified repair, you can get a waiver for that. So it's very likely that on the Orbiter you may have several hundred waivers outstanding. Am I not correct?

**THE WITNESS:** Well, I have to be careful myself because there is a language that we need to understand. Because there are standard repairs, there are return-to-print repairs, there are repairs that require a buy-off by engineering, and a waiver is an approved condition where we may not fix a problem or we may accept the condition as is.

**ADM. GEHMAN:** So my question is: Without going into any particular waivers, who can approve a waiver and what is the mechanism by which that's done? Do they come to the program manager?

**THE WITNESS:** We have strict criteria on who can and cannot approve a waiver. In most instances a waiver goes to this new board that I talked to you about because most waivers involve the processing of the vehicle, for instance, and the manager for launch integration who chairs that noon board for me on a daily basis, if required, would disposition those waivers, with the noon board membership being all the people in the program involved, the flight through the mission ops, the ground processing, all the engineering disciplines and all the projects, listening to the conversation, deciding whether it has merit or no merit.

There are other waivers that may not be a single flight type of activity. Let me put it in context. You're processing a vehicle and you have a criteria to check out a helium regulator and it has a requirement that says it must be plus or minus 50 psi from a particular level and it comes in at plus 50.5, violates the criteria. People would take that forward and for that half a psi exceedance, is that acceptable or not acceptable? Is it acceptable for one flight, two flights, or five flights? So these are the types of things we would have a discussion on.

There would be others that may be more significant, in which case, as the program manager, I require them to come to my board because they're not a single flight issue or a processing issue. They're more of a long-term agreement, and I must weigh in on those.

**ADM. GEHMAN:** But, in general, it's either you or your designated representative.

**THE WITNESS:** That's right. There's clearly defined who can approve waivers, and that has been identified in our documentation.

**ADM. GEHMAN:** Good. In your experience, is there a process, then, to review the accumulation of waivers?

**THE WITNESS:** Yes, there is. In fact, I'm trying to think how often this is; but I believe it's quarterly. I go through systematically and look at the changes, the number of waivers or exceptions, as we also have a term, that have happened over a quarter. I look at the changes in our hazards, in our critical items list, and I'm trying to determine whether we have a system that's going out of balance. Do I have too many waivers all of a sudden? I'm trying to look for flags. If I see too many all of a sudden, I'm asking what's going on in the system. So I do that on a quarterly basis. I don't do it any more often than that because the date is so bouncy you can't do it.

**ADM. GEHMAN:** Thank you. Again referring particularly to the prime contractor, the USA contract, what entity at your level -- and if it's not at your level, you'll just advise us -- but how is the contractor either rewarded or penalized? Who decides if the contractor is rewarded or

penalized for anything? I'm not talking about the loss of the Orbiter or crew here. I'm talking about anything -- delays, safety violations, whatever. How is the contractor rewarded or penalized?

**THE WITNESS:** It's generally done commensurate with the features of a contract. If the contract is an award fee contract or it has award fee features in the contract -- and USA does, that contract does -- then I would convene a performance evaluation board at the proper interval and we as a management team would get together and assess their performance over that time period. Once we have determined their particular performance, then I take that judgment to Mr. Kostelnik, who is the fee determining official. I present it to him. But yes, I do look at that.

**ADM. GEHMAN:** Thank you. My last question -- I thank you for bearing with us here. My last question again is kind of a process question. You were speaking about budgets and Mr. Kostelnik and Mr. Readdy. At NASA headquarters, is there any kind of a program evaluation office? I know there's a comptroller, I know there's a budget officer, but is there any kind of an office of program appraisal?

**THE WITNESS:** Well, that certainly doesn't ring a bell in my mind.

**ADM. GEHMAN:** Well, you would know it if there was one because you would be wrestling with them all the time.

**THE WITNESS:** Well, I'm wrestling; but that doesn't ring a bell.

**ADM. GEHMAN:** Thank you very much for your time, for bearing with us with the noon break and for being so forthcoming with your answers. It's been very helpful to the Board. There are matters which we will want to talk with you about some more, and we will ask you to return at some date in the future.

I would like to express on behalf of the Board, not only to you, Mr. Dittmore, but to the whole program, our thanks and our admiration for how hard and how diligently everybody's trying to get to the bottom of this. The energy, the zeal, the professionalism is quite evident to the Board. It's remarked upon frequently by the Board. It's very genuinely felt, and we know that you and your office want to find the cause of this tragedy just as much as we do. So we thank you very much for your cooperation. You're excused.

**THE WITNESS:** Thank you very much.

**ADM. GEHMAN:** Okay. We are going to continue on. If anybody needs to step away from the table at any time, please do so. We'll just continue on. I think I'm looking for Mr. Keith Chong.

Mr. Chong, good afternoon.

**THE WITNESS:** Good afternoon.

**ADM. GEHMAN:** We're very pleased to have you come join us, and I'm sure we're going to learn a lot. You're going to have to be patient with us. If you use any complicated words, we'll stop you. We are very thankful for you to come here.

I would ask us to start off by a couple of preliminaries. I'll read a statement that says you agree to tell us the truth. If you agree to that statement, just say, "I will." Then we would like for you to give us a short biographical sketch of where you're working right now and what your area of expertise is, if that's okay with you.

Let me just read the statement. Let me ask you to affirm that the information you will provide to this Board at this hearing will be accurate and complete to the best of your current knowledge and belief.

**THE WITNESS:** Yes, I will.

**KEITH CHONG,** having been first duly affirmed, testified as follows:

**ADM. GEHMAN:** Will you please state your full name and where you work and what your area of expertise is.

**THE WITNESS:** My name is Keith Chong. I'm a senior engineer scientist from Thermal Management Systems Group, Material Process Engineering Department, at Boeing Huntington Beach. Currently I work on Boeing Delta 4, EELV program, International Space Station.

**ADM. GEHMAN:** And the EELV program is?

**THE WITNESS:** Evolved expendable launch -- vehicle. Thank you very much.

**THE WITNESS:** -- and advanced development system program, which includes the space launch initiative, SLI; Orbiter express, and the X-37 vehicle.

Before this, I worked on the Space Shuttle Orbiter main propulsion system and reaction supply and distribution hardware, which includes the 17-inch disconnect, the small cryogenic feed lines that's used on the Orbiter, the feed lines that mate up to the 12-inch flanges of the main propulsion system, and the pre-valves closeout on the outer fuselage of the Orbiter. In addition to that, I served as a member of an External Tank thermal protection system working group sponsored by NASA Marshall Space Flight Center and worked with representatives from Lockheed Martin from Michoud and JSC, NASA Marshall Space Flight Center, and Kennedy Space Flight Center. I'm also as a focal point at Boeing in the Columbia accident foam debris analysis team.

I graduated from the University of Southern California with a Bachelor of Science degree in chemical engineering in 1984. I was asked to be here today to answer any questions you have regarding cryogenic foam insulation.

**ADM. GEHMAN:** Thank you very much. Just to be sure

we understand, you are presently employed by Boeing?

**THE WITNESS:** I was originally employed by Rockwell International in 1988 and since then, you know, would be part of Boeing.

**ADM. GEHMAN:** The External Tank is made by Lockheed Martin?

**THE WITNESS:** That's correct, sir.

**ADM. GEHMAN:** Just to make sure. In the current vernacular, then, you're a foamologist, according to the press. Is that right?

**THE WITNESS:** That's the first time I've heard that.

**ADM. GEHMAN:** That's what the press tells me. On the Delta 4 rocket, the expendable launch vehicle, it also uses foam for insulation, does it not?

**THE WITNESS:** That is correct, sir.

**ADM. GEHMAN:** Could you describe what your role in that is and is that an external foam applied blanket similar to the External Tank?

**THE WITNESS:** Basically, yes, they are applied on the exterior surface of the POFI tank. The way we have done it is basically we have the tank seated horizontally and rotate with the help of a roller and the robot arm which applies the foam that goes along the length of the tank. The foam that we put on there is a urethane modified isocyanate foam. I occasionally use it as calling it a spray-on foam insulation. In short it stands for SOFI.

**ADM. GEHMAN:** Now, in addition to that, are there any fixtures, appurtenances that have to be covered or insulated by hand?

**THE WITNESS:** We are working actually, looking at how we can improve the current process we have on the Delta 4 common booster core where occasionally we do perform plug holes on the spray-on foam insulation to basically verify the integrity of the bond of the foam to the substrate. We also perform densities on those foams. Those are the steps that we perform to validate how good the foam is, how well it's made. In addition to that, we at Boeing have performed 100 percent laser shearography inspections. We check for debond on the entire surface of the common booster core.

**ADM. GEHMAN:** Thank you very much for that introduction.

**DR. WIDNALL:** I actually did the mission assurance on the Delta 4. I think one question that the Admiral asked you which might not have come through, I think he was asking you whether you have foam covering of some of the protuberances where the solid rockets join the main tank. Are those also covered with foam?

**THE WITNESS:** Yes, they are.

**DR. WIDNALL:** So there's a kind of special process?

**THE WITNESS:** Well, that particular common feed line that hooks up --

**DR. WIDNALL:** Well, feed lines and structure lines.

**THE WITNESS:** Those are usually, they are done by pour in place where you basically clamp the mold onto the exterior surface of the feed lines and inject foam in.

**ADM. GEHMAN:** Thank you.

**DR. WIDNALL:** And this laser inspection, is that basically like a non-destructive testing technique that would allow you to sense the bond between the foam and the metal surface underneath?

**THE WITNESS:** That is correct. It's a non-destructive testing.

**DR. WIDNALL:** Do you also use ultrasound?

**THE WITNESS:** Not to my knowledge.

**DR. HALLOCK:** I'm interested in hearing more about the concept of acceptance criteria. What kinds of things do you have to look at when you're dealing with foams like this in the sense of how well it's been put on, i.e., the density of the material that's there or any kind of testing that's done before you say, yes, I am done and that's done the way it's supposed to be done?

**THE WITNESS:** May I get clarification? When you say acceptance tests, are you referring to the raw material when we receive it or after we apply it on the External Tank?

**DR. HALLOCK:** After you apply it.

**THE WITNESS:** In a case like this, what we do is we have a real-time recording of the temperature of the tank, the temperature of the spray booth, the temperature of the component in the hose, and the pressure of the hose while it's being applied onto the CVC tanks. After we applied it, basically we would perform a plug hole test, basically about seven plug holes, one on the leading area where it was sprayed, another one in the middle, and a last one is beneath the robotic arm where the spray gun leads out. We would perform those plug holes on those areas. We also perform two plug holes on the dome of each side. From those we would determine how well the foam performs. That's part of the acceptance tests.

**DR. HALLOCK:** How about when you put this foam on a rocket like this? Is there an issue about aging? Is there a problem about how long it's still viable after you put it onto the craft?

**THE WITNESS:** Well, for Delta 4 it's rather a new program, so I don't have the answer about how long the

foam would last.

**GEN. BARRY:** I would like to ask a question about ablative material. Is there any ablative material underneath the foam in the Delta 4?

**THE WITNESS:** The answer is no, sir. We apply the foam directly on the substrate. There is no ablative material underneath the foam.

**GEN. BARRY:** In your experience, can you give us any commentary on any value-added ablative material underneath the foam?

**THE WITNESS:** Unfortunately, no, I don't think I would have the opinion as far as --

**GEN. BARRY:** Are you familiar with cryopumping and some of the analysis that has been going on there?

**THE WITNESS:** The cryopumping? During our first flight we didn't have any experience with cryopumping on the entire facility surface of the CVC. However, we did some cryopumping on the BOFI, which stands for Bond On Foam Insulation.

**GEN. BARRY:** Are we talking about the Delta, or are we talking about the External Tank?

**THE WITNESS:** That's Delta. I only basically focus on Delta 4.

**GEN. BARRY:** But your position right now is you said you were on the working group for External Tank along with representatives from Lockheed Martin and Michoud, right? Okay. Are you involved with any of the analysis of the working group efforts as part of the mission response team?

**THE WITNESS:** No, sir. This ET working group was formed back in 1991 and basically ended in 94. That provided basically an avenue for us to discuss new developments and issues and problems that we run into with foam insulation. My main focus at the time was mainly on pour in place foam insulation.

**MR. TETRAULT:** Could you tell me whether the Delta program has experienced any loss of foam at launch and, if it hasn't, are you aware of any other programs that use foam which might have experienced that loss of foam?

**THE WITNESS:** No, I have not. I have not heard as far as what I got regarding foam loss from launch.

**MR. TETRAULT:** You haven't lost any on the Delta 4?

**THE WITNESS:** That I'm not sure. I wasn't aware there was any loss of foam.

**ADM. GEHMAN:** To follow up on that question, the insulating foam that you use, I mean the insulating foam, the design of it and the application of it, it is designed not

to come off. You're not assuming that you're going to lose it.

**THE WITNESS:** That is correct, sir.

**ADM. GEHMAN:** The expectation is that foam should not shed off.

**THE WITNESS:** It does in some way I've seen from some of the hot gas tests at Huntington where foam does so-called blade off on the testing.

**ADM. GEHMAN:** the Delta 4 uses the same fuels as the External Tank?

**THE WITNESS:** Yes, sir.

**ADM. GEHMAN:** About the same temperatures?

**THE WITNESS:** I would say so because the Delta 4 rockets have liquid hydrogen and liquid oxygen. Liquid oxygen in this case is an oxidizer.

**ADM. GEHMAN:** Do you get them from the same vendor, do you know? Does the foam come from the same source?

**THE WITNESS:** Yes, sir. Correct.

**GEN. DEAL:** I'd like to get a little bit back to the laser shearography and a little bit of perhaps nondestructive inspection 101 for the Board and the audience. Can you explain the value and the purpose of laser shearography on the Delta and also why it may or may not or should or should not be applied to External Tank, as well?

**THE WITNESS:** Well, to answer your second part, I would defer that question to NASA and a Lockheed representative. As far as for our Delta 4, we find it real helpful in terms of performing that NDE method, nondestructive testing, because I was informed it takes about 10 seconds to perform a section of about a 2-foot by 2-foot area. So they can move along the tank quite readily.

**ADM. GEHMAN:** Would you mind moving your microphone a little closer. Thank you.

Did I understand you to say that for the Delta 4 you do this laser shearography for 100 percent of the tank?

**THE WITNESS:** That's correct, sir.

**DR. WIDNALL:** When you do that, what sort of voids, if any, do you find? What do you find out when you do that?

**THE WITNESS:** Well, the voids that have been found were mostly coming from the BOFI foam, which is the bond-on foam insulation, not the spray-on foam insulation.

**DR. WIDNALL:** And these are attachment points that we talked about? The attachment points, places are -- I mean, the pour-on foam is for the attachment points for the solid

rockets?

**ADM. GEHMAN:** Or pipes and lines.

**THE WITNESS:** Okay. The pour in place?

**DR. WIDNALL:** Yes.

**THE WITNESS:** Okay. Can you repeat the question? Sorry.

**DR. WIDNALL:** Well, we don't want to get confused here. Why don't you tell me a little bit about the voids that you found.

**THE WITNESS:** Okay. The voids that we found are on the bond-on foam insulation. The way it's been done is they apply adhesive onto the panel of foam and they basically bond it in place to the metal substrate and they apply pressure to basically cinch the foam together and let it cure over a recommended time.

**ADM. GEHMAN:** So what you're saying is that what the laser shearography shows then is a problem in the foam or the bond?

**THE WITNESS:** The bond, sir.

**ADM. GEHMAN:** The bond. Thank you very much.

**GEN. DEAL:** As a former member of the External Tank working group, can you describe what your relationship was and what you dealt with as a member of that group?

**THE WITNESS:** I thought it was very well. We basically built up a core of folks from different what I would call sites. Basically it was very much an open book in terms of discussion or issues and problems because our main goal was to try to expedite issues and problems that may come up at Kennedy Space Center. You know, I thought it was really a good working relationship; and it was chaired at that time by Mr. Chris Raymond.

**GEN. DEAL:** What was your focus as a member of the ET working group?

**THE WITNESS:** My focus was mainly on at that time looking at qualifying an EPA compliant blowing agent for the foam. It was at that time a switch from the CFC11 to HCFC-141B.

**GEN. BARRY:** Just as a follow-up to that, are there any lessons learned from what you did on the External Tank that were applied to the Delta 4?

**THE WITNESS:** I would say no because, again, at that time I was mainly focused on the Shuttle Orbiter main propulsion system and the power reactive supply distribution hardware and those hardware are mainly using pour-in-place foam.

**DR. HALLOCK:** Can you talk a little bit about what

happens when you've fueled the rocket -- that is, you put the liquid oxygen and liquid hydrogen? When that happens, I understand that the shell itself is going to contract because of the temperature change. What does that do to that bond or the foam itself? Is there a problem with things like moisture being absorbed at that time?

**THE WITNESS:** I can share with you a little experience I had during the certification of these pre-molded foam segments that we were looking at certifying to replace the old method -- I call it old method that's being replaced, of injecting foam into the mold. During that time in the tests, Kennedy Space Center team members were building these foam blocks that we brought over to Stennis, Mississippi, to perform this certification. We basically installed these foam sections together and held together with aluminum tape. Basically we watched. I was fortunate to watch a Shuttle rocket being fired; and after it's fired, we all as a team went up almost immediately to witness the foam sections. Yes, it does shrink quite a bit; and it was through several iterations that we finally got a foam segment that didn't crack all the way through.

**ADM. GEHMAN:** Mr. Chong, you'll have to forgive this very, very layman's question about insulating these fuel tanks which are, of course, extraordinarily cold. I believe one is maintained at something like minus 250 degrees and the other one is at minus 400 or something like that. So obviously they have to be insulated. Would you tell me, please, why you put the foam on the outside of the aerodynamic surface instead of inside and keep the outside of the aerodynamic surface smooth?

**THE WITNESS:** Actually when I first was brought in from Rockwell to Boeing, there was a team at that time with McDonald Douglas that were looking at insulating the interior surface of the tank. Learning as far as I go, I realized in talking with the folks who were from the inspection group that it would be a nightmare trying to inspect foam inside the tank and also the fact that the foam, wanting to shrink, might pull away from the substrate, the metal substrate.

**ADM. GEHMAN:** Thank you for that. It's not clear to me that it pulls away any more or less by putting it on the outside of the tank than the inside -- I don't mean on the inside of the tank but I mean on the inside of the vehicle. Why don't you insulate the tank instead of insulating the rocket? Why don't you insulate the vessel rather than insulating the outside of the aerodynamic vehicle, because the aerodynamic vehicle is going to be stressed by launch and aerodynamic forces and all that kind of stuff? I'm just having a hard time figuring that out. I'm sure there's a good reason for it.

**THE WITNESS:** Maybe I need to understand your question. Are you referring to putting foam between a sandwich core?

**ADM. GEHMAN:** Right, having a tank inside and then having an aerodynamically clean exterior skin. In the case of Delta 4, it's probably not such a big deal because if some

of the foam comes off, there's nothing around it to do any damage; but in the case of the External Tank, if the foam comes off, there are a lot of things, a lot of moving parts and operating things that the foam could hit, not just the Orbiter wings. Orbiter control surfaces, Main Engines and Solid Rocket Booster motors. So I'm just wondering from an engineering point of view why would you imagine that they didn't insulate the fuel tanks and leave the outside aerodynamically smooth. There probably would be a good reason for it. I just didn't know if you knew what it was. I wouldn't want you to speculate.

I would like to go back to the question that General Deal asked about the External Tank working group that you were on, 1991 to 1994. Your role, as I understand it, was primarily to work on a group to make recommendations having to do with the changing of whatever that agent is --

**THE WITNESS:** The blowing agent.

**ADM. GEHMAN:** The blowing agent, right, because of environmental reasons essentially. The old one was what?

**THE WITNESS:** CFC11.

**ADM. GEHMAN:** Freon. Freon, which, of course, is environmentally hazardous. So you had to find another blowing agent. Was the consensus of your group that you went to the next best agent that you possibly could have, or do you think that you found a better agent?

**THE WITNESS:** I think at that time that was the best agent that's available in the industry for us to evaluate and use.

**ADM. GEHMAN:** But was it next best to freon or was it better than freon?

**THE WITNESS:** Okay. I heard that freon was better.

**ADM. GEHMAN:** This was the best that was available, not including freon?

**THE WITNESS:** Correct.

**ADM. GEHMAN:** Are you aware, of course, of what happened from the first time they used it on the ET, External Tank?

**THE WITNESS:** I was aware there was foam popping off, popcorning from the intertank.

**ADM. GEHMAN:** So NASA learned how to deal with that. Thank you very much.

**GEN. BARRY:** Could you give us a little bit of insight on the contractor oversight that we have with the Delta 4 program and, if you can, relate it to the way NASA operates? Do you have any insight on both sides? Or you can just share with us on how Delta 4 is doing. Government oversight of the program.

**THE WITNESS:** You know, I'm not sure I can answer that because I know -- I'm not being involved in that.

**GEN. BARRY:** Well, let me ask another question. Let's go back to the freon for a minute. What is the replacement spray? Is it GX6000? Does that ring a bell?

**THE WITNESS:** Can you repeat the question again?

**GEN. BARRY:** What is the replacement for freon? What did you call it, the spray-on foam? What was the type of spray-on that was?

**ADM. GEHMAN:** What is the name of it?

**THE WITNESS:** That's for the External Tank?

**GEN. BARRY:** Right.

**THE WITNESS:** As far as I know, it's North Carolina Foam Insulation 24-124.

**MR. TETRAULT:** I have one question. The working group that you were on, was that specifically look at replacing freon; or was it much more broad-based in terms of looking at all the problems there might be with regard to the External Tank?

**THE WITNESS:** It's more than just focusing on replacement of blowing agent. As an example I can cite to you is that I got requests from the folks from Kennedy Space Center as far as looking at another technique of applying the pour-in-place foam. Their recommendation was maybe put the foam, two-component foam into the melting bottle and shake it and then transfer it into the cavity they need to fill, instead of the previous method which was the foam was packaged in the chem kits that they mix. Their complaint, the challenge that they have was that you've got to be quick with those chem kit mixing because if you're not, the foam will basically literally squirt on you. So that was an improvement to the existing method, and from there we evaluated and basically certified it.

**MR. TETRAULT:** One final question. Was the periodic loss of foam which had been occurring considered by the working group to be a problem?

**THE WITNESS:** To be honest with you, that was not discussed.

**DR. WIDNALL:** I guess my question is somewhat similar. Your group ended in 1994. Are you aware of any other activities that have been going on in the External Tank to really improve the foam? I guess it's the second question that Roger asked. Was there any concern that one should continue to work this problem until one developed a foam and bonding system that had better adhesion properties?

**THE WITNESS:** Can you repeat the question? I'm sorry.

**DR. WIDNALL:** Well, I'm asking. The work that you

described stopped in 1994 with this development. Are you aware of any concern that such work should continue to develop foams that don't fall off during launch and, if you are aware of such activities, what was sort of the level of intensity of such activities?

**THE WITNESS:** Unfortunately I was not aware, as far as how much work. I do know that they're working on the issue, but I don't get intimately involved in the spray-on foam insulation on the ET Orbiter.

**ADM. GEHMAN:** Can I follow up on Dr. Widnall's question? In your present position, did you research various options for fuel tank insulation of the Delta 4 rocket? What I mean is you probably looked at other options besides using the same foam that's used on the Shuttle ET.

**THE WITNESS:** Okay. There is another candidate of spray-on foam that was looked at, and it was made by a Japanese company, in Japan. From what I know is that it was dropped as a candidate, to the North Carolina foam that we currently use, because of the costs.

**ADM. GEHMAN:** Let me ask you a couple more questions. In your experience even with the Delta 4 rocket, can the foam absorb water? Can it absorb moisture?

**THE WITNESS:** The answer is, I would say, no, mainly because the foam in itself, it has 90 percent minimum closed cell content. However, that 10 percent included is because there are times when you do trim or sand the rind off, which exposes the closed cell of the foam.

**ADM. GEHMAN:** You probably are aware that the STS system, the whole system of rockets and External Tanks is rolled out to the launch pad almost always 30 days prior to launch, sometimes five weeks prior to launch. Would it be your experience that the foam, including foam which had been locally repaired and cover plates which had been put back on locally and things like that, would you expect that there would be some moisture content in that foam?

**THE WITNESS:** If there is, it will be mainly on the surface of the cell that's been exposed.

**ADM. GEHMAN:** Then, of course, if that moisture was subjected to minus 400 degrees, it would turn to ice?

**THE WITNESS:** Yes.

**GEN. DEAL:** I asked you a while ago about if there's any lessons learned from the External Tank that you applied to the Delta 4. I'd like to ask you the converse of that now. Are there any things, inspections or processes that you have on the Delta 4 that we should consider applying to the External Tank?

**THE WITNESS:** Yes. One recommendation I have would be looking at shearography. Obviously that works for us.

**GEN. DEAL:** Anything else?

**THE WITNESS:** No.

**ADM. GEHMAN:** If you all are complete...

Thank you very much. You have been very helpful. I apologize if we have asked questions that are so low and mundane, but we appreciate your patience.

**THE WITNESS:** You're welcome.

**ADM. GEHMAN:** We are now expecting to see Mr. Harry McDonald take the table there.

Good afternoon, Dr. McDonald. Welcome. We appreciate very much your traveling here from a great distance in some not very pleasant weather to help us with this problem. I'll ask you to tell us briefly about yourself and your experiences and your last job that you had; but first I would ask, if it would be all right with you, I would ask that you just agree to this affirmation which I will read to you that you will tell us the truth, which I don't think will be much of a problem. If that's all right with you, I would like you to affirm to the Board that the information you will provide to the Board in this hearing will be accurate and complete to the best of your knowledge and belief.

**THE WITNESS:** I will.

HARRY McDONALD, having been first duly affirmed, testified as follows:

**ADM. GEHMAN:** Thank you very much. Dr. McDonald, if you would, please tell us a little about yourself before we start the questions.

**THE WITNESS:** I am a professor at the University of Tennessee, Chattanooga, and I hold the chair of excellence in computational engineering. Prior to that, I was the Center Director at the NASA Ames Research Center in Moffett Field, California. Prior to that, I was a professor at Penn State in the computational field also. Obviously I'm from Scotland originally, and I came to this country and never regretted it.

**ADM. GEHMAN:** Thank you very much. Maybe we could ask you to move your microphone a little bit closer. Thank you very much.

As the director of the Ames Research Center, you were the author or the chairman of a recent study of the Shuttle Program. Could you tell us the nature of that study, when it was, and why and how it got started?

**THE WITNESS:** Certainly. I've actually written a statement.

**ADM. GEHMAN:** Thank you. Go right ahead.

**THE WITNESS:** It covers that. If I may, I'll read it.

**ADM. GEHMAN:** Please go right ahead.

**THE WITNESS:** On July 25th of 1999, during the flight of the Space Shuttle *Columbia*, commanded by Eileen Collins, two separate malfunctions occurred which set in motion a significant series of events. At takeoff, a pin broke loose and ruptured cooling tubes in the Space Shuttle Main Engine, causing a slight reduction in the eventual attitude which the Shuttle achieved.

Separately, during that same launch, two of the Shuttle's engine controllers unexpectedly shut down. By design, backups seamlessly activated and assumed the lost controller functions and the vehicle made it safely into orbit and completed its mission and returned home.

Following that, a pattern of minor failure clearly had emerged that suggested to the NASA engineers a nascent wiring problem existed across the entire Shuttle fleet. After being informed of the engineers' concerns, NASA officials immediately ordered wiring inspections of all four Shuttles, grounded the vehicle; and while repairs were effected, NASA administrators also ordered a complete review of the Space Station Program with regards to safety and empowered an independent panel of experts to that end.

The group, which I chaired, was known as the Shuttle Independent Assessment Team or SAIT. Our mandate from NASA was to evaluate procedures, maintenance procedures in particular and processes, and to make recommendations for improvements, without regard to cost.

The administrator at that time, Dan Golden, took me aside and urged me to leave no stone unturned. Our work stretched from October of '99 to March of 2000. Among our more than 90 findings, SAIT determined that processes, procedures, and training which had evolved over the years and that had, in fact, made the Shuttle safer had, in fact, been eroded. The major reason for this erosion was the reduction in resources and appropriate staffing.

I believe the report is quite detailed on these issues and stands on its own merits. NASA agreed with our observations on the staffing issues and immediately moved to stop further Shuttle staffing reductions from the civil service side. They added safety inspections and sought additional resources for the program. Wiring inspections and repairs were extensively performed on all of the vehicles and monitored. Indeed, before we had submitted our formal report, NASA had added 100 new inspectors to the work force at Kennedy; and on the same day as we released our report, Joseph Rothenberg, the Associate Administrator for human space flight, at that time announced that 800 additional civil servants would be brought in to Kennedy Space Center. So clearly the agency took our report very, very seriously.

Following an extensive internal review of our findings of over 120 recommendations that we made, some were acted on without delay, as I have indicated. Some it was felt, would not be effective. They were submitted to the Space Station Program for their review, and their review came back that they felt some would not be effective and/or required significant resources or longer periods of time

before they could be implemented. Some were implemented. Some were deferred.

I was personally disappointed that more of our recommendations were not or could not be implemented. Documentation of the disposition by the agency of our recommendations exists and was made available to me for this meeting and I believe will be posted on the web for people who are interested in it.

In the SAIT report it was recommended that the implementation process be examined, the implementation of our recommendations be examined by another independent review team later. It was also recognized by SAIT that our particular team did not have the technical expertise to perform an in-depth review of other components of the space transportation system -- for example, the External Tank, the Space Shuttle Main Engine, and the solid rocket motor.

In the light of what was learned on the Orbiter, however, our team felt that a number of the issues were systemic in nature and such that an investigation of the other system components was, indeed, called for. Accordingly, it was one of our recommendations that an independent panel of appropriately qualified experts be formed to perform reviews of the Space Shuttle engines, Solid Rocket Motor and the External Tank.

The members of the SAIT were also asked for their views on the safety of the vehicle, the Orbiter, one of three, for a return-to-flight status. Much discussion took place by the team and it was concluded after extensive consideration that the SAIT response should be carefully restricted to a statement that in light of the extensive inspections of the vehicle which had been undertaken, and upon completion of some additional wiring inspections that we had recommended, it was likely that the vehicle would possess less risk than other Orbiters which had recently flown. SAIT did not express a view on the absolute level of flight safety or flight risk but expressed a view of the flight risk relative to other Orbiters that had been flown.

I'd like to conclude this particular part by recalling two statements from our report -- one being, "The Shuttle Program is one of the most complex engineering activities undertaken anywhere in the world at the present time," and the other being, "SAIT was continually impressed with the skill, dedication, commitment, and concern for astronaut safety by the entire Shuttle work force." I see no reason to qualify either of these remarks today.

Thank you, sir.

**ADM. GEHMAN:** Thank you very much.

**GEN. HESS:** Doctor, in reading through the report, one of the points that you make in here is that there seems to be a tendency for accepting risk, based on past success. I wonder if you would give us a few comments on how you came to that conclusion and what you think might be affecting that particular mentality inside of an organization

as complex as NASA.

**THE WITNESS:** Well, indeed, we did come to that conclusion after extensive review and discussion with the people involved. I think there was a basic flaw in the reasoning of many well-intentioned people; and that is the concept that if you have a 1-in-100 chance of risk or of an event occurring, the event can occur in the first or the last and it's equal probability when the event would occur. There seemed to be the perception within agency that if I have flown 20 times, the risk is less than if I have just flown once. And we were continually attempting to inform them unless they've changed the risk positively, you still have the same issue even after 50 flights or 60 flights.

Now, how do you address that issue? One of our big concerns is that clearly everybody in the agency has this desire and sense of the importance, critical importance of safety. There's no issue about that. The question is how do you translate that into a safe and effective program. That is very, very difficult, given the complexity of the issue.

One of the several of our suggestions really aimed at what I might call communication that we understand the level of risk that people are adopting. For instance, in tracking the pin ejection event, we discovered that the PRACA, Problem Reporting And Corrective Action data base did not have an appropriate recording of the ejection of the pin. Indeed, the real probability of a pin ejection was 1 in 10; and I don't think anybody realized that that was the probability of an event.

Now, the second part of that was that the Shuttle Main Engine was, in fact, designed to have cooling tubes fractured; and I believe the number is it can stand four tubes in the Eileen Collins flight. Only two were ruptured. So effectively it didn't reach a high visibility. But the real reason for pinning the oxygen ejectors is that a broken injector, which is what you were repairing, you pin it to stop the flow going through it. The real reason for pinning it is if the ejector tube is broken, there's a risk of fire in the power head of the Main Engine, which is a whole different ball game. So on the one hand you have an assumption of risk by well-meaning, well-intentioned people that is not appropriate in this system context.

So part of our thrust was to try and improve communications, improve the data bases so that you could have an immediate reaction to what is the probability of a pin failure and what is the effect, the true effect of a pin failure. So working on that type of resolution of the issue to try and translate these very well-meaning, well-intentioned safety-is-first into a safe and effective plan is what we were trying to bring attention to the fact that many of our process were, in fact, deficient, had been eroded. A long answer, I'm sorry, but it's a key question, I believe.

**GEN. DEAL:** Sir, as you have stated, you were disappointed that all the SAIT recommendations were not implemented. It's clear that you have confidence in those recommendations. Could you give us a flavor for maybe the top two or three recommendations that were not

adopted that you may still harbor concerns over?

**THE WITNESS:** If I may, I picked up the wrong file here. If I may, just so that I can be precise. It's in my briefcase.

**ADM. GEHMAN:** Help yourself. Being precise is a good idea.

**THE WITNESS:** I was fortunate to get this file from NASA Ames yesterday. Having left the agency, I had to file a FOIA request for my own memos, which is fine. You probably have all read the report or been exposed to it. It was given, as I mentioned, to the Shuttle Program for their review. They presented a very detailed critique of every single recommendation. Some they accepted; some they did not. We responded to all of their critiques, and I wanted to give you the sense of that before I went into some specifics.

This is our response to their critique. (Reading) The process described by the Space Shuttle Program to address the SAIT recommendations is one that SAIT viewed very favorably, i.e., that existing processes would be reviewed in detail to further examine the weaknesses suggested by the evidence obtained, observed by the SAIT. In several areas the SSP, Space Station Program, appears to have successfully fulfilled this approach. For instance -- then we give a series of cases where we believe they successfully implemented what it was we were trying to recommend.

Then we go on: In a number of cases, however, the SSP appeared not to have followed this process to the required degree. Existing procedures are occasionally quoted as a response, without seeming to provide an assessment of their adequacy or to address the SAIT's concern. Examples of these include responses to recommendations. Then we give a series of issues that we felt were not addressed.

In other responses, evidence provided by the SAIT is ignored. For instance, Issue 5 was written to address the actual breakdown in the process of performing green runs of repaired SSMEs. However, green run testing of the SSME and its failure was not discussed in the SSP response. Another example -- and so on and so on.

Category two, No. 13, in which the incident of spilled hyperbolic fluid caused by inadequate operator experience, as reported to the SIAT, was not addressed -- that was on *Columbia*, incidentally, in 1999. Other responses are based on assertions that dispute evidence observed by the SIAT, for example -- and we give a list.

In several case of disputed evidence, the SIAT interpretation of the evidence is corroborated by findings of the USA Orbiter Subsystem and Maintenance Process Review. And it goes on to give examples.

And lastly, finally some responses from the SSP do not provide enough information to assess their adequacy relative to the findings and recommendations.

Now, we can go into specific examples; but I was trying to

give you the flavor of our response. We concluded that particular exchange of memos by the general observation. The overall feeling left with the reader following a review of the SSP response is that the program views its highest risk as that being associated with human error. This leaves the program to address many problems with increased awareness, process management, and while these are clearly worthwhile activities, the SIAT felt that a higher priority should be given to creating solutions where the opportunity for making mistakes was reduced. This led the SIAT team to emphasize in-depth incident analysis, in particular human factors analysis of near-misses and diving catches and other incidents which could have had much more severe consequences than what actually occurred. Based on this analysis, actions could have and should have been taken to remove or reduce the probability of a repetition.

So that was our feeling on how the agency addressed the -- how the SSP addressed our concerns. I think there was one -- the closeout memo from myself to the Associate Administrator of Spaceflight closes with this observation. "Therefore I must reiterate the SIAT's recommendation to set up a follow-on independent review committee with a charter to provide additional continued inquiry into Shuttle processing and maintenance. This review committee should as a first action bring a detailed approach, implementation and results of SSP's response to the SIAT recommendations."

In other words, we had felt we had reached essentially an impasse, that we had said one thing, the program had said another and let's let some time pass, let's bring in another independent review team and make an assessment of what had been done and what had not been done, what was right and what was probably erroneous. I'm sure there were certain of our recommendations that were based on our poor understanding of their process. I'm sure that's the case, but not all of it was based on that.

**ADM. GEHMAN:** Thank you.

**DR. HALLOCK:** In your introduction, you used a phrase that there were a number of recommendations that could not be implemented. Could you expound upon that, please?

**THE WITNESS:** Well, I think the particular events I had in mind were events that were rather longer term in nature. I think I referred to them earlier, to straighten out the data bases that exists on problems and issues that occur, in order to make them accessible to certain Google-type searches so you could pull up all the instances and not only just on the particular local data base but throughout the entire data base that had been collected over the years on the engine or the rest of it. That's a long-term project requiring a considerable development, a considerable application of resources, of people, et cetera. And that was, in our view, quite appropriately put into the Shuttle upgrades program, which the Administrator at that time, Mr. Golden, had gone over and gotten \$1.7 billion for a Shuttle upgrade program. I believe that was the figure in the budget. We expected and hoped that programs, the longer-term programs that we had

advocated would be funded; and it was indicated that they would be funded as part of that practice. However, that program, as we all know, was significantly reduced and a number of these activities were either curtailed or not performed. Again, it gets down to risk perception and what the value of these issues were perceived to be to the program.

**GEN. BARRY:** Dr. McDonald, let me compliment you on your report. I think most of the Board has commented, I heard at least more than once, that it is one of the more thorough documents that certainly has helped us get a focus on some specific areas. With that in mind, I was intrigued with one of the comments that's reported here on problem reporting and tracking process.

Now, you know the E-mail discussions that have been going on in the paper; and, of course, we're in the process of reviewing that too and have done quite a bit of work there. One of the statements that you had is it does not provide high confidence that all potentially significant problems or trends are captured, processed, and visible to decision makers. Based on what you have read and also based on your report, can you comment on the NASA culture that might be indicated by what you capture in your report? I know you're going to want to comment on this, but it might help us with some insights.

**THE WITNESS:** Well, the PRACA data base was clearly built in an earlier era before modern information technologies became available, before browsers, before data base management tools. It was essentially a tracking procedure to ensure that a given problem would be properly signed off on, so just a data compilation that ensured that an operator could find out that a particular incident had been -- a repair had been performed.

**ADM. GEHMAN:** Dr. McDonald, you're referring to -- we use an abbreviation here, P-R-A-C-A, PRACA?

**THE WITNESS:** Yes. Problem Resolution, And Corrective Action data base. And there are several data bases. An in-flight anomaly data base date. And there's a problem resolution data base. You know, there are multiple data bases. We wanted to consolidate and make them accessible to modern search techniques so you that could pull off information like that.

I think it's not an issue that presented -- I have no concern at all that people like Ron Dittmore, presented with the facts, will make the right decision. No concern at all on that issue. The concern is presenting him with the facts, and many of them are very deep, frequency of certain events occurring -- for example, the pin ejection that we observed and, in your case, Flight 87, STS-87. What was the resolution of the foam issue on STS-87? What was the flight clearance process for STS-88? When the problem recurred on 88, how was it resolved for 90 and then 91? I mean, when someone like Dittmore goes and tries to make an assessment of what the risk is for the FRR, flight readiness review, the instant access to all of that past history would have become valuable, incredibly valuable, I

think; but we had not given it, in my view, sufficiently high priority.

**ADM. GEHMAN:** Thank you, sir. Let me ask a question, too. I've read your report and I agree with the other Board members that it's eerily prescient. The question that I want to get to is: Are you satisfied that in your report -- or did you cover this in your report -- are you satisfied that the NASA systems are sufficiently broad and stand-back far enough, that they could detect very subtle changes in risk factors just because, for example, the system is getting old or, for example, the original assumption back in 1975 and '76 when the RFP went out was that each Shuttle would fly 100 missions, that everything has to be built to last 100 missions? That's 30 years ago. That was a 30-year-ago assumption. It could be that there are trends out there that would suggest to us that that assumption is not going to be a reality.

Did you find, based on your report, that these macro trends, even though each indicator is just a tiny little pin dropping out, just like in your case where you lost a little pin and someone goes and fixes it and now it's fixed -- but, of course, it isn't fixed -- it's part of a bigger trend. To what degree are you content that these kinds of trends can be detected by the fault resolution and tracking system that we have?

**THE WITNESS:** I think it's best done by saying what the action was. There was considerable concern over precisely this point following our report; and with the complete support of the Associate Administrators, the administrator, Mr. Golden, we instituted two new programs designed for safety. One of its components -- and this is a research program, a clearly significant research program. It subsequently matured into something we all Engineering for Complex Systems. It was to try and provide the latest in terms of risk assessment techniques to the Shuttle Program office to help them, because it's a very difficult task that they faced, as well as some more advanced techniques that were focused on this issue of detecting very subtle trends and how important they might be. So a major program, research program was initiated by the agency to address precisely those issues. And other existing techniques like quality safety assessment techniques, QSRA, and other techniques that should have been routine were examined for their appropriateness in terms of the program. So it did galvanize the agency into a very significant effort in that regard. But insofar as implementing these procedures, well, no.

**GEN. HESS:** Doctor, one of the main things that has run through all of our examinations of the agency as part of this unfortunate disaster is the overall impact of reduction in the work force to maintain costs and schedule and the pressures that brings and actually the unintended consequence of sending perhaps a message to the work force that there is an imbalance between actually being safe and performing. Your report talks to that issue in several areas; but one that's particularly interesting to me is the part where you suggest that adopting industry standards for use in a program for the Shuttle, which is not really an operational

vehicle, is sending a mixed message to the work force. I was wondering if this was kind of backed up by your interviews or what was the basis of that particular part.

**THE WITNESS:** I think all of this was based on interviews with the work force and interpretation of what they were saying. I would point out that, yes, they had heard and believed at one level that safety was critical, extremely important. Many of these people were really, really responsible technicians and engineers and, in fact, several of our team members which came from the Air Force and the Navy, commented on where do you get these people from, the quality of the individuals. So they were clearly deeply concerned both with the turmoil in the agency, the cuts that had been made, what was their particular future, and if they had to go work for the contractor, then it would be a different basis of employment, what did that all mean.

There most certainly was this mixed message of safety is very, very important, it's No. 1, and yet we were cutting back mandatory inspection points, government mandatory inspection points. Clearly some of that was very appropriate to cut back in a number of inspections. As Mr. Dittmore said this morning, on the basis of experience we've learned that some inspections were not required; but from their perspective I don't think we did a very good job of convincing them that these inspections had been reduced because they were unnecessary.

So they did get this mixed message, and it was of deep concern to us. While it came across in the one-on-one interviews, it was very difficult to get them to say this to management and to other people. It was only the confidence that they began to get in our particular Board and its independence -- and clearly we were independent. I think the report shows clearly that we were under no constraints as to what was said, and the agency is to be complimented for the freedom which they gave us. So the concerns were there, the mixed messages were there, and we had done a very good job of convincing them of the real issues.

**DR. WIDNALL:** Okay. I, too, have a two-part question. In your report, you have some return-to-flight recommendations. I'm doing a quick read here, but my sense is that you were recommending that this issue of waivers and exceptions be re-examined and the processes that lead to accepting hardware and design that perhaps didn't meet original spec. Do you have any comments on that? Were those recommendations accepted, or do you still have concerns in those areas?

**THE WITNESS:** Well, I think they were accepted in part and our concerns reside in the qualitative nature of some of the assessments. In family, out of family -- we couldn't really get a really good definition. It varied from person to person. So there was no consistent definition. Fair wear and tear was a subjective judgment. So there were issues like that that permeated it. While it was clear that it was received, the implementation of a more rigorous process was difficult.

Again, we come back to this information flow. The flight readiness review would be looking at perhaps 200 waivers, some of them minor. It really bothered us that clearly they would not understand or would not be able to go into the history of each one of those waivers. They were relying on someone assessing whether or not a waiver was justified. And we had this concern exhibited with the pin, that a relatively incorrect or poor understanding of the risk might lead to something being granted a waiver that was inappropriate and the ability to interrogate each of the waivers in terms of history, complete engineering backup, all of these factors was something that we would have like to have seen implemented. So that went beyond what the program office could do at this point in time. So, you know, that was another problem.

**DR. WIDNALL:** I guess the second part of my question really has to do with risk. I sort of see two risk curves in this process. One is a descending curve, and the other is a rising curve. The descending curve kind of goes along with the R&D nature of the Shuttle in some sense. It is like a research project. Every time you have a successful flight, there is a sense that your region of uncertainty is being narrowed and maybe you are free to take “risks” that you wouldn’t have taken on the earlier flight. So that’s sort of a descending curve. On the other hand, you have the ascending curve, which is the aging of the vehicle. So I’m really struck by the assumption that one can expand the family, whatever that means, on the basis of previous successes. I might ask you to comment on that.

**THE WITNESS:** It was just simply that the safe way is to adopt the philosophy that you haven’t really done a whole lot to retire the risk. I mean, you’re still flying the same vehicle. You haven’t changed -- well, that is not quite correct. There were, of course, changes to the vehicle. The vehicle was becoming safer; but fundamentally unless you identify the risk that you are retiring, you have to stick with your original 1 in 100 or whatever it was. So the risk identification and the elimination is a critical point in allowing you to increase the safety of the vehicle. You have to understand the risk assumptions.

So I quite agree that, yes, in an experimental vehicle when you’ve flown once, you’ve made a big achievement. When you have flown twice --

**DR. WIDNALL:** Even better.

**THE WITNESS:** But fundamentally you started off with a 1-in-50 or 1-in-100 probability of failure; and you’re still in that ballpark. Yes, a great deal was learned in each flight, I believe, and improvements were made; but there was the unidentified risks or poorly understood risks that continue to remain that brought the overall probability to fairly low levels.

**GEN. BARRY:** Dr. McDonald, one of the issues that you brought up -- and I know you had a rather large, extensive human factors team as part of your effort, which was very insightful-- but it says here that one of the things that you do here on your Issue 6 is that you say the Shuttle Program

should systematically evaluate and eliminate all potential human single-point failures. Would you comment on that, on how much that was followed through on by NASA and maybe some others that you might look into?

**THE WITNESS:** Really, no, I couldn’t address that particular issue. Yes, we were concerned about it. How the agency followed up was operation-specific, item-by-item, operation-by-operation. We could have cited a couple of cases where we saw single-point human factors issues, but I think the concept was to try and implement a more general program of eliminating single-point human failure. That required the program to look rather specifically at the various maintenance operations to determine if there were and what these were and how they should be eliminated. We had several that we could have identified, but we were interested in a much more broader assessment by the office.

**ADM. GEHMAN:** Dr. McDonald, judging from your report and your comments here today, I would gather that -- I’ll make a statement, and let me see if you agree with me or not. Hiring more inspectors is really not the issue here; it’s a process issue, a process problem. It’s more complex. This is a very, very complex system; and when there are system failures, they’re usually complex failures. So just hiring more inspectors is not the issue. Am I correct?

**THE WITNESS:** You are. I think hiring inspectors for the particular problem that we were addressing of wiring, it is the only current -- it was then the only acceptable method of determining the wiring issues. It’s not a very good method. In general, what we’re talking about is much more of a process issue. I would agree with that statement.

**ADM. GEHMAN:** Thank you very much for traveling down here to Houston to talk to us. As you may have been able to tell from this Board, your report, because it’s not only the most recent study but also because we think it’s very, very well done -- and we regret that it seems to be very applicable -- has obviously resonated with this Board. We’ve all read it and gotten good ideas from it. So we thank you for your service, your continued service. I think you should feel good that your report was not put on the shelf someplace and filed away but seems to be a live document that’s still influencing things. So congratulations and thank you very much.

This Board is finished. Thank you very much for today.

*(Hearing concluded at 2:30 p.m.)*