NATIONAL TRANSPORTATION SAFETY BOARD

AIRCRAFT ACCIDENT OF ALASKA AIRLINES FLIGHT 261
BOEING MD-83, N963AS
PACIFIC OCEAN NEAR PORT HUENEME, CALIFORNIA
JANUARY 31, 2000
ACCIDENT: DCA-00-MA-023
PUBLIC HEARING

Board Room and Conference Center
National Transportation Safety Board
429 L'Enfant Plaza, SW
Washington, D.C. 20594

Wednesday, December 13, 2000
11:00 a.m.

Board of Inquiry

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JOHN C. CLARK, Acting Director
Office of Aviation Safety

DR. VERN ELLINGSTAD, Director
Office of Research and Engineering

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Boeing Commercial Airplane Group

CAPTAIN BILL WOLF
Air Line Pilots Association

DAVID G. PATRICK
Aircraft Mechanics Fraternal Association

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Peter Kovacik
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P R O C E E D I N G S

11:03 a.m.

MR. HAMMERSCHMIDT: Seeing that everyone's in place, let me say good morning, ladies and gentlemen, and welcome.

I am John Hammerschmidt, a member of the National Transportation Safety Board, and Chairman of this Board of Inquiry.

Today, we are opening a public hearing concerning the accident that occurred on January 31, 2000, in the Pacific Ocean near Port Hueneme, California, involving Alaska Airlines Flight 261.

The hearing is being held for the purpose of supplementing the facts, conditions and circumstances discovered during the on-scene and continuing investigation.

This process will assist the Safety Board in determining the probable cause of this accident and in making any recommendations to prevent similar accidents in the future.

While airline accidents are rare events, they are widely publicized and scrutinized by experts around the globe. When an accident such as this does occur, it is the responsibility of the National Transportation

Safety Board, with the assistance of the Federal Aviation Administration and other designated parties from government, industry and labor, to find out what happened, why it happened, and how we can prevent this unfortunate event from recurring.

The purpose of this hearing is twofold. First, the issues that will be discussed at this hearing, while technical in nature, serve to assist the Safety Board in developing additional factual information that will be analyzed for the purpose of determining the probable cause of the accident.

Secondly, this hearing also provides the opportunity not only to the aviation community but to the traveling public as well to see a small portion of the total investigative process and the dedicated efforts being put forth by investigators from many different organizations to find the cause of this accident.

There are members of some of the victims' families in the audience today as well as others watching on closed-circuit television on the West Coast. In fact, I had the opportunity to visit with them prior to the opening of this hearing.

I want to assure them that the Safety Board will pursue every lead toward an ultimate solution. The hearing is also available as a live web cast through the Safety Board's web site at www.ntsb.gov.

Public hearings such as this are exercises in accountability. Accountability on the part of the Safety Board that it is conducting a thorough and fair investigation. Accountability on the part of the Federal Aviation Administration that it is adequately regulating the industry.

Accountability on the part of the airline that it is operating safely. Accountability on the part of manufacturers as to the design and performance of their products, and accountability on the part of the workforce, including pilots and mechanics, that they are performing up to the high standards of professionalism expected of them.

As previously stated, these proceedings tend to become highly technical affairs, but they are essential in seeking to reassure the public that everything is being done to ensure the safety of the airline industry.

The purpose of this inquiry is not to determine the rights or liability of private parties, and matters dealing with such rights or liability will be excluded from these proceedings.

Over the course of this hearing, we will continue to collect information that will assist the Safety Board in its examination of safety issues arising from this accident. Specifically, we will concentrate on the following issues, and these are not necessarily in, of course, rank of importance. They just happen to be in this order.

Number 1. Flight control system design, maintenance and inspection.

Number 2. Aircraft component condition, monitoring and maintenance intervals.

Number 3. Alaska Airlines organization, maintenance program and practices.

Number 4. Alaska Airlines Safety Program.

Number 5. In-flight check and lubrication of the horizontal stabilizer jackscrew.

Number 6. FAA surveillance of Alaska Airlines.

Number 7. FAA certification and on-going airworthiness of the longitudinal trim system.

At this point, I would like to introduce the other members of the Board of Inquiry.

Mr. John C. Clark, Acting Director, Office of

Aviation Safety. Dr. Vern Ellingstad, Director, Office of Research and Engineering. Mr. Benjamin A. Berman, Chief, Major Investigations Division, Office of Aviation Safety.

The Board of Inquiry will be assisted by a technical panel consisting of the following Safety Board staff. Mr. Richard G. Rodriguez, Investigator in Charge and Hearing Officer. Mr. Jeff Guzzetti, Systems/Powerplants Group Chairman. Mr. Frank McGill, Maintenance Records Group Chairman. Mr. Joe Epperson, Metallurgy Group Chairman. Dr. Joseph Kolly, Fire and Explosion Investigator. Ms. Lorenda Ward, Structures Group Chairman. Dr. Dan Bower, Aircraft Performance Group Chairman. Dr. Malcolm Brenner, Human Performance Specialist. Captain Dave Ivey, Operations Group Chairman.

Mr. Terry Williams and his colleagues from the Safety Board's Public Affairs Office are here to assist members of the news media.

Ms. Sharon Bryson, Mr. Brian Fiffick, and Mr. Frank Sciaccio from the Office of Family Affairs are here to assist any family members in the audience here through the hearing, of course.

Mr. Erik Grossof and Mr. Gary Abe are

assisting the family members in San Francisco, California, and Bellevue, Washington, respectively.

Mrs. Carolyn Dargan is present to provide administrative support as needed. She will also be providing copies of exhibits to the witnesses.

Neither I nor any other Safety Board personnel will attempt during this hearing to analyze the testimony received nor will any attempt be made at this time to determine the probable cause of the accident. Such analyses and cause determinations will be made by the full Safety Board after consideration of all of the evidence gathered during our investigation.

We have a five-member Board, and I know in attendance here this morning, I can see one of my colleagues, Member John Black, in attendance, and I know that Member John Goglia is waving from the back of the room, and Chairman Jim Hall is also here. He also, of course, met with the family members this morning, and, of course, Member Carol Carmody is in the audience with us today. So, the hearing has the full attention of the five-member Safety Board.

The final report on the accident involving Flight 261, reflecting the Safety Board's analyses and probable cause determinations, will be considered for adoption by the full Board at a public meeting here at the Safety Board's Headquarters at a later date.

The Safety Board's rules provide for the designation of parties to a public hearing. In accordance with these rules, those persons, governmental agencies, companies and associations whose participation in the hearing is deemed necessary in the public interest and whose special knowledge will contribute to the development of pertinent evidence are designated as parties.

The parties assisting the Safety Board in this hearing have been designated in accordance with these rules. As I call the name of each party, would the designated spokesperson please give his or her name, title, and affiliation for the record?

The Federal Aviation Administration.

MR. DONNER: Mr. Chairman, my name is Buck Donner. I'm the Manager of the FAA's Accident Investigation Division, in the Office of Accident Investigation.

MR. HAMMERSCHMIDT: Thank you, Mr. Donner.

Alaska Airlines.

CAPTAIN FINAN: Good morning, Mr. Chairman. My name is Kevin Finan. I'm the Vice President of

Flight Operations, Alaska Airlines.

MR. HAMMERSCHMIDT: Thank you, Captain Finan.

Boeing Commercial Airplane Group.

MR. HINDERBERGER: Good morning, Mr. Chairman. My name is Ron Hinderberger, and I'm the Director of Airplane Safety for Boeing Commercial Airplane Group.

MR. HAMMERSCHMIDT: Okay. Thank you, Mr. Hinderberger.

The Airline Pilots Association.

CAPTAIN WOLF: Mr. Chairman, Captain Bill Wolf, Chief Accident Investigator, Airline Pilots Association, for Alaska Airlines.

MR. HAMMERSCHMIDT: All right. Thank you, Captain Wolf.

The Aircraft Mechanics Fraternal Association.

MR. PATRICK: Mr. Chairman, David Patrick, Party Coordinator, AMFA.

MR. HAMMERSCHMIDT: Okay. Thank you, Mr. Patrick.

I would like to acknowledge the support of Pratt and Whitney, the Association of Flight Attendants, and the National Air Traffic Controllers Association, who were parties to the investigation during the field phase of the investigation.

I also want to thank publicly all of the other private, municipal, county, state and federal agencies that have supported the Safety Board throughout the investigation.

On December 6th, this month, the Board of Inquiry held a pre-hearing conference in Washington, D.C. It was attended by the Safety Board's Technical Panel and representatives of the parties to this hearing.

During that conference, the areas of inquiry and the scope of the issues to be explored at this hearing were delineated, and the selection of the witnesses to testify on these issues was for the most part finalized.

Copies of the Witness List developed at the pre-hearing conference are available in the foyer. There are numerous exhibits that will be used in this proceeding. Copies of the exhibits may be ordered through our Public Inquiries Branch at the following phone number: (202) 314-6551. Again, that's (202) 314-6551. There are a lot of exhibits.

For those of you who are attending this public hearing here in Washington, of course, that office is located at our Headquarters here in this same complex, and you can, of course, go up there and do it firsthand.

The witnesses testifying at this hearing have been selected because of their availability to provide the best available information on the issues of aviation safety pertinent to this accident investigation.

The first witness will be the investigator in charge of the accident investigation, who will summarize pertinent facts about the accident and the investigative activities that have taken place to date.

The remaining witnesses will be questioned first by the Board's Technical Panel, then by the designated spokesperson for each party to the hearing, followed by the Board of Inquiry.

As Chairman of the Board of Inquiry, I will be responsible for the conduct of the hearing. I will make all rulings on the admissibility of evidence, and all such rulings will be final.

The record of the investigation, including the transcript of the hearing, and all exhibits entered into the record will become part of the Safety Board's public docket on this accident and will be available for inspection at the Board's Washington office.

Anyone wanting to purchase the transcript, including the parties to the investigation, should contact the court reporter directly.

Before proceeding to Mr. Rodriguez, I think I should go over a few of the logistical details of this public hearing. As mentioned, we are beginning each day of this hearing at 11 a.m. Eastern time, to accommodate the people, the family members, out on the West Coast, who are watching via live telecast.

Therefore, our time frames each day will be something along this line. After convening at 11, I typically like to take a comfort break about every hour and a half. In terms of a midday lunch break, I would hope we could take that some time in the vicinity of 2 p.m. to 3 p.m.

Because we have a lengthy witness list, we will need to go into the evening each day more than likely, which should be in the neighborhood of going to 7 to 8 p.m. I believe we'd like to try for 7 each evening, depending on how the witnesses sort out, but we very likely could extend that to approximately 8 p.m.

We had originally planned on a three-day public hearing, but because of information that was late in obtaining, we were able to see the need to add some more witnesses to the witness list which more than likely, according to what staff tells me, in particular Mr. Rodriguez, that this will push us into Saturday. So, the likelihood is for a Saturday session, and you never know whether it may go on into the day Saturday and perhaps into the evening. But that's just our best guess at this point.

We don't ask witnesses questions for a set amount of time, like sometimes is the case, such as in the congressional hearing. We ask the witnesses questions until we're satisfied that we have all the information that we're seeking, and when a witness might take -- I've seen the case where a witness might take four hours, and the next witness might take 20 minutes. We never really know exactly how long each will take, and, so, we cannot be much more specific in terms of giving you a good idea as to our time frames, but that's the general plan we're going to operate under.

If anyone has any further questions about this general time line that we'll be using, please see either Mr. Rodriguez or myself, and we'll try to make accommodations.

When initially it comes to not knowing exactly what witness we'll be getting to at what time, that may indicate that a witness may appear, for example, the last witness one day, of course, he may end up being the next witness the next day. So, we will try to accommodate you as much as we can.

Mr. Rodriguez, are you ready to summarize the investigation and enter exhibits into the docket?

MR. RODRIGUEZ: Yes, sir.

MR. HAMMERSCHMIDT: Please take the witness stand and proceed.

MR. RODRIGUEZ: Good morning, Mr. Chairman, ladies and gentlemen.

On January 31st, 2000, at about 1621 Pacific Standard Time, Alaska Airlines Flight 261 --

MR. HAMMERSCHMIDT: Mr. Rodriguez, pardon me for interrupting. Is your microphone fully on? Do they have you hooked up?

MR. RODRIGUEZ: Test.

MR. HAMMERSCHMIDT: I think your voice is now a little better.

MR. RODRIGUEZ: Is it on now?

MR. HAMMERSCHMIDT: Yes.

MR. RODRIGUEZ: Can you hear me? A Boeing MD-83, November 963AS, crashed into the Pacific Ocean, approximately three miles north of Anacopa Island, near Port Hueneme, California.

The flight from Puerto Vallarta, Mexico, to Seattle, Washington, with an intermediate stop in San Francisco, California, was operating under 14 Code of Federal Regulations Part 121.

All 83 passengers and five crew members were fatally injured, and the aircraft was destroyed.

Visual meteorological conditions prevailed at the time of the accident.

The Safety Board was notified of the accident on January 31st, about 1945 Eastern Standard Time. As the assigned investigator in charge, we proceeded to assemble at Ronald Reagan National Airport in Washington, D.C., and we arrived at Port Hueneme at approximately 0500 Pacific Standard Time.

Meanwhile, the investigators from the Safety Board's Southwest Regional Office proceeded directly to Port Hueneme to establish liaison with local emergency response authorities. The board member on scene was Member John Hammerschmidt.

An organizational meeting was held at 0700

February 1st, 2000, at the Naval Facilities Engineering Service Center at Port Hueneme, and the investigative team was organized. Investigative groups were formed in the following specialty areas: Aircraft Operations, Human Performance, Air Traffic Control, Witnesses, Structures, Systems and Powerplants and Maintenance Records.

Subsequently, the Flight Data Recorder, Cockpit Voice Recorder, Aircraft Performance, Metallurgy and Grease Groups were formed in Washington, D.C. All groups functioned under the leadership of a Safety Board Group chairman.

The following organizations were given party status to provide technical assistance to the Board: the Federal Aviation Administration, Alaska Airlines, Boeing Commercial Airplane Group, Pratt and Whitney Engines, the Airline Pilots Association, the Aircraft Mechanics Fraternal Association, the Association of Flight Attendants, and the National Air Traffic Controllers Association.

Additionally, although not formally recognized as parties to the investigation, the Safety Board team received tremendous support from the following organizations: Ventura County Sheriffs

Office, Ventura County Emergency Management, the California Highway Patrol, the California Office of Emergency Management, Federal Bureau of Investigation, the U.S. Coast Guard, U.S. Navy, National Oceanic and Atmospheric Administration, the Base Security and Fire Departments, Salvation Army, and the American Red Cross.

A brief history of the flight follows. The accident crew arrived in Puerto Vallarta the day before the accident. They remained overnight and met the in-bound crew of November 963AS at the airplane for the start of that third day trip.

The in-bound crew reported that the only discrepancy was an overhead latch in the cabin. The flight called for taxi at 1331 and departed at 1337 Pacific Standard Time.

At about 1549, the crew of Flight 261 contacted Alaska Airlines Dispatch and Maintenance Control in Seattle to discuss a problem with the stabilizer and a possible diversion into Los Angeles.

Following an extended period of discussion with Dispatch and Maintenance Control in Seattle, and Operations and Maintenance in Los Angeles, the crew elected to land in Los Angeles. They indicated that the stabilizer appeared to be jammed.

At about 1610, the crew stated, "Center, Alaska 261, we are, uh, in a dive here." When they were asked to repeat the transmission, they responded, "Yeah. We're out at 26,000 feet. We're in a vertical dive. Not a dive yet, but, uh, we've lost vertical control of our airplane."

They then reported, "We're at 23.7, request, uh, yeah, we've got it back under control there." This was followed by a second voice in the background, "No, we don't."

At about 1611, the crew advised they were at 24,000 feet, unstabilized, "and we're slowing here, and, uh, we're going to, uh, do a little trouble-shooting." They requested and received a block altitude assignment between Flight Level 200 and Flight Level 250.

At about 1612, the crew told Los Angeles Maintenance that they had tried the pickle switch on the yoke, and they got a full nose-down runaway trim. According to the mechanic, the crew stated that "We are in a worse situation than we were. I'm afraid to try it again to see if we can get it to go in the other direction."

At 1615 and 19 seconds, the crew contacted Los Angeles Center and reported, "We have a jammed stabilizer, and we're maintaining altitude with difficulty, but we can maintain altitude, we think."

The pilot stated, "I need to, uh, get down about 10, change my configuration, make sure I can control the Jep, and I'd like to do that out here over the Bay."

The controller issued clearance to 17,000 feet and a heading of 280 degrees, which the crew acknowledged. At 1656, the crew acknowledged a frequency change and requested the latest altimeter setting. The controller responded, "The LA altimeter is 3018." At 1617:01, the crew acknowledged, "Thank you." This was the last transmission from the flight.

Examination of the flight data recorder information showed the autopilot was first engaged during the climb from Puerto Vallarta when the aircraft was passing through 6,200 feet. 13 minutes later, when the airplane had leveled at 28.5, the autopilot parameter switched from engaged to off.

It is also noted that the pitch trim did not change from about this point until the initial upset several hours later. The flight continued to climb with the autopilot off and proceeded to an altitude of 31,000 feet and slowly increased the air speed from 280 knots to over 300 knots.

The flight was still located over Mexico as depicted in this chart of radar data from the United States Air Force, 84th Radar Evaluations Squadron. The flight continued to operate at 31,000 feet and close to 300 knots for the next hour.

At 1546, the autopilot was re-engaged and remained engaged for approximately three minutes, then disengaged for 20 seconds, and then was re-engaged.

By 1608, the flight was located east of Santa Catalina Island, and at 1609:15, a comment was reported on the CVR by the captain about needing a switch, and at 1609:16, the autopilot parameter switched from engaged to off.

Also at this instance, the sound of two or three bumps was heard on the CVR. Immediately after this autopilot disconnect, the FDR indicated the pitch trim position moved in the nose-down direction for the next two seconds, to 2.4 degrees. This was the first movement of the stabilizer reported on the FDR since the climb-out from Puerto Vallarta.

As soon as the stabilizer began to move, the aircraft began to pitch in the airplane nose-down direction. The airplane then descended over the next two minutes and maintained a maximum speed of 353 knots in the descent.

During the descent, speed brakes were deployed, and elevators were deflected from neutral to close to half of their operating range. The airplane's descent rate was arrested and stabilized near 24,500 feet, and speed was reduced to 250 knots.

The flight continued in a controlled fashion and descended to close to 18,000 feet by 1618. The recorded stabilizer position remained at 2.4 degrees. As the airplane was level at 250 knots, the leading edge slats and flaps were deployed. The flaps and slats were then retracted 20 seconds later.

At 1619:35, at an air speed of 270 knots, the flaps started to deploy once again. One second later, an extremely loud noise is heard on the CVR. The next several seconds of data show a maximum pitch rate in the nose-down direction of close to 25 degrees per second, and the vertical acceleration quickly changing to negative and reaches a negative three gs within three seconds.

The airplane reached 80 degrees nose-down pitch attitude within six seconds and rolled inverted. The airplane rapidly descended until impact.

Before the team departed for the scene, the Safety Board contacted the U.S. Navy, Superintendent of Salvage and Diving, called SUPSAL.

(Technical problems)

MR. RODRIGUEZ: The cockpit voice recorder was recovered on February 2nd, and the flight data recorder was recovered the next day.

The first major piece of wreckage recovered was the horizontal stabilizer section with a jackscrew assembly still attached. It was recovered on February 8th, 2000.

Approximately 75 percent of the aircraft was recovered by the ROV. Subsequently, the Sea Clipper, a commercial trawler, recovered an additional 15 percent of the wreckage, and all organized wreckage recovery was suspended on March 15th, 2000.

A two-dimensional lay-out of the wreckage was accomplished in Building 546, a warehouse adjacent to the pier facilities. There was no evidence of any pre- or post-impact fire. The right side and crown of the aircraft exhibited more extensive damage, and none of the airframe fracture surfaces examined showed any signs of pre-existing fatigue or corrosion damage. There was no evidence of foreign impact damage.

Other major investigative activities have been initiated and/or completed over the past nine months. All system components recovered from the airplane, including the entire flight control system, fuel system, pressurization system, avionics, and both engines, were examined in detail.

In some cases, components were operationally tested in laboratories. Except for the components of the horizontal stabilizer trim system, the examinations did not reveal any evidence of pre-impact mechanical malfunction.

The horizontal stabilizer jackscrew assembly was examined in detail by the Structures and Systems Group as well as the Safety Board metallurgist at Port Hueneme. It was noted that the Acme screw had thin spiral metallic material attached, and the bottom of the torque tube was fractured.

The jackscrew was removed from the mounting structure and along with related parts which were found separately were shipped to the Safety Board Materials Laboratory for further examination.

A sample jackscrew display has been provided in the foyer for close examination by the audience during the breaks. That is not the jackscrew from the aircraft.

As a direct result of the investigation of the horizontal stabilizer jackscrew, Boeing issued Service Bulletin DC-9-27A362 on February 11th, 2000, and the FAA issued Telegraphic Airworthiness Directive AD-2000-03-51 on February 11th, 2000.

The service bulletin and AD required all U.S. owners and operators of the DC-9 and MD-80-type aircraft to perform certain visual inspections of the jackscrew assembly to accomplish end-play and free-play checks within 2,000 flight hours and to lubricate the jackscrew assembly at intervals of 650 flight hours.

A separate group was formed in July to investigate the types of greases used in lubrication of the jackscrew and their effects on wear. Alaska Airlines replaced Mobil 28 with AeroShell 33 in December 1997.

Preliminary results of a Safety Board survey indicates that Alaska Airlines was the only major operator in the United States that was using AeroShell 33 to lubricate the jackscrews in their fleet.

AeroShell 33 was developed to Boeing

Specification BMS-3-33 in 1995 as a new general purpose grease. We will discuss some of the details surrounding this activity during the hearing, including the development and selection of greases used for lubrication of the jackscrew.

This also includes a discussion of the results of tests of the grease residue recovered from the jackscrew wreckage and of tests performed on Mobil 28 and AeroShell 33 by the U.S. Navy's Aerospace Materials Division at Patuxent River, Maryland.

Because the investigation of greases, lubrication in general and wear are still underway, analysis or interpretation of these results as they pertain to wear of the jackscrew will not be discussed during the hearing.

Technical discussions regarding the results of the U.S. Navy's tests have begun with technical experts in the field of wear. Wear testing of the component materials using the lubricating greases of the jackscrew are in progress at Failex Corporation of Aurora, Illinois.

The Maintenance Group, the Maintenance Records Group was organized on February 2nd, 2000. They examined all records and documents relating to the maintenance history of November 963AS. They also reviewed the maintenance records and related documents concerning the horizontal stabilizers on November 973AS, November 981AS, and November 982AS.

Additionally, the group interviewed 30 company employees and FAA personnel concerning Alaska Airlines' Maintenance Program and FAA surveillance. The results of this activity will be discussed in detail during this hearing.

Before I conclude my statement, I would like to again publicly thank all of the parties and their team representatives for their continued cooperation.

Also, I want to thank the citizens, both paid and volunteer, affiliated with the Salvation Army and the Red Cross, who gave us such tremendous support during the on-scene investigation activities under very difficult and stressful conditions.

The record of this investigation to date is contained in Exhibits 1-A through 16-F as described in the Exhibit List, and other documents, correspondence and verbatim transcripts of interviews conducted by investigators since the accident.

All material is now public and available for examination or purchase through the Public Inquiry

Section.

Mr. Chairman, this concludes my remarks.

MR. HAMMERSCHMIDT: Thank you, Mr. Rodriguez, for that very comprehensive summary.

We will -- is there any other business that you need to tend to before you --

MR. RODRIGUEZ: Well, I can explain the next series of witnesses with the four Tech Panel here, if you will.

MR. HAMMERSCHMIDT: From your position there?

MR. RODRIGUEZ: Yes, sir. I can do it here.

MR. HAMMERSCHMIDT: Please proceed. I might mention just in passing that Mr. Rodriguez has been working for the NTSB for a long time, in fact since Day 1.

He has been working for the NTSB, therefore, in the 1960s, the 1970s, the 1980s, the 1990s, and now beyond year 2000, and he has a lot of experience not only in aviation investigation but also in process, and I just wanted to acknowledge that in case many of you who are watching this long distance may not see that in a bio that's hopefully included in some of this information for you.

But I just point that out parenthetically before you proceed.

Please proceed.

MR. RODRIGUEZ: For the information of those not party to the hearing, the first four witnesses, Mr. Jim -- I'm sorry -- Mr. Ken Umeda, Mr. Terry Khaled, Mr. Jim Talay and Mr. Peter Kovacik will be questioned in a panel format to facilitate the testimony that they will give in a logical sequence.

The questioning will be accomplished by Mr. Guzzetti, Dr. Bower, Ms. Ward and Mr. Epperson of the Technical Panel.

So, if you like, you can call those four gentlemen now.

MR. HAMMERSCHMIDT: Okay. Would those four gentlemen please come forward and take a position at our witness table?

(Pause)

(Witnesses sworn in)

MR. HAMMERSCHMIDT: While we're getting set up here, I might also mention in case it was lost in the opening statement, but Mr. Rodriguez is also wearing two hats. He's not only the investigator in charge of this accident investigation, he is also the hearing officer for this public hearing, just to clarify that in terms of our process.

Gentlemen, let me first say welcome. We certainly appreciate your participation here today, and, Mr. Rodriguez, please proceed.

Interviews of Ken Umeda, Dr. Terry Khaled,
Jim Talay and Peter Kovacik

MR. RODRIGUEZ: Yes, sir. I would like to qualify each of the witnesses in turn. I'll begin specifically with Mr. Kovacik and address my questions to him.

Would you state your full name, sir, and your occupation?

MR. KOVACIK: My name is Peter Thomas Kovacik. I'm a Senior Mechanical Engineer with the Boeing Company.

MR. RODRIGUEZ: And what is your business address?

MR. KOVACIK: My business address?

MR. RODRIGUEZ: Yes.

MR. KOVACIK: 3855 Lakewood Boulevard, Long Beach, California 90846.

MR. RODRIGUEZ: And would you briefly summarize for us your aviation background?

MR. KOVACIK: I have a Mechanical Engineering

Degree from Carnegie-Mellon University in Pittsburgh, Pennsylvania. I have 14 years' experience with the Boeing Company in Mechanical Systems, particularly with Aircraft Flight Control Systems, and I'm also currently a member of the NTSB Systems Group investigating this accident.

MR. RODRIGUEZ: All right, sir.

Mr. Talay, would you state your full name and address, please?

MR. TALAY: James Edward Talay. Business address is 35 -- 3855 Lakewood Boulevard, Long Beach.

MR. RODRIGUEZ: Okay. And your current occupation?

MR. TALAY: Currently the Manager of the Hydromechanical Group within Service Engineering at Boeing.

MR. RODRIGUEZ: And would you briefly summarize your aviation background for us?

MR. TALAY: Sure. I graduated from the College of Aeronautics in New York in 1979, have been with Boeing Products Support since 1980, primarily Twin Jet Flight Controls.

MR. RODRIGUEZ: And, Mr. Umeda, would you state your full name for the --

MR. UMEDA: My name is Kenneth Kadashi Umeda.

MR. RODRIGUEZ: Push the red button, Ken.

MR. UMEDA: Excuse me. My name is Kenneth Kadashi Umeda.

MR. RODRIGUEZ: And your occupation, sir?

MR. UMEDA: I'm a Manager in Structure Analysis at Boeing.

MR. RODRIGUEZ: And what is your business address?

MR. UMEDA: 3855 Lakewood Boulevard, Long Beach, California. Zip code 90846.

MR. RODRIGUEZ: Okay. And would you briefly summarize your aviation background for us?

MR. UMEDA: I've been at Boeing for 21 years. I have 21 years of experience in Aircraft Structure Analysis and Structural Substantiation. I have a B.S. Degree in Engineering from UCLA, and I am a Structural-Designated Engineering Representative for the FAA.

MR. RODRIGUEZ: And, finally, Dr. Khaled, would you give us your full name, sir?

DR. KHALED: My name is Terry Khaled. I work for the FAA, National Resource Specialist, Metallurgy.

MR. RODRIGUEZ: And what is your business address, sir?

DR. KHALED: 3960 Paramount Boulevard, California -- excuse me -- City of Lakewood, California 90712.

MR. RODRIGUEZ: And would you briefly summarize your aviation background for the record?

DR. KHALED: I have a degree, Bachelor's Degree in Metallurgy and a Doctorate in Material Science. I have worked in the aerospace industry for over 25 years, beginning with Aerospace Hughes Aircraft, Allied Signal, now Honeywell, and finally Rockwell, now Boeing.

MR. RODRIGUEZ: All right, sir. With your permission, Member Hammerschmidt, Mr. Guzzetti will begin the questioning. Is that okay?

MR. HAMMERSCHMIDT: Yes. Please proceed.

MR. GUZZETTI: Thank you. Good morning, Mr. Kovacik.

MR. KOVACIK: Good morning, Mr. Guzzetti.

MR. GUZZETTI: Please explain to me why the Boeing Company is here to discuss an airplane that was originally designed by the Douglas Aircraft Corporation and then built by the McDonnell-Douglas Corporation.

MR. KOVACIK: Yeah. There's a straight-forward answer for that. The original design, as you say, was through the Douglas Aircraft Company.

Douglas Aircraft Company was founded in 1928. In 1967, there was a merger with McDonnell Aircraft Company, which formed the McDonnell-Douglas Corporation.

Subsequent to that, in 1997, a subsidiary corporation of the Boeing Company purchased the MDC, McDonnell-Douglas Corporation, and we are now currently a wholly-owned corporate subsidiary of the Boeing Company.

MR. GUZZETTI: Thank you. So, that would mean that you would have responsibility and cognizant over the older Douglas DC-9s as well as the MD-80?

MR. KOVACIK: Yes, that is correct.

MR. GUZZETTI: Could you please briefly describe the lineage of the airplane, from the DC-9 all the way up to the most recent version of that aircraft model?

MR. KOVACIK: Right. The original DC-9 Series 10 was designed and certified in the middle 1960s. There have been a number of subsequent derivative airplanes based off of that original DC-9, a number of series of DC-9. Just for instance, DC-930, 50.

We also have the MD-80, which is essentially a DC-980 series derivative. Subsequent to that, we have an MD-87 derivative airplane, an MD-90 derivative airplane, and the Boeing 717 airplane, which was originally designated the MD-95 airplane.

So, those are essentially all derivative airplanes of the original DC-9 series airplane.

MR. GUZZETTI: Okay. Thank you. So, the accident airplane was a McDonnell-Douglas MD-83, is that correct?

MR. KOVACIK: That is correct.

MR. GUZZETTI: And would that be technically considered on the type certificate data sheet a DC-9 Series 83?

MR. KOVACIK: I believe so, yes. It's just another designation in the series of MD-80 airplanes.

MR. GUZZETTI: Okay. Can you please describe just generally the differences between the MD-80 series tail and horizontal stabilizer with that of the earlier DC-9 and the later Boeing 717?

MR. KOVACIK: Okay. The differences between the DC-9 and the MD-83, from a structural standpoint, the stabilizer for the MD-83 is larger than the original DC-9. The interworkings, the mechanism of the stabilizer actuation is essentially the same. There may be some minor differences in terms of the length of the Acme screw in the system.

MR. GUZZETTI: Okay. I -- could you please describe the horizontal stabilizer trim system of the MD-80 series, including its purpose, its operation, the components that make it up, and generally just the design philosophy of it?

MR. KOVACIK: Yes. In fact, we've put together a short presentation that I think will give an excellent overview and orientation to the stabilizer actuation system.

So, if we may, we'd like to continue with that.

MR. GUZZETTI: Certainly. Mr. Chairman, is that okay?

MR. HAMMERSCHMIDT: Of course.

MR. GUZZETTI: Great. I take it you -- this is a summary of a lot of data? 30 some years or --

MR. KOVACIK: Yeah. We'll be attempting to condense about 35 years of design history and over 95 million flight hours of in-service experience into a rather short period of time.

Let me get the machine working here. You know, being so short, we'll be only able to touch on some of the design considerations that went into this particular design, including functionality, simplicity, redundancy.

With this presentation, I would want to provide the participants and the audience with a basic orientation of what the system is, and how the system operates.

By the time I have completed the overview, I will hope to have conveyed to you an understanding of two fundamental concepts regarding the horizontal stabilizer.

1. The horizontal stabilizer is an important flight control surface, and it is necessary for the control of the airplane.

2. Because the horizontal stabilizer is important, many design features, such as redundancy, are included in the stabilizer control system design.

Can we stand by just one second, please?

(Pause)

MR. KOVACIK: There we go. I'm ready to proceed.

MR. GUZZETTI: Okay.

MR. KOVACIK: A basic question might be what is the horizontal stabilizer, and what does it do? Well, we need to begin with a short course on the nature of an airplane in flight.

Here, we see a side view of an MD-83 jet. Taking a quick inventory of the components, we see on the far left side the cockpit, fuselage, wings, engine, the tail of the airplane, including the rudder, and the horizontal stabilizer.

An airplane in flight is all about a balance of forces. The engines in the rear of the airplane provide a thrust that propels the airplane forward. Resisting the thrust is what is termed the "drag force".

When the thrust exceeds the drag, the airplane will accelerate forward. Because of the unique cross-sectional shape of the wings, a lifting force is generated with this forward motion. Resisting the lift is the weight of the airplane. When the lift equals the weight, the airplane will begin flying.

You might have noticed that the lift and the weight forces do not react at the same point on the airplane. In order to balance the airplane, that is to keep the nose of the airplane level, a force directed downwards at the tail of the airplane is needed. This force is noted as the tail load. This tail load is primarily generated by the horizontal stabilizer.

So, from this initial high-level perspective, the horizontal stabilizer is an important control surface, and it is necessary to maintain proper balance of the airplane.

Let's proceed and look closely at the tail of the airplane and see how the tail loads are generated and how they are adjusted.

Here's the horizontal stabilizer. It is essentially a small inverted wing on the tail of the airplane. Inverted in that a wing is usually thought of as providing a lifting or upwards force. In this case, the lifting force is actually directed downwards.

Attached and hinged to the horizontal stabilizer are the elevator surfaces. That's noted in orange. Both the elevator and horizontal stabilizer surfaces are used individually and in combination to change the amount of tail load generated.

Basically, the initial target tail load is set by the position of the stabilizer. The elevators are then used to add or subtract from this load as required. Changing the force balance of an airplane through changes in these tail loads is fundamental to aircraft pitch attitude control.

Pitch attitude is basically the orientation of the nose of the airplane, nose up, nose down, or nose level. Changing the pitch attitude of the airplane is needed for all aspects of flight, including take-offs and landings, ascents and descents, and during normal cruise.

This ability to alter the tail load's end pitch attitude accommodates all of the weight and loading changes of an airplane, such as the number of passengers and the amount of cargo and fuel carried. This adjustment ability allows the performance of the airplane to be optimized in all airplane flight conditions.

Let's first examine the role of the elevators in pitch attitude control. The elevators can rotate up and down about their hinges on the horizontal stabilizer. When the elevators move, the overall load generated by the tail changes due to aerodynamic effects. With this change in tail loads comes a change in the pitch attitude of the airplane.

An obvious question from this point, well, so, how are the elevators controlled? We need to take a look in the cockpit of the airplane.

The means of positioning the elevators is through the control columns. They're noted there on the screen. There are two columns, one for the pilot and one for the co-pilot, and they work together in unison. The control columns are hinged, so that they can be moved forwards or back.

Show a little animation here. Columns moving forward, elevator surface moving. Bring the columns back to neutral, elevator surface returns to neutral, and the opposite is true. Moving the columns back, elevator goes up.

To simplify this presentation, I won't get into the details of the control system between the control columns and the elevators, nor will I discuss the role and function of the elevator control tabs.

Suffice to say, as we saw in the animation, pushing forward on the control columns results in the elevators rotating downwards. Pulling back on the control columns results in the elevators moving upwards.

This next graphic will demonstrate the relationship between control column, elevators, and the pitch attitude of the airplane. We have three panels. Upper left is the control column schematic, the upper right, the tail of the airplane, and below that is the actual airplane.

Move the column from the neutral position forward, we see the change in the elevator surface position and a corresponding change in airplane pitch attitude. Bringing the columns aft, elevator's trailing edge up, and the nose of the airplane raises.

Let's now look at the horizontal stabilizer more in detail. Shown here is a side view of the installation. The reddish line is a cross-sectional outline of the stabilizer at the root of the surface. The stabilizer structure is hinged in the rear, so the front or leading edge of the stabilizer can be raised or lowered. This hinge also holds the stabilizer to the vertical stabilizer structure.

The jackscrew mechanism itself is located on the center forward portion of the horizontal stabilizer, enclosed within the vertical stabilizer structure. We use the term "jackscrew" somewhat interchangeably with the term "Acme screw actuator" or "horizontal stabilizer actuator". The term "jackscrew" is a little less cumbersome to use.

To give a perspective on the size of the mechanism, the overall length from top to bottom, from this point down to the bottom, is about four and a half feet, and the overall weight is approximately 100 pounds. The Acme screw itself, here, is about 30 inches in length, and the screw diameter is a little less than two inches.

This may be a little larger than a conventional screw or bolt that you might be thinking about when you hear these terms mentioned. The actual jackscrew assembly is displayed in the foyer as was stated before.

The horizontal stabilizer serves two purposes. 1. The jackscrew is the device that moves the stabilizer up and down. 2. The jackscrew's also the structural connection between the horizontal and vertical and holds the stabilizer in place after the proper airplane pitch attitude or pitch trim setting is achieved.

This next sequence shows how the stabilizer can be used to change or maintain the pitch attitude of the airplane just as the elevators can. So, we see in this screen, we have the upper left, the control column, the right, the tail of the airplane, and below, the airplane itself.

In this case, instead of using the column to adjust pitch attitude, we will use trim. A nose-down trim comes from the effect of moving the horizontal stabilizer leading edge up. Return to neutral. A nose-up trim, the leading edge of the stabilizer moves down, and the nose of the airplane comes up.

As you can see, the pitch attitude of the airplane can be adjusted through the elevators or through the horizontal stabilizer. In fact, the stabilizer trim can be used to replace an elevator input and result in the same airplane orientation.

This ability to trim out elevator input is important. Pushing or pulling on the control column takes effort by the pilot. If elevator input is needed for a long period of time, to achieve a certain airplane attitude, horizontal stabilizer trim can be used instead to achieve the same desired airplane effect.

This will relieve the workload from the pilot since control columns can be returned and kept to the neutral position as shown in the upper left panel. This position of the control column requires little or no effort by the pilot to maintain.

Let's proceed and take a look at the jack-screw mechanism a little bit more in detail. The mechanism itself consists of several main components, Acme screw, drive torque tube within the Acme screw. This torque tube has also been known as the "Quill shaft", the Acme nut, gear box and support assembly, electric trim motors, upper rotational stops, lower rotational stops, and a clamp-up washer and nut.

Let's go through this a little more slowly and in detail. At the top of the actuator are the electric motors. Beneath the motors are the gear box. Below the gear box is the support assembly. We have an upper mechanical rotational stop, and a companion one on the lower side. We have the Acme screw here, the inner torque tube within the Acme screw itself, and the Acme nut.

The support assembly, I'll highlight here, is rigidly attached to the horizontal stabilizer. The motor gear box is then mounted to the top of the support assembly, and the electric motors in turn are mounted to the gear box.

Note that there are two motors, a larger motor for the primary system here, and a smaller one for the alternate system. We'll explain the reason for these two motors at a later point in the presentation.

The Acme nut is located within a gimbal

mounting attached to the vertical stabilizer structure. This gimbal allows the Acme nut to rotate side-to-side as well as forward and backward. This ability to rotate is necessary to allow the stabilizer to move up and down when driven by the jackscrew mechanism. Basically, this is an issue of component geometry.

There are four ways the horizontal stabilizer trim is operated by the flight crew. We have two control wheel thumb switches, the suitcase handles, and the alternate trim levers. On each of the control wheels in the cockpit is a thumb-operated switch which turns the primary trim motor on. Here's a close-up look at the switch.

Pushing up on the switch causes the nose of the airplane to lower. Pushing down on the switch causes the nose of the airplane to raise.

On the control pedestal between the pilot and co-pilot are levers that have come to be known as the "suitcase handles". These handles also control the primary trim motor and can override the thumb-operated switches. Normally, the control wheel switches are the preferred choice for commanding trim with the suitcase handles being used only as a back-up.

On the control pedestal as well are two

smaller levers which turn the alternate trim motor on. Normally, the flight crew will adjust the stabilizer with the primary system, but the alternate motor is available to be used as a back-up, and they would use these two levers to accommodate that.

You may have noticed that for each of these controls, there are actually two side-by-side switches or levers. In order for the pilot to command trim, both switches or levers must be moved together in the same direction.

Here's the thumb switch here, and we can note that there are two side-by-side switches.

Having two independent switches like this prevents inadvertent movement of the stabilizer due to failure in one of the switch electrical circuits. The horizontal stabilizer trim can also be operated automatically by the autopilot system.

When the autopilot is on, horizontal stabilizer trim will be controlled through the alternate trim motor. The autopilot senses the amount of elevator commanded in any situation and can in turn command the horizontal stabilizer to move and replace or null out that elevator input.

The remaining cockpit control we want to identify here is a switch mounted on the pedestal, identified as the "primary trim shut-off switch". This switch allows the pilot to stop the stabilizer from moving if there is a failure in the primary trim control system that causes the motor to run inadvertently.

The amount of horizontal stabilizer motion up and down is limited by an electrical shut-off system that cuts power to either trim motor when specific stabilizer angle limits are reached. This system is not shown on this screen.

Mechanical rotational stops mounted to the Acme screw, here and here, are provided as back-ups, if, for some reason, the electrical stops are not functioning properly. In this failure case, the mechanical stops will rotate into a mating stop phase at the top and bottom of the Acme screw -- excuse me -- of the Acme nut and will prevent the Acme screw from turning.

In normal operation, however, the Acme screw will stop rotating because of the electric shut-off system before these mechanical stops are contacted.

We've touched on the fact that there are two trim motors, the primary and the alternate, the primary motor being the large one, the alternate being the smaller motor.

Basically, there are two motors and two independent control systems for safety and redundancy. The primary motor moves the horizontal stabilizer faster than the alternate motor, essentially a faster pitch trim rate. During normal airplane cruise conditions, the horizontal stabilizer is not required to move this quickly, and thus the slower alternate trim system is used by the autopilot.

One of the redundancy benefits of having one fast and one slow motor is that the primary motor, the fast motor in this case, can override the alternate, if, for some reason, there is a fault in the alternate trim system.

As was noted previously, if there was a fault in the primary trim system, the pedestal shut-off switch will be able to override or shut off that control.

At this point, we'd like to take a look at a very brief video clip that shows the operation of the jackscrew mechanism. What we will see is a view from the airplane production line. Many of the structural panels have been removed to clearly show the movement of the screw.

Here's our production line. We're zooming in on the tail of the airplane, and we can see the vertical stabilizer and the horizontal. We're seeing the leading edge of the horizontals come down because of the Acme screw rotation. We're seeing a nose-up airplane trim.

Now, noticing that the computer is showing somewhat of a jerky motion associated with the stabilizer. In reality, the jackscrew and the horizontal stabilizer moves smoothly and continuously when commanded.

Here's a more schematic look at what we just saw in the short video clip. We can see that when the Acme screw rotates and engages further into the Acme nut, the leading edge of the horizontal stabilizer lowers. Also, the reverse is true. When the Acme screw rotates in the other direction, the horizontal stabilizer raises up.

Let's look at the jackscrew mechanism a little bit more in detail to see exactly how the actuator works and how it moves the horizontal stabilizer.

We're going to focus in on a particular area of our actuator assembly, just beneath the gear box assembly. This is a cut-away view of the jackscrew mechanism. Note that the gear box and motors are not shown.

Let's look at a quick inventory of components. This is the support assembly here, as we saw in slides previous. We have the Acme screw in red, inner torque tube in gold, and upper and lower mechanical rotational stop in blue.

Extending out below the support assembly is the Acme screw and inner torque tube combination. The torque tube attaches inside the support assembly at a spherical bearing that allows it to rotate, turn, as well as move side-to-side. Here's the torque tube, and here is the spline connection here.

There's a specific design for the spline, so it allows the jackscrew and torque tube to articulate as well as rotate along axis.

When I say spline joint, I indicated the spline joint where it connects. Think of gear teeth meshing together. This ties the torque tube through that spline joint directly to the gear box and ultimately to the electric motors.

The torque tube and the Acme screw are

connected at the bottom portion of the screw at another spline joint, indicated here. This spline causes both the Acme screw and the inner torque tube to rotate together.

Below this joint, at the bottom of the Acme screw, is a large flat washer, here, and a large nut that is screwed on to the lower portion of the torque tube. This nut ties the torque tube and Acme screw together in the up and down direction.

So, the question might be, how is the Acme screw driven? Following the component chain, rotation of the electric motors is transferred through the gear box and into the inner torque tube through this spline joint here.

As the torque tube rotates, the rotation is transferred to the Acme screw through the bottom spline joint, and as the Acme screw rotates into the Acme nut, motion of the horizontal stabilizer will occur.

Depending on the direction the motor is turning, the screw will either move further into the Acme nut, horizontal stabilizer leading edge down, or will move further away from the nut, essentially horizontal stabilizer leading edge up.

To summarize, the horizontal stabilizer is an important component that is necessary for the control of the airplane, and because of this importance, the critical elements of the stabilizer control system, such as the control switches and the trim motors, for instance, are designed redundantly to ensure that the positioning of the horizontal stabilizer remains under the control of the pilots, and that concludes my presentation.

MR. GUZZETTI: Thank you very much. That certainly does clarify some things and sets up a good base of jargon for our technical discussion.

Just a couple of follow-up questions for a few more details. Regarding the motors themselves, you have a primary and an alternate motor, is that correct?

MR. KOVACIK: That is correct.

MR. GUZZETTI: Could you please describe the capability of those motors in terms of torque and speed?

MR. KOVACIK: As can be ascerned by the size of the motor, the primary motor is a very strong capable motor. It has an output torque reflected at the jackscrew of over 18,000 inch pounds. That compared with the alternate motor, which is on the order of 4,000-4,400 inch pounds as reflected at the jackscrew mechanism.

MR. GUZZETTI: Okay. Thank you. And as Mr. Rodriguez testified earlier, there was some indications of troubleshooting by the flight crew in the air traffic control transcripts.

Could you -- I just wanted to step you through some very basic combinations of those two motors. For example, if you activated the -- what is being known as the pickle switch, the control column trim switch, --

MR. KOVACIK: The thumb switches.

MR. GUZZETTI: Thumb switches. In the, say, nose-down direction while simultaneously grabbing the suitcase handles and moving them in the nose-down position, what effect would that have on the speed and torque of the jackscrew?

MR. KOVACIK: Okay. Both of those switches, the thumb switches and the suitcase handles, command the primary trim motor. If, as you say, they're commanded in the same aircraft nose-down direction, you're essentially commanding the same command to the primary trim motor. So, you're just going to be moving the primary trim motor. So, there's really no effect, no difference in that scenario.

MR. GUZZETTI: Okay. What if you moved either of those controls in the opposite direction? Nose-down with the thumb switch, nose-up with the suitcase handles.

MR. KOVACIK: Right. As was stated in the presentation, the suitcase handles can override a thumb switch input. So, in that case, the command of the suitcase handles would be the one that is communicated to the jackscrew mechanism.

MR. GUZZETTI: Okay. And, finally, what if you moved the primary trim motor, whether it be through the thumb switches or the suitcase handles, and the alternate trim motor in the same direction? What effect would that have on the speed and torque of the jackscrew, both on the ground, sitting static, as well as in flight?

MR. KOVACIK: Okay. If -- as was mentioned in the presentation, the benefits of having the two motors is one can override the other. If, for instance, there is a command for primary trim and a command for the alternate trim, say, in the same pitch direction, essentially by the design of the gear box, you will get a speed summation of the two trim motors, you know.

In the case here, we have a third of a degree per second primary trim motor pitch trim rate and a tenth of a degree per second alternate pitch trim rate. So, essentially you would get the additive of both of those trim rates.

MR. GUZZETTI: I see. Would that be both on the ground and in flight?

MR. KOVACIK: Yes, it would. To a certain extent, yes. The gear box is a differential gear box. It is a speed sum device.

What -- if they're both in the same direction, you know, on ground or in the air, you're going to get the summation of that, you know, both speeds.

MR. GUZZETTI: Okay. And what about the torque sum? Will the torque output also be additive on the ground and in flight?

MR. KOVACIK: The gear box by design is not a torque sum device. So, what will happen in that case, the torque output seen at the jackscrew will be that only of the primary trim motor.

MR. GUZZETTI: Okay. So, to -- are there any hazards or major malfunctions that occur -- that could occur if you were to activate any of the sequences that we just discussed, to your knowledge?

MR. KOVACIK: To my knowledge, no. You know, in my limited knowledge of operations, I don't think that is something that we, you know, instruct the flight crew to do, but I don't see any, you know, problems or, you know, anomalies associated with that.

MR. GUZZETTI: Okay. The -- a brief description about the autopilot, and I know you're not an autopilot expert, but is it possible for the auto-pilot to automatically disengage if, for some reason, the horizontal stabilizer ceases to operate and fails to automatically trim the airplane?

MR. KOVACIK: I believe the system is designed to enunciate if on autopilot, the system is designed to enunciate if there is a challenge with the stabilizer trim mechanism, you know, accomplishing trim. I believe it's a light that says there's a trim condition.

To get into the details of that, that's a little beyond my expertise.

MR. GUZZETTI: Okay. That's fine. Thank you. Could you please describe what we found in the wreckage as it relates to all of the system components of the horizontal stabilizer trim system? Just a brief inventory.

MR. KOVACIK: I guess beginning at the nose of the airplane, we did find one of the control wheel thumb switch assemblies. It was badly damaged, and part of the control yoke that was recovered.

We recovered, I believe, all four of the electric relays associated with those thumb switches. I'm not certain if the -- if any of the pedestal switches were found. I believe the pedestal itself was recovered, and I believe the alternate trim levers were a part of that damaged pedestal.

We did recover several of the components from the related systems, particularly the position-sensing system. We did recover, I would say, my recollection, about 75 percent of the cable system associated with the follow-up system.

Moving back to the jackscrew mechanism itself, the gear box, the support assembly, the Acme screw, the upper mechanical stuff and the inner torque tube were recovered together as an assembly still attached to the horizontal stabilizer.

The two motors were recovered separately. They had broken away from the gear box mounting surface. The lower stop was recovered separately. It was found detached from the Acme screw. The lower clamp-up washer and torque tube nut were not recovered.

From the mating side, the Acme nut, the Acme nut was recovered still within its gimbal mounting structure, and that gimbal mount was still affixed to the vertical stabilizer, but obviously that was recovered separately from the horizontal stabilizer.

MR. GUZZETTI: Okay. Thank you. Aside from the jackscrew assembly and its components, but the other components forward of the jackscrew assembly, did -- were you involved in the examination and testing of some of those components?

MR. KOVACIK: Yes, I was. With the Systems Group, I was a part of those tear-downs and examinations.

MR. GUZZETTI: And again, aside from the jackscrew assembly, were there any obvious indications of pre-impact mechanical malfunction?

MR. KOVACIK: No, there were not.

MR. GUZZETTI: Okay. Could you provide just a very brief gross description overview of the Acme screw as you first observed it when it came off on to the dock at Oxnard as well as the Acme nut?

I think we have a couple of photographs from

Exhibit 9-B, Photographs 4 and Photographs 8, that -- do 4 first. Photograph 4 is the Acme screw, just to show the audience. There it is right there, Mr. Kovacik.

MR. KOVACIK: Okay. Thank you. Well, the Systems Team was on site as the horizontal stabilizer was taken by crane off the boat on to the dock, and our group was one of the first on scene to get a close-up visual inspection of the components.

As I had mentioned, a portion of the jack-screw assembly, consisting of the gear box, the support assembly and the Acme screw and inner torque tube, were found still attached to the horizontal stabilizer.

I guess the initial inspection, we noted the absence of the lower stop, and we noted that, you know, at a point just below the end of the Acme screw, which would have normally been where the washer and the torque tube nut would be, were not present. We did note that there were, you know, metallic ribbonlike material interwound along the screw threads, some sitting nicely in the screw valley between the threads, and some bent and skewed out from the Acme screw itself.

MR. GUZZETTI: Okay. And the Acme nut, could you provide a little very brief summary of what you observed with that, and I think that's Photograph 8 that we're about to put up? There it is.

MR. KOVACIK: Yeah. The Systems Group was also present when this component was recovered. What we noted, first of all, is that the nut element within its supports, along with the silver round, what we call the gimbal rings, those were all still intact, and it was still mounted to the vertical stabilizer surface.

Closer inspection, looking down the bore of the nut, revealed that, you know, there were no nut threads present. We noted that, you know, the installation or the assembly was somewhat wet and somewhat dirty.

MR. GUZZETTI: Okay. What happened to the Acme screw and the Acme nut and all the associated Acme screw assembly hardware after it was examined by you and the Systems Group?

MR. KOVACIK: Very soon after the NTSB Metallurgy Group, Materials Group, came on scene, they removed the components from the vertical stabilizer as well as from the horizontal stabilizer, packaged them up and brought them back to Washington, D.C.

MR. GUZZETTI: Okay. Thank you. And, Mr.

Chairman, at this time, I'd like to turn over the questioning to Mr. Epperson, who will get into the more detailed metallurgical observations of these parts, and if I could ask Dr. Khaled to move over where Mr. Kovacik is because he needs immediate access to that visualizer. Is that okay?

MR. HAMMERSCHMIDT: That sounds very good. Mr. Epperson, do you know about how long you're going to be in your questions?

MR. EPPERSON: It'll probably be in the order of 40 minutes, 30 to 40 minutes.

MR. HAMMERSCHMIDT: All right. I believe we're going to take a break here within about 10 or 15 minutes. Would you like to take it now or would you like to get started?

MR. EPPERSON: This would be quite all right with me.

MR. HAMMERSCHMIDT: To break now?

MR. EPPERSON: Yes.

MR. HAMMERSCHMIDT: Okay. Why don't we take a break and reconvene here in approximately 10 minutes? 10 or 12 minutes.

Thank you.

(Whereupon, a recess was taken.)

MR. HAMMERSCHMIDT: Thank you. Mr. Epperson?

MR. EPPERSON: Thank you, Mr. Chairman. Dr. Khaled, I'd like to go through a round of questioning with you basically discussing the Materials Group's observations and findings as they relate to the actual accident aircraft hardware from 261.

I believe you were -- became a member of the Materials Group. Could you briefly describe how you -- what your initial appointment to the Materials Group, and when you came on board for us, please?

DR. KHALED: Yes. My management first involvement was in the first week of February. I was advised that I'm going to be working with the NTSB on Flight 261, and I immediately started gathering drawings with the help of some FAA people and the Boeing people, and then my first hands-on on the hardware was after some partial disassembly at the NTSB office in Washington, D.C., 15th of February 2000.

MR. EPPERSON: Okay. So, you became -- you actually first saw the hardware of the jackscrew on or about the 15th. Were you at the accident site prior to that?

DR. KHALED: No.

MR. EPPERSON: Did you -- were you at the accident site following that date as a part of the Materials Group?

DR. KHALED: Yes. The last week of March, 23rd to 27th.

MR. EPPERSON: You are then familiar with not the jackscrew as it was retrieved from the ocean but after it was removed from the horizontal stabilizer and forwarded to Washington?

DR. KHALED: Yes.

MR. EPPERSON: Okay. However, you are familiar with the structure of the jack -- of the horizontal stabilizer on following visits?

DR. KHALED: Yes, that's correct.

MR. EPPERSON: I would like to kind of take you through some brief general observations and findings as they relate to the jackscrew components at this time.

I believe you have available several of the exhibits from the Materials Group's Section of the Exhibits 15, and can you use those to help describe some of your observations?

Would you please start with some general observations of the jackscrew system as you first saw it in Washington?

DR. KHALED: This is a photograph of the jackscrew and the associated details as they were recovered at Port Hueneme. I have seen the jackscrew at the office of NTSB here in Washington, D.C.

Observations were that the -- of course, was disconnected from the nut, the Acme nut. The second thing, the Acme screw was bent aft and left. The Acme screw was covered with reddish rust and with whitish deposits along areas of its length.

There was a frontal crack at the front of the upper portion of the Acme screw. There was a crack about a 180 degrees around the circumference, and the general appearance of the white deposits was just localized areas.

There were metallic windings or filaments or thread remnants, as they became known later, around -- coiled loosely around the Acme screw in its mid-length in about two groups.

The Acme screw was dented. It had indications of contact on the aft side and on the front side, contact with the -- one of the spars and contact with the lower support plate of the gear box.

MR. EPPERSON: Okay. Thank you. Let's see. Lower mechanical, as Peter referred to it, as the rotational mechanical stop. Was that attached to the jackscrew?

DR. KHALED: Yes. The lower mechanical stop -- excuse me -- the upper mechanical stop was attached to the jackscrew.

MR. EPPERSON: How about the lower mechanical stop?

DR. KHALED: It was not. It was recovered separately. It was separate.

MR. EPPERSON: Later on examined?

DR. KHALED: Yes.

MR. EPPERSON: Let's stay with a little bit more general -- what was your observation of the condition of the jackscrew torque tube?

DR. KHALED: The torque tube was fractured at the lower end, and the separated part of it was not recovered. I only saw the end of that tube fracture.

MR. EPPERSON: The torque tube on this jackscrew is actually a titanium --

DR. KHALED: Titanium 6 Element, yes.

MR. EPPERSON: Okay. And it's -- the torque tube nomenclature is actually slight misconstrued. It's actually a solid shaft, is it not?

DR. KHALED: For the most part, it is.

MR. EPPERSON: Okay. Let's talk about -- a little bit about your observations of the lubrication and grease that were apparent during your examination at the Materials Lab.

DR. KHALED: Specifically on the Acme screw, on the upper portion, there was an oily sheen to it. On the lower portion of the Acme screw, there was evidence of sandy grease that could be seen by the eye.

However, in the mid-section, there appeared to be lack of grease.

MR. EPPERSON: So, in the middle section, how big of a middle section? How do you define the middle section?

DR. KHALED: The working zone, where the Acme nut would ordinarily function.

MR. EPPERSON: Okay. So, by the working zone, you're referring to the area between the electrical stops or between the mechanical stops?

DR. KHALED: Between the mechanical stops.

MR. EPPERSON: As the working zone of the screw, there was no grease in that entire length of the screw?

DR. KHALED: No. Just in the middle between of them, you know. Near the stops, I believe that there was evidence of grease. Sandy grease on the bottom, oily sheen on the top.

MR. EPPERSON: Okay. When the lower mechanical stop was recovered, what was its condition in relation to lubrication or grease?

DR. KHALED: It had a black oily substance on the top surface, grease.

MR. EPPERSON: Okay. That's -- that object to the left in the figure. Thank you. Let's talk a little bit more about the lower mechanical stop while it's up there.

Did you do an examination or were you privy to an examination of the lower mechanical stop?

DR. KHALED: Yes.

MR. EPPERSON: Could you let us know a little bit about your general observations and findings upon that?

DR. KHALED: Yeah. We are looking here at the upper surface of the lower mechanical stop. This would be the surface that is facing the bottom of the Acme nut, and there was evidence of contact marks, several contact marks on that upper surface. Some of them mild, ranging from just chipping the paint to dents that are engraved in the metal, and the indicated decimation of those marks indicated movement clockwise and counterclockwise. That's about it.

MR. EPPERSON: Were you able to determine what made those marks?

DR. KHALED: There were corresponding contact marks on the lower surface of the Acme nut.

MR. EPPERSON: Okay. So, are you referring to the lower surface of the Acme nut in terms of -- in the area of the stop lugs or what portion of the Acme nut?

DR. KHALED: Of the contact lug itself, the stop lug and elsewhere.

MR. EPPERSON: Was there any evidence of damage on the normal contacting surfaces of the lower mechanical stop where the stop bolts or anything that would indicate a rotation of the Acme nut into the lower stop?

DR. KHALED: My recollection is no.

MR. EPPERSON: Was there -- did you have any more observations on the damage to the lower stop?

DR. KHALED: The splines had damage to them, suggesting tilting of the Acme screw.

MR. EPPERSON: Okay. These are the splines that are on the inside diameter?

DR. KHALED: On the inside of the nut -- excuse me -- the inside of the lower mechanical stop, and those are the splines that mate with the Acme screw.

MR. EPPERSON: Okay.

DR. KHALED: And also on the lower surface, which is the surface that corresponds to the retaining nut and washer. There was an engravement, an impression of the washer on to one side, suggesting again tilting of the Acme screw.

MR. EPPERSON: So, the spline damage and the lower surface damage indicated that the -- were indicative of a twisting or a tilting of the stop on the Acme screw?

DR. KHALED: That is correct.

MR. EPPERSON: Let's divert our attention just slightly into the Acme nut as it was recovered and examined.

I might note that almost all of the exhibits that he's showing are from Exhibit 15-A with the one exception of, I think, a previous one was from 15- -- was it 15-C? Lower stop. Yes, 15-C.

If you could -- as those --

MR. CLARK: Is this one from 15-A?

MR. EPPERSON: This is from 15-A.

MR. CLARK: Page Number?

MR. EPPERSON: If you could identify as you bring up a photograph the page number and the exhibit number when it comes up?

DR. KHALED: Okay. This is Exhibit 15-A, Page 34, Figure 19. This shows the Acme nut assembly as it was retrieved. As I mentioned, this is not how I saw it. I saw it after they have taken it away from the surrounding structure, and it came here to the NTSB Lab in Washington, D.C.

First observation is that there was some evidence of a reddish grease on the outside of the support structure that is around the Acme nut itself.

When I reached inside the Acme nut itself to feel the place where the threads are supposed to be, there was no feel of a thread, only small bumps, and as you reach inside, you can see the spiral pattern of those bumps, indicating that they were the threads, but that that was all that's left of them.

There was also evidence of some blackish residue around those spiral patterns.

MR. EPPERSON: From what you examined, was there any external damage to the nut that was major external damage that was apparent?

DR. KHALED: No. There didn't appear to be external damage, and the nut could gimbal in all directions.

MR. EPPERSON: Okay. Let's turn our attention just a little bit to the thread remnants, as they've been known, become known, in the -- that were on the Acme screw itself.

DR. KHALED: Okay. Maybe it's best if I show the first picture first, which is this one. Okay. Those are the thread remnants we're talking about.

MR. EPPERSON: Okay. This is again Exhibit 15-C, Page --

DR. KHALED: 15-A, Page 24. Now, with more specific on the -- are we going to show the whole thing? This is Exhibit 15-A, Page 42.

MR. EPPERSON: What does that diagram -- what is it showing us?

DR. KHALED: This diagram shows the relative position of the metal windings that were found. Those were the -- in blue, and the pale red or pink shows the position of the Acme nut at various attitudes. We'll get to that in a minute.

We had two major groups, about eight inches in length, in the mid-part of the Acme screw, and those -- the Acme nut in the seven degrees nose-up coincides with the two groups, and the Acme nut in the .4 degree aircraft nose-down coincides with only the lower group.

Those were, by the way, the locations where the windings or the thread remnants were found and not necessarily where they have separated. I don't know that.

MR. EPPERSON: If I understand you correctly, you're saying that those were just where they were found, and you're not indicating that they separated at those positions?

DR. KHALED: That is correct.

MR. EPPERSON: Okay. About how much of the thread was found?

DR. KHALED: In measuring the length of the helical windings, it was estimated about 75 to 83 percent of the total length of the thread was found.

MR. EPPERSON: Okay. And those were verified as being the same material as the aluminum -- as the Acme nut?

DR. KHALED: Yes.

MR. EPPERSON: Can you tell me a little bit about the geometry of -- after these were removed, correct, from the screw and examined more closely?

DR. KHALED: Okay. We want to look at the -- actually the two of them, and that is Exhibit 15-A, Page 45. The filaments or thread remnants had a rather complicated geometry.

To orient everyone, this is a cross-section or a side view of a filament of a winding. What should I call them best? The thread remnant, and this would be the end which was attached at the root, and this would be the edge inside of the nut. So, that would be the minor diameter. The major diameter, upper surface, lower surface. Upper and lower orient the jackscrew as it is in the aircraft.

MR. EPPERSON: As it is in the aircraft. Was that how these were recovered, also?

DR. KHALED: I'm not sure. I don't -- my recollection is that they weren't.

MR. EPPERSON: That they weren't recovered in this orientation?

DR. KHALED: Oh, you mean -- no. Yeah. The up is up and the down is down. Yeah.

MR. EPPERSON: Okay. Can you tell us a little bit about what these can tell us in terms of geometry?

DR. KHALED: Okay. The first observation is the upper surface was more or less flat, concave, if you will, a little concave, with no evidence of wear marks on.

The lower surface of the remnant, of a typical remnant, had three bevels to it, and the last two bevels, Number 2 and 3, seemed to correspond fairly well with the flank and chamber of the Acme screw thread tooth.

There was a shear fracture at the OD on the outside here, and that shear fracture indicated that it -- that we had a movement up. That shear happened with the part of the remnant moving up.

MR. EPPERSON: In terms of a thread remnant moving up relative to the nut?

DR. KHALED: Yeah.

MR. EPPERSON: Okay. You mentioned bevel. What are you meaning by "bevel"? What is your nomenclature to using in that?

DR. KHALED: This is -- can we throw this down a little? This is Bevel 1, Bevel 2, and Bevel 3.

MR. EPPERSON: Okay. And if I understood you correctly, Bevel 2 and Bevel 3, was it, that matched the profile on this group?

DR. KHALED: Yes.

MR. EPPERSON: Okay. Bevel 1 didn't match a profile of the screw?

DR. KHALED: No. I mean, not the way it is oriented now.

MR. EPPERSON: Okay. Can you tell me about how thick the area was that sheared in these samples?

DR. KHALED: Okay. Let me move -- the shear area here varied from 13 to 17,000ths of an inch. The overall dimension of the remnant cross section was about one-eighth of an inch, that's .125, in this direction, and there was the thinned-down section here that was even lower than -- lesser than the 13 to 17,000ths in some cases.

I forgot to mention that there was also a radial fracture separating the remnants from one another, and that radial fracture had tensile overload features with some twisting in the end.

MR. EPPERSON: Okay. So, you're telling us that to the left of those views, that the fractures there were shearing, nuts sliding -- the tooth cutting away from the nut, and then that the individual thread filaments were separated from each other by these other fractures?

DR. KHALED: That is correct.

MR. EPPERSON: In terms of strength, are there some simple calculations that could be performed telling us what the load-carrying capability of those remnants were as they are?

DR. KHALED: Yes. Calculation was performed on a completely healthy thread, and it showed the shear capability of about 2.2 million pounds.

MR. EPPERSON: That was for an entire nut or for a thread?

DR. KHALED: Yeah. To remove all the threads at the same instant.

MR. EPPERSON: In relationship, what would be the load-carrying capacity of that thread, if all the threads were of that size?

DR. KHALED: Can you clarify the question?

MR. EPPERSON: If all the threads were reduced down to that 13 to 17,000, what would be the load-carrying capacity?

DR. KHALED: The 13,000 would bring an order of magnitude down, like it would become about a 191,000 pounds force, and for one tooth, it would be about 5,800 compared to 68,000 pounds of the healthy thread, one tooth.

MR. EPPERSON: As, I guess, a relative -- to get everybody up to speed on relative size of these teeth, these were 13,000ths. How large is a -- how thick is a per-design tooth originally manufactured?

DR. KHALED: At the base -- we have a trapezoidal cross-section, at the base of which, we have .15 inches, --

MR. EPPERSON: So, --

DR. KHALED: -- and at the top, we have about .1 inches, and the height of the tooth would be .125.

MR. EPPERSON: Okay. By the base, you're talking -- you're referring to the major diameter location?

DR. KHALED: Yes.

MR. EPPERSON: Okay. So, at the major diameter on a new tooth to the original drawing tooth, it would be about a 150,000ths, is that correct?

DR. KHALED: That's correct.

MR. EPPERSON: And on these thread remnants, there are about 13 and 17,000ths?

DR. KHALED: Yes.

MR. EPPERSON: 13 to 17,000ths?

DR. KHALED: Yes.

MR. EPPERSON: Okay. Thank you. Let's get into something that's a little bit more esoteric. Let's get into some kind of metallurgy, what they pay us for.

In dealing with the Acme screw, the Acme nut, and the torque tube, there was a series of tests and examinations performed on the Acme screw. Could you briefly tell us the metallurgical results of those?

DR. KHALED: Yes. The metallurgical tests of the Acme screw consisted of case depth determination, case hardness determinations, core harness determination, and general microstructure examination, and the case depth was about 4 to 7 mil --

MR. EPPERSON: 4 to 7,000ths of an inch?

DR. KHALED: I'm sorry. Yes. 7 mils. 4 to 7 mils.

MR. EPPERSON: Okay. Were those measurements -- did those comply with engineering drawing requirements?

DR. KHALED: Not at the time of manufacture. At the time of manufacture, the requirement was 3 to 5 mils -- I'm sorry -- 3,000 to 5,000 inch case depth, and subsequently, in two iterations, it was changed to .003 or 3,000 to 7,000, and then 3,000 to 10,000.

So, what we have per se does not conform to the time of manufacture requirements, but it conforms to later requirements.

MR. EPPERSON: So, basically, you're telling me that the requirements changed --

DR. KHALED: Yes.

MR. EPPERSON: -- on the blueprint, and that original requirements at the time this was manufactured, this would not have met requirements?

DR. KHALED: Yes. Only inasmuch as case depth is involved.

MR. EPPERSON: Okay. How about the other -- were they in or out of requirement?

DR. KHALED: They all conformed, case hardness, core hardness, microstructure, everything conformed, and the material, of course.

MR. EPPERSON: And the material. How about the finishes on the screw? Were they examined?

DR. KHALED: Yes. They all conformed. We had basically in our collection, we had two finishes, you know, cadmium on the extremes and black oxide coatings, and for part, we had the threads, and they conformed. It was coated.

MR. EPPERSON: Okay. And also, was the surface finish measured? The surface roughness measured, and what were the results of that?

DR. KHALED: I'm not too clear on that. The surface finish on that particular one, I believe, conformed to the 32 rms requirement.

MR. EPPERSON: So, the surface roughness was --

DR. KHALED: Yes.

MR. EPPERSON: -- in compliance?

DR. KHALED: Root mean square, rms.

MR. EPPERSON: Let's move to the aluminum -- the Acme nut a little bit, a little bit more in detail. What were some of your initial observations and some of the -- with regard to the -- particularly with regard to the grease fitting passageways in the area around?

DR. KHALED: Okay. If I may first just introduce a cross-section, just to clarify what we are talking about, what I'm talking about. Can I get this one, please?

MR. EPPERSON: That is Exhibit 15-A- --

DR. KHALED: 15-A-55.

MR. EPPERSON: -- 55?

DR. KHALED: 55. So that we all kind of talk the same, this is what we call the "grease fitting", otherwise known as "zerg" fitting by some people. This is what we call the passway, and this is the counterbore. This is the inside of the nut. You can see the threads. This is the outside, the aluminum support bracket.

MR. EPPERSON: So, to help clarify for me, this is an illustration of a cross-section --

DR. KHALED: Yes.

MR. EPPERSON: -- through -- okay.

DR. KHALED: Okay. With this in mind, let me go back to the top one. Okay. The first thing we have done is that we removed the grease fitting, also known as the zerg fitting, and it was noticed that it had a reddish grease on it. It was soft, looked like good grease, if I may.

On the outside, you can see the color here, and on the inside, the fitting appeared not to have anything, and I'd stress the word "appeared". Okay. Second thing we did is we probed with a wire from this end of the fitting, and the wire came with a little sample, if you will, or piece of reddish grease close to the injection end of the grease or zerg fitting.

MR. EPPERSON: Okay.

DR. KHALED: The next thing we did -- mind you, all this was before doing anything to the nut.

The nut was still intact because, subsequently, we sectioned it.

Second, this one again, of course, we had already removed the grease fitting. The passway appeared clogged, and it was very hard to remove. We had to employ a flat punch and put it in from this side and punch it to get what's sent out, and then we had to come in with a sharp tool and scrape what's in here.

The end result of all of this is what we have in this lower picture here, and we are 15-A, Page 54, Figure 50. I'm sorry. I'm oscillating back and forth.

MR. EPPERSON: If you'd just make sure that we know the exhibit number and the exhibit page.

DR. KHALED: Yeah. This one is 15-A, Page 54, Figure 50. You can see the assortment of debris obtained from inside of the passway and the nut, and this particular piece here came from the passway itself. It looked like it was a plug in there.

This debris came by the sharp tooth from the counterbore, and in various analysis, suggestive of grease remnants or residue, and there were metallic couple-like particles, specifically aluminum and bronze, later, and that's it.

MR. EPPERSON: So, this material that you're showing now was actually inside the grease passageway of the nut and was visible looking in, was it, to the nut?

DR. KHALED: That is correct.

MR. EPPERSON: Okay. Did the Materials Group perform any tests on that material?

DR. KHALED: On the grease itself?

MR. EPPERSON: On the blockage material?

DR. KHALED: I'm not sure. I said it was grease residue, grease residue, I believe.

MR. EPPERSON: Okay. Can you talk to us a little bit about the grease, the examination of the gimbal ring for grease, and --

DR. KHALED: Yeah. The -- in both gimbal rings, the grease fittings were removed, and the holes inside there, we found red translucent grease, suggestive of Mobil 28, Mobil Grease 28, I think.

MR. EPPERSON: Okay. So, that's Exhibit what, 15-A?

DR. KHALED: 15-A, Page 56, Figure 53.

MR. EPPERSON: Okay. This is a view looking at?

DR. KHALED: Looking inside the passway or the hole inside the gimbal ring.

MR. EPPERSON: Okay. And that material there that's -- is that what you're referring to as the grease?

DR. KHALED: Yes.

MR. EPPERSON: Okay.

DR. KHALED: That's consistent with Mobil Grease 28, if I remember correctly.

MR. EPPERSON: Okay. At some point in your -- in the Materials Group examination, the accident Acme nut was cut and additional tests were performed on it. Could you describe some of those observations and findings?

DR. KHALED: Okay. Exhibit 15-A, Page 57, Figure 55. We did -- after we secured all the samples inside and send them for analysis, we cut the Acme nut in half, as you can see in this figure, and we looked at the profile, the remaining profile of the threads and compared them with an exemplar nut that we pulled out, I think, from Trig Engineering. The top one.

MR. EPPERSON: So, in that view, the exemplar is the top one, and the accident nut is the bottom one?

DR. KHALED: Yes.

MR. EPPERSON: Okay. And those are longitudinal cross-section screw nuts?

DR. KHALED: Yes, and you can note how in a "healthy" nut, you have the thread profiles so prominent, and over here, you can't hardly see them.

Let's go to a higher magnification here on that. This one. This is a higher magnification of the Acme nut. We're talking about this surface is the cut surface of the nut, and the helical patterns are like so, and you can see how these bumps --

MR. EPPERSON: The bumps on the top surface there?

DR. KHALED: Yeah. Those are the bumps that were on the spiral pattern that described the initial thread.

MR. EPPERSON: Were they -- were there any other marks on the inside of that nut?

MR. CLARK: This -- the bumps is what is left from the threads?

DR. KHALED: Yes.

MR. CLARK: The threads are gone, and what's left are the bumps?

DR. KHALED: Are those little bumps in the spiral pattern.

MR. CLARK: Okay.

DR. KHALED: There was, of course, evidence of black residue, probably grease, around the spirals, but it was dried. It was not soft, and there were other marks, scratches if you will. We are talking about Exhibit 15-A, 15-A, Page 60, Figures 58 and 59.

58 -- am I there? I wanted the top one first. In Figure 58, we can see those are the spirals that we were talking about, where the threads were, and those are circumferential marks that suggest that the Acme screw had moved after the Acme nut threads had separated.

MR. EPPERSON: So, the -- could you point out the spiral that you were talking about?

DR. KHALED: Spirals, and this is circumferential. Okay.

MR. EPPERSON: Okay. And those marks are basically telling you what again?

DR. KHALED: That the Acme screw had rotated after the Acme nut threads had separated in that location.

MR. EPPERSON: Okay. Were there additional marks on the inside of the --

DR. KHALED: Yes. There were longitudinal. Now, remember, this is the length of the nut. There were longitudinal marks, see, that also suggest there was movement of some object in there. I don't know what.

MR. EPPERSON: Okay. The -- I believe that's all I have for you, Dr. Khaled.

With the Chairman's permission, additional questioning will be performed by Ms. Lorenda Ward of the Tech Panel.

MR. HAMMERSCHMIDT: Okay. Thank you, Mr. Epperson.

Before proceeding to Ms. Ward, let me point out again just a minor edit that was noted when we were on Figure 55 on Page 57, in which the caption of the photograph refers to one Acme nut thread profile as top, the other one as below, and that should be in reverse.

For those who are following this in their exhibits, you need to make that correction, if you would. We've caught it up here. So, just point that edit out to those --

MR. EPPERSON: Okay. Figure --

MR. HAMMERSCHMIDT: That's Figure 55.

MR. EPPERSON: -- 55. I'll -- okay. I'll make sure that that gets corrected in the record.

MR. HAMMERSCHMIDT: Okay. Thank you. And

now, we proceed to Ms. Ward.

MS. WARD: Okay. Thank you, Mr. Chairman. If Mr. Umeda could change places with Dr. Khaled, please.

Mr. Umeda, we've now heard testimony on both the systems and metallurgical findings. What I'd like for you to do is to give us the details of the significant structural findings on the empennage of the accident airplane, starting with the center section of the horizontal stabilizer.

MR. UMEDA: Ms. Ward, this is a front view of the horizontal center section front spar.

MR. HAMMERSCHMIDT: Okay. What -- did we identify the exhibit?

MR. UMEDA: This is in Exhibit 7-Q, and that's Page 7, Photograph 14.

MR. HAMMERSCHMIDT: Excuse me. I might interject here just a word of process, that it's important to identify the exhibits and the page numbers for the purposes of the written transcript in particular. So, even though we're seeing them here very clearly, it -- there is a purpose for going through that procedure.

So, thank you.

MR. UMEDA: As I just mentioned, this is a view looking aft at the horizontal stabilizer front spar center section. As you can see, these are the brackets that attach the horizontal front spar to the jackscrew assembly.

If you notice, both these brackets, both right- and left-hand side, are bent over to the right. If you notice closely, the lower legs on both brackets, both left- and right-hand side, are fractured.

If you notice over here, this is the lower spar at forward tang. There is a circular indentation, and there is thread impression visible in that indentation. The upper spar cap, both right- and left-hand side, are fractured in the same manner.

MS. WARD: Mr. Umeda, could you clarify when you said right on support brackets?

MR. UMEDA: These support brackets here?

MS. WARD: Yes.

MR. UMEDA: These support brackets support the jackscrew assembly to the front spar of the horizontal stabilizer.

MS. WARD: I meant the direction of the bend.

MR. UMEDA: Well, we're looking aft at this picture here, but if you're looking forward, they're bent over to the left.

MS. WARD: Thank you. Okay. Could you next describe the elevators?

MR. UMEDA: I have a few more observations in the aft section of the horizontal stabilizer system.

MS. WARD: Okay. Thanks.

MR. UMEDA: You can't really see some of the important points of this.

MR. HAMMERSCHMIDT: This is Exhibit 7-Q, Page 10.

MR. UMEDA: This is Page 10, Photograph 19. Excuse me.

This is a view looking forward on the rear spar of the horizontal stabilizer center section. There are ribs, there are production ribs aft of the rear spar, and there are production holes that the elevator control sector shaft would penetrate.

If you look at the left-hand side rib, looking outboard, you see the hole, the production hole. It's elongated at the 2:00 position. If you look at the right-hand rib, looking outboard, the production hole is elongated at about the 8:00 position.

If you would notice the center section rear spar, lower spar cap, aft tang, both right- and left-hand side aft tangs are fractured and bent up.

MS. WARD: Okay. Now, could you describe the elevators for me?

MR. UMEDA: Both the left- and right-hand side elevators were recovered, along with their respective tabs, both control, geared and anti-float tab.

The right-hand elevator was separated into five sections, where the left elevator was recovered in three sections.

MS. WARD: Could you describe the overall condition of the recovered horizontal stab?

MR. UMEDA: Yes, Ms. Ward. The right side of the horizontal stabilizer is more fragmented than the left-hand side.

MS. WARD: Could you continue on with the description of the vertical stabilizer?

MR. UMEDA: The left -- the full left scan of the vertical stabilizer still remained attached to the fuselage. The lower six feet or so of the rear spar remained attached to the rear spar bulkhead in the fuselage section, and the entire rear spar and the fuselage bulkhead exhibit the 45-degree rotation, in a clockwise rotation, if you will look downward.

The center spar is also attached to the vertical stabilizer -- excuse me. The center spar vertical stabilizer is attached to the center spar bulkhead in the fuselage and exhibits the same 45-degree rotation as the rear spar.

MS. WARD: Could you go into detail about the findings that were on the upper hinge on the rear spar?

MR. UMEDA: This is Page 13, Photograph 25. This is the upper rudder hinge looking downward. If you notice, there's a shroud on both left- and right-hand side in the deformed downward.

There are marks on both shrouds, left- and right-hand side, in these locations here. Those marks approximately match the dimension of the elevator sector fully.

MS. WARD: I'd just like to mention that all the photos that will be shown at this time all come from Exhibit 7-Q. So, any time he refers to a photograph, it's in Exhibit 7-Q.

Could you go into detail about the description of the structure that surrounds the gimbal and the vertical?

MR. UMEDA: This is on Page 12, Photograph 23. The Acme nut and gimbal is attached to the vertical stabilizer with these fittings, and these fittings are attached to the vertical stabilizer with two ribs, the forward rib and the aft rib. These are the lugs that are attached to the Acme nut and gimbal rings.

As you can see in this photograph, the aft rib is fractured approximate in the -- down the center line and torn away, and the left-hand side looking forward is torn away from the vertical stabilizer side skin. Also in this picture, the left-hand side of the vertical stabilizer skin is not present.

MS. WARD: And this photo was taken after the Metallurgical Group removed the gimbal?

MR. UMEDA: Yes, it was.

MS. WARD: Could you describe the horizontal pivot?

MR. UMEDA: This is on Page 12, Photograph 22. This is a view, a side view of the horizontal to vertical joint or the pivot joint. This is the lower surface of the horizontal stabilizer. This is the rear spar of the vertical stabilizer, and the closure spar here.

Here's the pivot joint in this area here. This is the lug attached to the horizontal stabilizer lower surface. This is the hinged lug attached to the vertical stabilizer.

As you can see, the joint still remains intact. The retainers, the through bolts, the lugs are not failed. If you would -- at the lower section of the horizontal stabilizer lug, there is a grease fitting, and also a flat portion of that lug to house the grease fitting. Those grease fittings are sheared off.

Also, if you look inside of the vertical stabilizer lug, there seems to be -- there is a scrape mark in a circular fashion that corresponds to the location of the grease fitting.

There's also a mark on the horizontal stabilizer lug that corresponds with this rear spar edge of the vertical stabilizer fitting or fitting lug.

MS. WARD: Could you go into detail about the vertical tip faring?

MR. UMEDA: The vertical tip faring is a faring that --

MS. WARD: Could you state the page number?

MR. UMEDA: Oh, excuse me. This is Page 11, Photograph 20. The vertical tip faring surrounds the upper portion of the horizontal stabilizer.

As you can see in this picture, this is the mid section of the vertical tip faring. Normally, it's not shaped in this fashion. It comes straight across, and this is the aft section of the vertical tip faring.

The forward portion of the vertical tip faring or the upper leading edge, about 25 percent of the tip faring, was not recovered.

If you look closely at the forward end of the mid section, the forward end is crushed. Also, there are two fasteners on both the left- and right-hand side, are still in place, and those fasteners attach that portion of the tip faring to the vertical stabilizer.

If you notice the right-hand side of the tip faring, that you see over here, is more damaged than the left-hand side, looking forward.

There is a fracture along this lower portion of the cut-out of the tip faring, both left- and right-hand side, that matches the location of the elevator control sector shaft.

MS. WARD: Were the fractures from the mid section and the aft section of the vertical tip faring matched?

MR. UMEDA: This location here, yes. Yes, they do match.

MS. WARD: Okay. Could you go into the condition of the rudder?

MR. UMEDA: Three major portions of the rudder sections were recovered, along with several smaller fragments, and those fragments vary in size from about four inches to about two feet in length.

MS. WARD: Do we have any significant findings on the rudder?

MR. UMEDA: Yes, we do. This is on Page 13, Photograph 24. This section of the rudder is the upper aft portion of the rudder. The right-hand side. If you notice, there is damage in the upper portion of the rudder here, and the size of that damage matches the elevator control sector shaft.

Also, there are ping abrasion marks scraping along in this section here, actually multiple ping abrasion marks in that section.

MS. WARD: Was the rudder placed inside the horizontal stab, the aft section, this recovered piece, and did it match up to any pieces that were lodged in the horizontal stab?

MR. UMEDA: Yes. On the recovered piece of the horizontal stabilizer, there are brackets that house a faring that seals the interface between the horizontal stabilizer and the tip faring, and in the upper portion of that fitting, there were pieces, composite pieces found in that faring that's from the rudder.

MS. WARD: Okay. Thank you for the overall description of the damage.

I'd now like to move on to talk about the rigid body model. Did Boeing produce a rigid body model?

MR. UMEDA: Yes, we did.

MS. WARD: Why?

MR. UMEDA: This was in response to an NTSB request to determine the component interferences as the horizontal leading edge, horizontal stabilizer leading edge rotates in the upward fashion beyond its normal operating limits.

MS. WARD: Okay. Could you describe the rigid body model?

MR. UMEDA: The rigid body model uses a Unigraphics Tool Program that we use for lay-out and solid modeling, and we took information that we used from production to provide a solid model of the horizontal stabilizer and its surrounding structure.

MS. WARD: Okay. Could you use Exhibit 7-T and go through the rotation of the horizontal stab and contact points that came up with the rigid body model?

MR. UMEDA: Yes, I can. This is Page 4 of the exhibit. At 2.1 degrees, the electrical stop actuates or stops the rotation of the jackscrew assembly.

This is Page 7 of the exhibit. At 2.6 degrees is when the mechanical rotation of stop engages with the Acme nut stop. That's this portion in this illustration here.

MS. WARD: Now, during the normal operation of the airplane, would it engage the mechanical stop?

MR. UMEDA: No, it would not. Normal operation of the airplane will limit the travel at 2.1 degrees at the electrical stop.

At 3.1 degrees, that's when the gimbal nut stop lower surface would contact the rotational stop upper surface. This location here.

MS. WARD: Could you give the page number, please?

MR. UMEDA: This is Page 10. Excuse me, Ms.

Ward.

MS. WARD: Thank you.

MR. UMEDA: Would you like me to go on?

MS. WARD: Yes, please.

MR. UMEDA: At 3.6 degrees, the horizontal stabilizer front spar, upper cap, upper surface, would contact the vertical stabilizer tip faring, in this location here.

MS. WARD: Could you give the page number?

MR. UMEDA: I'm sorry. This is Page 12.

MS. WARD: Thank you. Did you find evidence of contact on the accident airplane in this area?

MR. UMEDA: Yes, we did, Ms. Ward. The -- as I mentioned before, there are two fasteners here that attach this section of the tip faring to the vertical stabilizer, and they were intact.

The lower surface of this tip faring where the two fasteners are were crushed, and there were corresponding witness marks in the same location on the front spar, horizontal front spar, upper cap, upper surface, that matches the location of that tip faring location.

MS. WARD: Thank you.

MR. UMEDA: This is Page 16 of the exhibit.

At 3.7 degrees, the elevator control sector pulley contacts a horizontal web in the vertical tip faring.

MS. WARD: And did we have matching marks there on the accident airplane?

MR. UMEDA: Yes, we did, Ms. Ward. We found matching marks in -- at the edge of the lightening hole, and those marks matched closely to the dimension of the elevator control sector shaft.

MS. WARD: Okay.

MR. UMEDA: This is Page 19 of the exhibit. At 4.6 degrees, the jackscrew primary motor, upper surface, contacts a former on the upper portion of the vertical tip faring, at this location right here.

MS. WARD: The area you just pointed to, is that the location where we do not find the 25 percent of the vertical tip faring?

MR. UMEDA: Yes. This portion that I'm outlining here was not recovered at the crash site or was not recovered at all.

MS. WARD: Thank you.

MR. UMEDA: This is Page 22 in the exhibit. At 6.4 degrees, the elevator control shaft contacts the tip faring cut-out, lower cut-out surface, at this location over here.

MS. WARD: And did we have matching marks?

MR. UMEDA: Yes, we did. Previously, I mentioned from the photograph we saw of the tip faring, there was a fracture, both left- and right-hand side, that matches that location of the elevator control sector shaft.

This is Page 29 in the exhibit. At 11.6 degrees, the horizontal stabilizer constant section, rear spar, lower cap, aft tang, contacts the tip faring cut-out at its lower section, at this location right here.

MS. WARD: And did we have matching marks?

MR. UMEDA: Yes, we did. As previously mentioned from the photographs, those tangs, both left- and right-hand side, are fractured and bent upward.

MS. WARD: Okay.

MR. UMEDA: This is Page 30 in the exhibit. At 15 degrees, leading edge horizontal stabilizer rotation, that is the point when the jackscrew exit the Acme nut, at this location right here.

MS. WARD: Okay.

MR. UMEDA: This is Page 25 in the exhibit. At 16.2 degrees is when the horizontal stabilizer pivot lug, grease fitting area, located right here, contacts the vertical stabilizer rear spar cap.

MS. WARD: And do we have contact marks?

MR. UMEDA: Yes, we do. As previously mentioned, the grease fitting was sheared off.

This is Page 26 in the exhibit. At a 105.3 degrees, horizontal stabilizer leading edge up, the elevator control sector pulley contacts the A-frame or the rudder upper hinge at this location over here.

If you look down on that A-frame, when looking down on the A-frame, the contact area is this location of the A-frame.

MS. WARD: Is this in the exhibit?

MR. UMEDA: Yes. This is Page 28 in the exhibit. Excuse me.

MS. WARD: Thank you. Now, do we have matching marks on the accident airplane?

MR. UMEDA: We do have matching marks, Ms. Ward, but our model indicates that rotation of the horizontal stabilizer would not match those -- the location of the matching marks on the shroud of that -- of the upper hinge fitting, which was found in this location here.

In order for that to happen, the elevator control sector would have to displace or the horizontal stabilizer would have to clock or rotate.

MR. CLARK: Which rotation were you talking about first? You said the rotation would not match. Do you mean upward rotation?

MR. UMEDA: If you rotate the horizontal stabilizer leading edge up, without any rotation, as if you look down or clocking, the --

MR. CLARK: The clocking, you were -- there's rotation of the leading edge up, and then there's also rotation you referred to as clocking.

MR. UMEDA: That clocking -- okay. The way you could look at that is if you're looking down at the horizontal stabilizer, and it's clocking in a yaw direction of the airplane.

MR. CLARK: That would be if the horizontal -- if you're looking downward, and the horizontal stabilizer is twisting, --

MR. UMEDA: That's correct.

MR. CLARK: Okay.

MS. WARD: Did you state earlier that the elevator shafts looked like they had came in on to the faring or the -- I should say the aft production holes?

MR. UMEDA: Yes, that's correct. There are -- as I stated earlier, from the photographs, there are two ribs, both left-hand and right-hand rib, that extends out from the rear spar of the horizontal stabilizer, and the production holes that the elevator control shaft penetrates is elongated.

The left-hand rib, looking outboard, is elongated in about the 2:00 position, and the right-hand rib, looking outboard, is elongated at about the 8:00 position.

MS. WARD: Thank you.

MR. CLARK: If you don't mind, just -- if you'd leave that back up just a quick second.

What I understood you to say is that if the leading edge simply rotates up, you cannot get the damage you saw in the wreckage?

MR. UMEDA: That is correct, Mr. Clark.

MR. CLARK: You also have to have it rotate up and then do the clocking motion, such as rotate the entire stabilizer left or right to create that damage?

MR. UMEDA: That's correct.

MR. CLARK: Okay.

MR. UMEDA: That completes the results of the rigid body model.

MS. WARD: Okay. Mr. Umeda, did you participate in the dimensional check that was held at the Alaska Airlines facility in Seattle, Washington, on the 21st of July in the year 2000?

MR. UMEDA: Yes, I did, Ms. Ward.

MS. WARD: And what was the purpose of this visit?

MR. UMEDA: The purpose of the visit is to conduct a dimensional check on a production MD-83 and to compare those dimensions within the normal operating limits of the horizontal stabilizer and as clearances to various components to that of the rigid body model.

MS. WARD: Can you describe what happened during that visit?

MR. HAMMERSCHMIDT: Ms. Ward, if I might interrupt your interesting and informational line of questioning, the new clock in the new Board Room has just struck 2:00, and I believe we would like to recess one hour for lunch.

Would you be able to hold that last question until we reconvene?

MS. WARD: Yes, sir.

MR. HAMMERSCHMIDT: This would be an all right place to take a break?

MS. WARD: Yes.

MR. HAMMERSCHMIDT: Very good. We therefore will take a lunch break, and we stand in recess until 3 p.m.

(Whereupon, at 2:01 p.m., the public hearing was recessed, to reconvene this same day, Wednesday, December 13th, 2000, at 3:00 p.m.)

A F T E R N O O N   S E S S I O N

3:04 p.m.

MR. HAMMERSCHMIDT: We will reconvene this public hearing. The time is 3:04 Eastern Standard Time, and a note. We're missing one person from our Witness Panel, but is he going to be asked questions in the next few minutes, Ms. Ward? Mr. Talay?

MS. WARD: No, sir.

MR. HAMMERSCHMIDT: Okay. Very good. I might mention again for those who may have arrived at the Washington location here, of course, this is also being telecast to the people and the family members of those who were on this plane, who are located in both Washington State and California.

But for those here that may have arrived late, let me just mention that this public hearing is primarily a work session of the National Transportation Safety Board. We term it a "public hearing" because the public is welcome to attend and is attending, and therefore it affords the public an opportunity to see part of their government in action, and I want to emphasize that it is a working session. It's not choreographed in any way really, and we will proceed with the questioning by Ms. Lorenda Ward, who is the Structures Group Chairman on this investigation.

Ms. Ward.

Interviews of Ken Umeda, Dr. Terry Khaled,
Jim Talay and Peter Kovacik Resumed

MS. WARD: Thank you, Mr. Chairman.

Mr. Umeda, we established that you did attend a dimensional check that was held at the Alaska Airlines facility.

Now, could you describe what went on during that dimensional check?

MR. UMEDA: Yes, Ms. Ward. I'm sorry. Is this working? This was an NTSB Structures Group activity. We went to Seattle, and we obtained the MD-83 aircraft courtesy of Alaska, and we -- the first part of the procedure was to determine the zero horizontal trim, which we lined up production rivets on the leading edge of the horizontal stabilizer to rivets on the vertical stabilizer that's used for production rigging, and that establishes your zero degree horizontal stabilizer trim.

We placed a digital protractor on the upper surface of the horizontal stabilizer and calibrated it at zero degrees. We rotated the horizontal stabilizer leading edge up to its electrical stop and also to the mechanical stop when -- the mechanical rotational stop when the gimbal nut stop contacts the lower stop in a rotational fashion.

Several measurements were taken. May I refer to Exhibit 7-T, Page 3, to help in the description of the dimensions taken?

MS. WARD: Could you give the page number, please?

MR. UMEDA: That's Page 3. Excuse me. The measurements that were taken were the upper surface of the jackscrew primary motor to the former on the upper faring skin here. Also, the dimension that was taken was a clearance between the horizontal front spar upper cap, upper surface, to the bottom of the vertical tip faring cut-out at this location here.

Also, clearances were measured between the elevator control sector shaft to the lower portion of the tip faring cut-out at this location, and the elevator sector control pulley clearance between the horizontal web and the tip faring to the control sector pulley.

Also, the clearance was measured between the Acme nut stop to the lower surface of the rotational stop collar.

MS. WARD: Could you go into the results?

MR. UMEDA: Measurements were taken at those locations and compared with the dimensions predicted by the Boeing Rigid Body Model, and it was determined and decided, the group decided that no other measurements would be necessary on additional airplanes to have confidence in the Boeing Rigid Body Model.

MS. WARD: At this time, Mr. Chairman, I'd like to go ahead and pass the questioning of Mr. Umeda over to Dr. Dan Bower.

MR. HAMMERSCHMIDT: Very good. Please proceed, Dr. Bower.

DR. BOWER: Thank you, Ms. Ward. I just wanted to check to see if this was on.

I have some questions for Mr. Umeda. Mr. Umeda, could you describe the loads and forces that act on the horizontal stabilizer in normal operation?

MR. UMEDA: Yes, I can, Dr. Bower. I have a presentation that will aid in the understanding of the basic loads on the horizontal stabilizer and how those loads are reacted to the jackscrew assembly, if I may.

DR. BOWER: Certainly. Proceed.

MR. UMEDA: There are two types of loads on the horizontal stabilizer, those due to the weight of the stabilizer and those due to the aerodynamics or air loads.

The horizontal stabilizer sweeps back, and due to this swept configuration, the center of gravity of the weight of the stabilizer, shown here with the blue line, is located behind the pivot point.

Since the center of gravity shown by the blue line in the previous slide is located behind the pivot point, this direction being forward, the weight pushes down like a teeter-totter and wants to rotate the front of the horizontal stabilizer up. This is reacted by the jackscrew assembly and produces tension in the assembly.

Likewise, the summation of the aerodynamic loads, called the center of pressure, is also located behind the pivot point and produces tension in the jackscrew assembly for normal operating flight conditions.

I think that concludes my -- this portion of the presentation, Dr. Bower.

DR. BOWER: Just a little bit of follow-up. Does that also follow, that if there's any loads on the elevators, that those will be transmitted into the stabilizer?

MR. UMEDA: I'm sorry. Could you repeat the question again?

DR. BOWER: If there's any loads on the elevator, elevators, that those will be transmitted into the stabilizer, also?

MR. UMEDA: Yes, that's correct. Change in elevator deflection will change loads on the horizontal stabilizer.

DR. BOWER: And what other factors tend to change the overall load on the horizontal stabilizer?

MR. UMEDA: There are many factors that change the loads on the horizontal stabilizer. Air speed, change in center of gravity of the aircraft, the altitude, angle of attack, elevator deflection, horizontal trim angle, wing configuration, flaps up, flaps down, slats out.

MR. CLARK: Let me ask. All of those things change the load, but, in general, the loads are always in tension most always? The loads to the jackscrew?

MR. UMEDA: In most cases, the loads are in tension. There are design cases that we certify the aircraft to that are extreme.

MR. CLARK: Okay. But that's not applicable in this accident?

MR. UMEDA: Those are not normal operating flight conditions.

MR. CLARK: Okay. And the weight of the horizontal stab itself tends to raise the leading edge and put the jackscrew in tension, and the aerodynamic loads also tend to raise the leading edge and put the jackscrew in tension?

MR. UMEDA: That is correct, Mr. Clark.

MR. CLARK: Thank you.

DR. BOWER: In the normal operation flight, just to get an idea of the loads we're talking about here, what type of loads will we have, say, on the jackscrew in tension?

MR. UMEDA: I guess that depends on the type of flight. Let's say horizontal trim angle approximately zero degrees, aircraft speed 300 knots, elevator deflection close to zero. Typical cruise of flight would generate approximately 4,000-pound jackscrew load.

DR. BOWER: And that would be at close to a trim condition?

MR. UMEDA: Yes.

DR. BOWER: Now, when this whole horizontal stabilizer was originally designed, what type of design limit load was used in the design of the stabilizer?

MR. UMEDA: The condition for maximum design limit load is a two and a half g dive speed, balanced maneuver steady state pitch, that has an elevator deflection of about seven and a half degrees trailing edge up, and that produces an overall horizontal hinge movement of about 1.75 million inch pounds which equates to a jackscrew load of approximately 37,500 pounds limit.

DR. BOWER: Okay. So, that's the -- that would be the maximum load expected?

MR. UMEDA: Yes. That is the maximum design load -- maximum design limit load to which the jack-screw has to be good for for certification.

DR. BOWER: Okay. I'm going to put up a slide real quick. If I could have my first slide? This is just a replot of some information contained in Exhibit 13-C, Page 8, and this is information from the flight data recorder, and I've just included a few parameters from the accident flight at the time of the first pitch down.

Now, you described a jackscrew load and cruise of approximately 4,000 pounds. Would that be similar to the condition we have immediately before the first pitch down?

MR. UMEDA: I'm sorry. Similar that we had immediately before?

DR. BOWER: Yes.

MR. UMEDA: Yes, that is correct, Dr. Bower.

DR. BOWER: Now, we see here in this data at the time of the first pitch down, when the stabilizer moves down to a lower position, approximately 2.4-2.5 degrees.

Have you been able to determine what the load is on the jackscrew after this movement in position?

MR. UMEDA: The jackscrew loads during or after the first pitch over are still in the development, and I'm not able to answer that question.

DR. BOWER: Okay. That's still under investigation.

In relative terms, can you just describe how this change in stabilizer position would affect the load? Just so we're sort of clear, this first pitch down I'm referring to occurs at time of about 1609 and 16 seconds, right in the middle where the --

MR. UMEDA: Well, you have decreasing altitude and increasing horizontal trim. Aircraft nose down. Increasing elevator deflection, trailing edge up. That would increase the jackscrew loads.

DR. BOWER: So, we do expect to see an increase in the load on the jackscrew after this first stabilizer movement?

MR. UMEDA: Yes, I would, Dr. Bower.

DR. BOWER: Okay. If I could put up my Slide Number 2, --

MR. CLARK: Just a second. Before you go on, you talked about the loads. You don't know what the loads are. Do you have -- surely you have an idea of magnitude from that zero trim to the 2.5 degrees. How much would the loads be at zero degrees? Do you have any idea?

MR. UMEDA: Again, the loads are under development, and I'm not able to answer that question, Mr. Clark.

MR. CLARK: Do you have an idea, a rough idea, to the nearest thousand pounds or something like that?

MR. UMEDA: Certainly any variation in parameters may vary the loads by more than that magnitude.

MR. CLARK: Well, just -- okay. Before the elevator moved to the 2.5 degrees in the normal flight regime, you're telling me that those -- to determine those loads is still under development?

MR. UMEDA: I'm sorry. Would you repeat that question again, Mr. Clark?

MR. CLARK: Yes. At the point where the pitch trim is still less than one degree, at that point in time, we have a speed, and we have an altitude, and we know reasonably well the settings, and Boeing hasn't developed numbers yet for the load on that jackscrew at that point?

MR. UMEDA: That was -- are you speaking before the first pitch over?

MR. CLARK: Yes.

MR. UMEDA: Yes, we have, and as I testified to Dr. Bower, that was about 4,000 pounds.

MR. CLARK: Okay. I missed that. And then, the 2.5 degrees, the step beyond that is -- that's the numbers that are still under development?

MR. UMEDA: Yes, that's correct.

MR. CLARK: Okay.

DR. BOWER: Okay. If I could have my Slide Number 2 up, please? Okay. This is a reproduction of some data included in Exhibit 13-C, Page 7, and again this is a reproduction of a few of the parameters.

From the top down, we have computed air speed. In the middle is elevator, and the third plot is pitch angle, and this is for the approximately nine minutes between the first pitch-down event and the second pitch-down event described by Mr. Rodriguez.

Could you just -- you've mentioned how some of these parameters affect load. Could you just again go through, describe how the parameters shown would affect the load on the jackscrew?

MR. UMEDA: Yes, I can, Dr. Bower. As you see here, the computed air speed varies in magnitude from 350 knots and drops down to about 250 knots, increases again to approximately 340 knots, drops down to again about 250 knots. That would cause variation in the magnitude of the jackscrew loads.

The elevator trailing edge up went from zero to about negative 12 degrees. It was reduced to about seven degrees, and I see it also obtained approximately

14 or 13 degrees. That would also affect the jackscrew loads, and that would produce varying magnitudes of jackscrew loads throughout this sequence.

DR. BOWER: Okay. So, if we were to assume that we had a constant stabilizer angle, would we expect the jackscrew load to vary in a similar fashion to what we see with the elevator traits?

MR. UMEDA: Yes.

DR. BOWER: Okay. That's all I have for Mr. Umeda. I do have a couple of questions for Mr. Kovacik.

MR. HAMMERSCHMIDT: Please proceed, Dr. Bower.

DR. BOWER: Mr. Kovacik, in Exhibit 9-I, from the Systems Group Report, refers to a Tulsa ground test that you participated in. Could you just briefly describe the purpose of the Tulsa ground test?

MR. KOVACIK: One of the purposes of the Tulsa test was to evaluate the stabilizer position-sensing system to determine with greater than normal horizontal stabilizer positionings how the stabilizer position sensor system would react to that. What kind of numbers would be produced by the position sensor for the horizontal stabilizer?

DR. BOWER: And could you describe some of these -- any of the results you saw in terms of the stabilizer position sensor?

MR. KOVACIK: Right. Let me first explain just briefly the nature of that system. We have a cable follow-up system from the jackscrew mechanism itself, and from that follow-up cable system, we drive several different functions, one of which is the electrical shut-off system.

One of the other systems is the position-sensing system. So, as the stabilizer moves, the cable is moved as well, and we get that function.

For the Tulsa tests, we exercised the stabilizer in its normal operating range to gain a baseline reading of what the position sensor would read out on the flight recorder.

Subsequent to that baseline establishment, we decided to modify the system so we could essentially over travel that cable system to simulate higher aircraft nose-down orientations of the horizontal stabilizer.

As we continued with the test, we noted that there are limits of travel of that cable system when we exceed the normal range of the stabilizer travel. We noted essentially two areas where the cable system would be inhibited from moving further.

When we identified the first impediment to further cable travel, we removed that from the system and proceeded with, you know, actuating the cable to even higher levels of stabilizer aircraft nose-down position, and we resulted in finding another point at which the cable system would no longer drive.

Essentially that point occurred actually at the point where we have the position sensor installed in the system.

I guess if you want me to conclude, what we found is that when we exceed the range, the normal operating range of the system, we get to a point where the position sensor will not read any higher aircraft nose-down stabilizer readings.

DR. BOWER: And that would be also reflected in the flight data recorder data?

MR. KOVACIK: Yes. The position sensor feeds into the flight data recorder, yes.

DR. BOWER: Could you also describe what was performed in these Tulsa tests in regard to the elevator position sensor?

MR. KOVACIK: Yes. We wanted to again

explore the issue of what sort of position sensor readings we can achieve from the position sensor installation at the elevators themselves.

First, establishment of the baseline, exercising manually the elevators, you know, trailing edge up and trailing edge down, to establish, like I said, the baseline.

From that point, we removed from the system several mechanical components to attempt to exercise the sensor beyond what it would normally be driven to to see what the sensor could potentially read.

In addition to that, we also removed the electrical connections to those position sensors to see what sort of response the flight data recorder would note because of that.

DR. BOWER: And what sort of indications were noted on the FDR?

MR. KOVACIK: Right. When we removed the electrical connectors, the sensor output essentially, as recorded from the DFDR, went to an extreme range, a very high reading of elevator angle in both the trailing edge up and trailing edge down, something beyond which we could obtain obviously through normal excursions of the elevator, but more so even when we tried to exercise the system with mechanical components removed. Removing the connector gave us readings well beyond what we could achieve there as well.

DR. BOWER: Okay. Would that be well beyond the physical limits of the elevator?

MR. KOVACIK: Yes. That's a more concise way of putting it. Thank you.

DR. BOWER: You're welcome. Mr. Chairman, I have no further questions. At this point, I'll turn it back over to Ms. Ward.

MR. HAMMERSCHMIDT: Mr. Clark?

MR. CLARK: On the maximum reading you could get, that was for the trim position of the elevator position or both?

MR. KOVACIK: Well, in the case of the stabilizer, it primarily was to find the physical limitations of that position sensor reading.

MR. CLARK: And what was that number?

MR. KOVACIK: I don't recall --

MR. CLARK: Was that the 2.5 degree, Dr. Bower? Let me ask it this way. For what you saw on the FDR, that was consistent with what you measured in your tests. Is that a fair way to approach it?

MR. KOVACIK: I believe the number that we recorded in the test for the first stopping point was in the realm of what was recorded on the DFDR.

MR. CLARK: And what was the first stopping point?

MR. KOVACIK: The first stopping point was associated with our shut-off system, our stabilizer shut-off system. Essentially the stop was a mechanical interference in that shut-off area, and that limited, you know, further cable travel being transmitted to the position sensor.

MR. CLARK: And if the stabilizer traveled beyond that, you would not read a higher value then, is that correct?

MR. KOVACIK: That is correct.

MR. CLARK: Okay. So, if it went up to 3 or 3.5 degrees, you would still see the -- whatever that lower value was?

MR. KOVACIK: Right. Unless, of course, that physical stop or mechanical interference would be somehow removed in that case.

MR. CLARK: Right. Okay. Thanks.

MR. HAMMERSCHMIDT: Okay. Ms. Ward, do you have further questions?

MS. WARD: My questions will be to Mr. Umeda.

MR. HAMMERSCHMIDT: Please proceed.

MS. WARD: Okay. Mr. Umeda, could you please describe the normal load path of the jackscrew, and how it interacts among the jackscrew assembly itself?

MR. UMEDA: Yes, I can, Ms. Ward. I have a presentation that will aid in the understanding of the normal loads on a jackscrew and its load path, if I may.

First, I want to touch upon something. As Mr. Kovacik has expressed the importance of the redundant nature of the trim control system, the same design philosophy has been considered in the design of the structural load path of the jackscrew assembly.

I would like to explain how structural integrity is designed into the jackscrew assembly through fail-safe or redundant load paths. But because this system has moving components, the wear issue must also be addressed to maintain the multiple load path philosophy.

First, let me define multiple load path. Multiple load path design is the capability of a structure assembly to withstand loads after failure of an element.

In other words, if a single part fails, the load will be distributed to another part or remaining parts in that assembly. When I use the term "fail", I simply mean that the part cannot support the load any longer.

Now, let me describe the basic load path of the jackscrew assembly. Two pivot points along the hinge lines support the horizontal stabilizer. The other support point is the jackscrew assembly, attached here to the front of the horizontal stabilizer, and attached here to the vertical stabilizer.

Now, allow me to describe the multiple load path in the jackscrew assembly starting from the top. The jackscrew is attached to the horizontal stabilizer with multiple brackets and fasteners on the left-hand side and on the right-hand side and will maintain structural integrity when any fastener or bracket failed.

Also, this upper support assembly here in the jackscrew assembly has multiple load paths and will maintain structural integrity for any component failed.

The normal loading in the jackscrew assembly lowers the torque tube here, and this is reacted by the torque tube washer and nut on the bottom here. Then that transfers the loads into the Acme screw, and then that Acme screw load is reacted by the Acme nut over here.

If the torque tube fails, the Acme screw will carry the load, and if the Acme screw fails, the torque tube will carry the load. The Acme nut support assembly consists of multiple components and fasteners and will maintain structural integrity for any fastener or component failed.

This section of the Acme nut contains the threads that interface with the corresponding threads on the Acme screw. This section is sandwiched or encased by these multiple supports, so that a crack in this nut section won't split the nut and let go of the screw.

If you look closely at a conventional bolt or nut, you will see a single thread that wraps continuously around. Unlike any conventional bolt or nut, the Acme screw nut contains two independent threads. Notice one thread is in yellow and the other in red. The reason behind having two independent threads is that if one of the threads were to fail, the other thread will carry the load.

We have just been through the multiple load path in the jackscrew assembly. Now, I would like to describe how structural integrity is maintained with the three elements of a wear design.

The Acme nut threads will carry the load, and as the horizontal stabilizer moves up and down, they are expected to wear, much like brakes on a car. Therefore, the Acme nut thread is a wear component.

Here is a cross-section of one of the threads in the Acme nut. The portion in the orange represents the thread material worn away. Since the two independent threads in the Acme nut are both subject to wear due to jackscrew rotation, we took this into account when we designed the system and defined the maintenance procedures to manage and inspect the wear.

These are, Number 1, when the threads are designed, they are designed with robust strength; as such, when the Acme nut is new, the strength of the thread's over 15 times in excess of design loads.

Number 2, the wear rate is managed by lubrication, and, Number 3, the wear is monitored by an inspection program, and the jackscrew assembly is removed when the threads still have a significant level of remaining strength.

In summary, the jackscrew assembly is designed with multiple load paths, and that a failure in one part will not affect the structural integrity of the jackscrew assembly.

The wear component, the Acme nut threads, are designed with robust strength. The wear rate is managed by lubrication, and the wear is monitored by inspections, and the jackscrew is removed when the threads still have significant level of remaining strength.

That concludes this portion of the presentation, Ms. Ward, and I hope that helps people understand the multiple load paths and the wear component in the jackscrew assembly.

MS. WARD: Okay. Thanks for describing what happened in a normal aircraft situation.

Now, could you please describe what the load path was for the accident jackscrew after the wearing of the threads of the Acme nut?

MR. UMEDA: If the Acme nut were to wear such that -- it wore in such a manner that the Acme screw or the Acme nut could no longer carry the load, the horizontal stabilizer would continue to rotate leading edge up. Then the Acme nut stop would come in contact with the upper surface of the rotational stop collar.

At that point, load will be applied to the torque tube washer and nut to create an offset load, to create bending and tension stresses in the torque tube.

MS. WARD: Okay. In relation to that, did Boeing produce a finite element model?

MR. UMEDA: Yes, we have, Ms. Ward.

MS. WARD: And why was that model produced?

MR. UMEDA: Well, first, the NTSB and FAA had asked Boeing to determine the capability of the jack-screw assembly due to this very unusual unique condition.

As a response to that, we did recognize that the load paths and the loading condition is very complex. It is complex because of the redundancy due to multiple mating parts with the slow-in configuration as well as the non-linear behavior of bearing surfaces as well.

That -- when we reviewed this very complex loading system, we realized that traditional hand-calculated textbook analysis would not only be cumbersome and impractical but would yield inaccurate and incorrect results.

MS. WARD: Could you go into some detail about the finite element model, please?

MR. UMEDA: The finite element model uses a program called "Abacus for a Solution Generator". The model considers material and geometric non-linearities, and also contact surfaces of elements are included in the model to correctly idealize bearing surfaces.

Bearing surfaces are surfaces such that those surfaces could only transmit load through compression but not tension.

MS. WARD: And what were the areas that you guys used to model for those surfaces?

MR. UMEDA: When we reviewed the details of the jackscrew assembly for this very unique loading condition, the contact surfaces we included in the model were the Acme screw splines, between the Acme screw splines and the rotational stop collar splines, between the torque tube splines and the inner splines of the Acme screw, between the torque tube washer upper surface and the rotational stop lower surface, and between the torque tube washer and the lower surface of the Acme screw.

MS. WARD: Okay. Did Boeing approach the NTSB and inform us that they would like to run a static load test on the closed shaft?

MR. UMEDA: Yes, we did, Ms. Ward.

MS. WARD: And what was the purpose of this test?

MR. UMEDA: Well, the purpose of the test was to -- since we had a very complex model, using state-of-the-art techniques, it requires test data for correlation to validate the model.

Boeing has produced a test plan which describes the test fixture, the test specimen, the test set-up, the loading, the test procedures. We submitted this test plan to the NTSB for not only the NTSB concurrence, review and concurrence, but also the participating investigating parties.

MS. WARD: Could you go into detail about the first static load test?

MR. UMEDA: Yes, Ms. Ward. For the first static load test, the jackscrew and the Acme nut was not restrained from rotation. Due to the uneven surfaces between the gimbal nut stop and the lower stop collar, the jackscrew or the Acme screw or Acme nut started to rotate.

This rotation reduced the loading bearing surface to the point where crushing failure occurred in the lower rotational stop collar.

Because of this crushing failure, the lower surface of the Acme nut rested against the upper surface of the lower rotational stop collar to produce a tension load in the torque tube, and we failed to produce an offset load to generate a bending tension mode in the torque tube.

We continued to test anyway, and we -- and the test failed at about, I think, 75,000 pounds.

MS. WARD: Was there discussion to run a second test?

MR. UMEDA: Yes. Since we did not achieve the offset load or bending tension fracture of the torque tube, that defeated the primary purpose of the test.

Again, the primary purpose of the test is not to simulate a condition that may have occurred in the accident, but to collect test data to correlate with the finite element model for validation.

So, we reviewed the orientation -- different orientation of contact of the Acme screw -- excuse me -- Acme nut stop on top of the lower rotational stop collar, and we chose a location which we would have confidence that we would achieve fracture of the torque tube in the bending tension mode.

Also, there is no -- at this particular loading condition, there was no evidence on the -- on

261 lower rotational stop collar that the Acme nut made contact at this location for Test Number 2.

MS. WARD: Could you go into some more detail about Test Number 2?

MR. UMEDA: Yes, I can. For Test Number 2, we restrained the Acme screw and Acme nut from rotation by developing special fixtures that would restrain both components from rotating but still allow vertical stroke or for the jackscrew assembly to deflect vertically.

We continued that test until we obtained failure, and we did achieve a bending tension mode of fracture on the torque tube. The torque tube fractured at 25,567 pounds with a stroke of .426 inches.

MS. WARD: And what were the results of the test as far as being used for the finite element model?

MR. UMEDA: It is standard engineering procedure when you perform a test to validate the model or calibrate the model. You would examine very carefully the test specimen. You look for errors of local yielding, local deformation, and see how that agrees with the model results. That evaluation is still on-going.

MS. WARD: So, at this time, you don't have any results from the finite element model then?

MR. UMEDA: We are still calibrating the finite element model to produce realistic results and to calibrate the model with the results from Test Number 2.

MS. WARD: Thank you, Mr. Umeda. Mr. Chairman, I'm done questioning Mr. Umeda, and I'd like to pass it over to Mr. Joe Epperson.

MR. CLARK: Let me ask --

MR. HAMMERSCHMIDT: Oh, Mr. Clark?

MR. CLARK: The Test Number 1, did it produce a failure in the nut or the torque tube?

MR. UMEDA: Yes, it did. That was the tension mode of failure.

MR. CLARK: At the 75,000 pounds?

MR. UMEDA: Well, I'm looking at the factual now, and it's 74,400 pounds.

MR. CLARK: Okay. And then, Test Number 2 also, did you -- it produced a failure in the torque tube?

MR. UMEDA: That's correct. It produced a failure, and we were able to achieve a bending tension mode of failure of the torque tube.

MR. CLARK: And at what load?

MR. UMEDA: 25,576 pounds.

MR. CLARK: Okay. So, just the difference between the two tests was to stabilize the jackscrew, to keep it from rotating, and then the loads could drop down to a much lower load before we had a failure?

MR. UMEDA: Yes, but what one must understand is the reason to keep the jack -- the Acme screw and Acme nut from rotating is to maintain a consistent, constant contact area between the Acme nut stop and the lower stop collar, --

MR. CLARK: Okay. And --

MR. UMEDA: -- so you won't -- so the crushing failure won't occur in the stop collar.

MR. CLARK: Okay. But that -- is that consistent with the damage to the -- from the wreckage we have?

MR. UMEDA: From Test Number 2?

MR. CLARK: Yes.

MR. UMEDA: The way we loaded the test, there is no physical evidence from 261 that suggests that the Acme nut stop made contact with the lower rotational stop collar at the location that we ran for Test Number 2.

Remember, the reason for running the test was not to try to simulate a possible configuration in the accident airplane, but the primary purpose of the test is to collect test correlation data to validate the model.

MR. CLARK: Okay. In the real world, though, is it likely that that whole bearing nut will not rotate or it will rotate, if this were to happen in flight?

MR. UMEDA: In the real world, the rotation is -- given that the Acme nut is stationary in the gimbal, attached to the vertical, the Acme screw is restrained from rotation from the motors and the gear box.

MR. CLARK: So, the second test in one sense is -- would be more realistic in the fact that it's restrained and not allowed to rotate?

MR. UMEDA: Then again, the purpose of that test was not to try to simulate the accident flight. It was to produce data to validate the model.

MR. CLARK: Okay. Yes. No. I understand that, but what I'm asking is, in -- when this whole assembly is mounted in an airplane, and we were to drive -- to pull up on the leading edge of a stabilizer, any stabilizer, would that promote the rotation of that nut or the stop nut or would it -- would the tendency to rotate be stopped by the motors, the primary trim motors?

MR. UMEDA: The primary trim motor and the -- and also since the Acme nut is mounted rigidly in the vertical stabilizer.

MR. CLARK: So, it would tend not to rotate in the real world? In a real world environment?

MR. UMEDA: Yes.

MR. CLARK: Okay. Thank you.

MR. HAMMERSCHMIDT: Let's see. Mr. Epperson?

MR. EPPERSON: Thank you, Mr. Umeda. I've got just a very, very few questions for you.

From basic hand calculations, what would you estimate that the braking strength of an undamaged torque tube in a normally-loaded condition would be?

MR. UMEDA: Normal-loading condition would be tension without bending. That is a very straight-forward calculation that doesn't require finite element techniques, and if you use minimum design allowables, we would produce a tension capability of approximately 60,000 pounds.

MR. EPPERSON: That's using minimal material, minimum handbook material strengths for the torque tube?

MR. UMEDA: Yes. The minimum material allowable as required by the FAA for certification.

MR. EPPERSON: All right. Was the torque tube in that test -- in Quill Shaft Test 1 tested for what its actual strength was?

MR. UMEDA: I'm sorry. Could you repeat that question, Mr. Epperson?

MR. EPPERSON: What was the material of Quill -- the first Quill Shaft test tested after the Quill Shaft Test for its -- to determine its ultimate strength?

MR. UMEDA: Yes, it was. Coupons were taken, and typically material allowables on the actual specimen will be higher than what is used for certification, minimum design properties. That is the reason why Quill Shaft Test Number 1 failed at 74,400 pounds as opposed to 60,000 pounds.

MR. EPPERSON: Okay. So, your -- if you ran your numbers again, your basic numbers, using the actual strength of the torque tube material, plugged it into your equations, you would come up with the number that's similar to the 75,000 pounds?

(No response)

MR. RODRIGUEZ: Mr. Umeda, are you not --

MR. UMEDA: No. I'm sorry. I thought I heard someone speak up. Yes. Yes. I'm sorry. Would you rephrase the question again, Mr. Epperson?

MR. EPPERSON: if you -- instead of using the minimum material properties for your calculation of ultimate strength of the ultimate load capacity of the torque tube, and you inserted the actual tensile strengths that were determined by ASTM tests, what number would you end up with as load-carrying capacity of the torque tube?

MR. UMEDA: It would closely agree with the results of Test Number 1.

MR. EPPERSON: So, approximately 75,000 pounds?

MR. UMEDA: That is correct.

MR. EPPERSON: Okay. In an abnormally-loaded condition now, where we have got bending and tension loads applied to the torque tube through an offset, through the lower stop, did I understand you correctly that at this point in time, your finite element model won't -- has not established what the ultimate load-carrying capacity is for an abnormally-loaded condition?

MR. UMEDA: That is correct. That model calibration is currently going on.

MR. EPPERSON: What would you expect the results to do in terms of that, if you increase/ decrease?

MR. UMEDA: Yes. If you apply an offset load to introduce bending, in addition to the tension component, across that lower portion of the torque tube, I would expect a decrease in capability.

MR. EPPERSON: Significant?

MR. UMEDA: It depends on the offset. The greater the offset, greater the bending load, greater reduction in the capability of the torque tube.

MR. EPPERSON: Let's assume that we have an offset about what we saw for damage on 261.

MR. UMEDA: I would expect the significant decrease.

MR. EPPERSON: Significant. Half?

MR. UMEDA: I'm unable to answer that at this time, because the model correlation is still on-going.

MR. EPPERSON: Okay. You will let us know as soon as that -- you get that number?

MR. UMEDA: Yes, I will.

MR. EPPERSON: Okay.

MR. CLARK: Mr. Epperson, is that in the same area that we had test results of 75,000 and 25,000 pounds? Is that what we're talking about? That's a factor of three.

MR. UMEDA: That's a very good question, Mr. Clark. The degree of offset was greater for Test Number 2 than Test Number 1. So, to compare the results of Test Number 1 directly to Test Number 2 for the effect of bending load with the same amount of offset would be misleading.

MR. CLARK: Okay. But between the two tests, we had a factor of three, and then also in the first test, it had a certain amount of relieving capability because the nut would twist. Would that suggest that if it -- that -- the first test failed at 75,000 pounds.

Would you expect it to fail at a higher load if it could have -- if the first test failed at 75,000 pounds, had you had the same offset as for Test 2, would that number have gone up or down?

MR. UMEDA: It would definitely have gone down for Test Number 2 with the same amount of offset.

MR. CLARK: Okay. Test Number 1 failed at 75,000 pounds. If it had the same offset as Test

Number 2, would that 75,000 go lower or higher?

MR. UMEDA: It would go lower --

MR. CLARK: Lower.

MR. UMEDA: -- with the offset.

MR. CLARK: All right. Thank you.

MR. EPPERSON: Let's get into something a little bit more even esoteric than load paths. Let's get into some fracture mechanics.

Has Boeing undertaken to perform any fracture mechanics analysis of the torque tube in relationship to the findings of 261?

MR. UMEDA: We have performed some fracture mechanics evaluation, but at this time, we have not been able to perform a fracture mechanics evaluation for the type of observation that was observed on 261 fractured quill shaft.

MR. EPPERSON: Okay. So, basically, for the observations from 261, -- you could -- fracture mechanics residual strength calculations could be calculated on the torque tube, assuming normal classical crack shapes and conditions, penny-shaped cracks and stuff like that.

MR. UMEDA: Yes, that's correct.

MR. EPPERSON: The difficulty with applying those same principles to 261 is in what means?

MR. UMEDA: From the metallurgy report -- I'm not a metallurgist. May I comment on that? Is that something you might want to address to Dr. Khaled?

MR. EPPERSON: Yes. We'll bring that up with Dr. Khaled.

One more question for you, though. These torque tubes, this basic design is the same, relatively the same since the beginning of DC-9s, is that correct?

MR. UMEDA: That's correct.

MR. EPPERSON: There have not been any significant changes in materials, construction, form for the torque tubes, other than in the area of the lower threads?

MR. UMEDA: The basic design philosophy remained the same.

MR. EPPERSON: Okay. Has there been any report -- does Boeing know of any instances of pre-existing and/or fatigue cracks being reported or having found fatigue cracks in other torque tubes from other aircraft?

MR. UMEDA: We have no reported cases of fatigue failures or fatigue damage on this torque tube design for the four basic models, DC-9, MD-80, MD-90-

717, and that is over 95 million accumulated flight hours, and it considers over 2,300 airplanes delivered.

MR. EPPERSON: Thank you, Mr. Umeda.

Mr. Chairman, this is all I have for this witness. I do -- would like to talk with Dr. Khaled again.

MR. HAMMERSCHMIDT: Before you question Dr. Khaled, I think Mr. Berman has a question.

MR. BERMAN: Thank you, Mr. Chairman.

Mr. Umeda, Mr. Kovacik mentioned that the jackscrew and torque tube design was of a redundant design, and you mentioned that there's a multiple or dual load path inherent in that design.

How can it be considered to be redundant or dual load path if the Acme screw is required to transfer the motion of the torque tube over to the Acme nut? How is that a dual load path?

MR. UMEDA: As I addressed in my presentation, the Acme nut thread has two independent threads, such that if one of the threads were to fail, the other thread will carry the load.

But since the Acme nut thread is a wearing component, that must be addressed in the design and maintenance procedures for the Acme nut thread. As such, when the Acme nut is new, the thread is very robust. The strength of the threads are over 15 times what's required for the maximum design loads.

MR. BERMAN: I understand -- I'm sorry. Go ahead.

MR. UMEDA: Also, since we know it's a wearing component, we have placed maintenance procedures in place, the lubrication to manage the wear rate, and the inspection to manage the wear.

Also, we have defined when the Acme nut or the jackscrew assembly should be removed from the airplane, and at that wear level, the Acme nut thread still has robust strength.

MR. BERMAN: I understand where you're talking about the Acme nut threads being redundant with each other, and I know we are going to go into this whole concept a little bit more, but what I was asking about was prompted by your testimony and Mr. Kovacik's right now about the torque tube and the Acme screw backing each other up.

It would seem to me that if the Acme screw were to break at some portion of its shaft, such as between the stop nut on the bottom and the Acme nut, that it would no longer -- there would be no way to transfer the torque from the torque tube over to the nut, and, so, it didn't sound like a true redundancy.

MR. KOVACIK: Mr. Berman, can I add some comments --

MR. BERMAN: Sure.

MR. KOVACIK: -- here?

MR. BERMAN: Yes, sir.

MR. KOVACIK: I think from the -- in terms of the drive mechanism, the torque tube and the Acme screw are used in conjunction to drive the Acme screw. I think the presentation showed that, where we actually physically turn the inner torque tube which in turn will turn the Acme screw.

So, in terms of the drive mechanism, both parts are utilized at the same time for the function of the jackscrew.

In terms of the duality of the load path, they're actually again being used at the same time. You know, the jackscrew tension or the inner torque tube tension load is transferred via the lower washer and nut to the lower portion of the Acme screw. That is true as well.

When there is a failure case, a failure of the Acme screw, the companion component, in this case the torque tube, would take the resulting load, and the reverse is true. If there's a failure in the screw, there could be -- you could have the torque tube, you know, taking the load.

Did I say that properly? Both cases are true. If you fail the Acme screw, you have a torque tube. If you fail the torque tube, you have the Acme screw. Both those components will shoulder the entire load in that case.

So, even though they're being utilized at the same time for both the drive mechanism and normal loading, in the failure case is where the redundancy feature manifests itself.

MR. BERMAN: It seems like that that presumes that both parts maintain somewhat of their structural integrity, but I'll leave that for later questioning, if I may.

Mr. Umeda, just to clarify a point that you were making just a couple of minutes ago, were -- in the Quill Shaft Testing -- I'm sorry -- in the inspection of the accident wreckage, were you able to estimate an offset of the accident unit based on the markings on the Acme nut?

MR. UMEDA: There are several hits on the --

there are several marks on the lower rotational stop collar. One of the marks would produce offset load of about one inch from the center line of the torque tube.

MR. BERMAN: And how does that compare with the second -- the offset on the second Quill Shaft Test?

MR. UMEDA: The offset on the second Quill Shaft Test was greater than one inch.

MR. BERMAN: Okay. Thank you.

MR. HAMMERSCHMIDT: Thank you, Mr. Berman. Let's see. Mr. Epperson again.

MR. EPPERSON: Thank you, Mr. Chairman.

For Dr. Khaled, it would probably be best to move to the visualizer table.

Dr. Khaled, we have -- in your earlier testimony, you merely testified that the lower torque tube or the torque tube was fractured at the lower end of the screw, the Acme screw.

We're going to -- I'm going to try to explore a little bit more the details of that fracture, particularly in light of Mr. Umeda's recent testimony.

You did examine extensively the torque tube fracture from ASA-261?

DR. KHALED: Yes.

MR. EPPERSON: That included what kind of instrumentation, and what were some of your basic observations in relation to the torque tube fracture?

DR. KHALED: In brief, --

MR. EPPERSON: Excuse me. Exhibit and page number, please.

DR. KHALED: I'm sorry. Exhibit 15-A, Page 65, --

MR. EPPERSON: And if you would --

DR. KHALED: -- Figure 66.

MR. EPPERSON: -- pull the microscope -- microphone -- I'm more used to microscopes than microphones. Microscope up, so that we can hear you.

DR. KHALED: Okay. Can you hear me?

MR. EPPERSON: If you've got a microscope, pull it out, too.

DR. KHALED: Okay. Exhibit 15-A, Page 65, Figure 66. This is the -- in the middle here is the 261 torque tube end. This is the fracture surface, and this is the end where we cut it to facilitate its examination.

Those are two exemplar torque tubes that we put alongside for comparison here. One of them have a thread relief, and the other one doesn't. The fractured one from 261 does not have a thread relief.

MR. EPPERSON: And the location of the fracture on 261 in relationship to the thread relief, where was that?

DR. KHALED: It was right in the area where the thread relief would be. I mean, the fracture in the torque tube was at the first full thread below the splines.

MR. EPPERSON: Okay.

DR. KHALED: Okay.

MR. EPPERSON: You had some observations of the fractography, the fracture surface. Could you elucidate us with your findings?

DR. KHALED: Exhibit 15-A, Page 66, Figure 68. This is an overall view of the fractured surface of the torque tube or quill shaft, however you want to call it, and the most notable feature in there was a reflective band that covered almost the entire circumference and surrounded by areas -- excuse me -- and in the middle, there were areas that are not as reflective as that band.

MR. EPPERSON: And what does that band tell you about its presence?

DR. KHALED: This band, seen here at higher mag, 15-A, 68, Page 68, Figure 71, when examined at higher magnification, showed some evidence of time-dependent mechanism, such as fatigue.

MR. EPPERSON: By time-dependent, are you basically telling us that that torque tube fracture didn't happen all at once?

DR. KHALED: Yes, that's precisely what I'm saying.

MR. EPPERSON: And were you able to identify what the time-dependent mechanism was that produced that reflective band?

DR. KHALED: Fatigue cycling.

MR. EPPERSON: How did you establish that that was indeed fatigue cycling?

DR. KHALED: In more than one way, but the most obvious way was that the fracture features seen in that band were consistent with fatigue fracture and included some faint indications of striations and the like.

MR. EPPERSON: Okay. For a little bit of background, what is a good working definition of fatigue?

DR. KHALED: It's a changing load or a changing strain.

MR. EPPERSON: Excuse me. I didn't quite hear that.

DR. KHALED: Oh. Fatigue is a cycling failure mode. Cycling of load or cycling of stress or strain.

MR. EPPERSON: So, it's multiple cycles --

DR. KHALED: Multiple events.

MR. EPPERSON: -- that eventually produce a crack. There are a couple of different bandied-around -- a couple of different names, kinds of fatigue. I won't say kinds. Nomenclatures of fatigue. High-cycle fatigue, low-cycle fatigue.

Could you tell us basically what the difference between these two is?

DR. KHALED: Low-cycle fatigue is high-cycle fatigue. Small number of cycles.

MR. EPPERSON: So, --

DR. KHALED: Did I get that wrong way? Okay.

MR. EPPERSON: What is low-cycle fatigue?

DR. KHALED: Low-cycle fatigue is the cycling at high stresses to get failure at low cycles, low number of cycles.

MR. EPPERSON: High stresses, low number of cycles, and then I presume --

DR. KHALED: The other --

MR. EPPERSON: -- the opposite is true for a high-cycle fatigue.

DR. KHALED: Sorry about that.

MR. EPPERSON: Did you or the Materials Group perform any additional testing to further establish that this C-shaped reflective band was indeed a result of a fatigue mechanism?

DR. KHALED: Yes, we did.

MR. EPPERSON: And could you please describe what those tests and experiments were?

DR. KHALED: We used compact tension specimens, STME-8, except that the gauge length had threads in it to simulate what the situation is at the end of the torque tube, where the failures were -- excuse me -- 261 failure happened.

Okay. So, those samples were cycled at various high-stress loads or high-stress situations, and the preliminary results show that all of them produced that C-shaped reflective band around the circumference.

MR. EPPERSON: Okay. You said preliminary results. These results are still in work, have not been published as yet?

DR. KHALED: They have not been published.
MR. EPPERSON: Okay. They will be in the near future?
DR. KHALED: Yes.
MR. EPPERSON: Okay. At -- did you -- were -- did you participate or view the results or the test of the Quill Shaft Test 1 and/or 2?
DR. KHALED: Both.
MR. EPPERSON: Both? Did you examine the torque tube failures that occurred as a result of those tests?
DR. KHALED: Yes.
MR. EPPERSON: What were your findings in relationship, in comparison, between those two tests and the 261 accident torque tube?
DR. KHALED: The two validation tests fractures did not have the C-shaped band around the circumference, whereas the accident, the 261 fracture, had it. That's the main difference between them.
MR. EPPERSON: So, basically, you don't consider one cycle to be fatigue?
DR. KHALED: No.
MR. EPPERSON: Okay. And they were positively confirmed with -- to be entirely over-stress

in nature as we saw?

DR. KHALED: Yes. We spent a great deal of time on that.

MR. EPPERSON: That's all I have for -- in relationship to the accident for this witness. However, there's another line of questioning I would like to open with you in terms of examination of other jackscrews and other hardware from other aircraft that were examined by the Materials Group.

MR. CLARK: Joe, let me ask a quick question on the low-cycle fatigue.

What kind of loads does it take to generate a low-cycle fatigue?

DR. KHALED: It depends on the material. I don't -- there is a threshold load, in all likelihood, of stress, but I -- it varies from material to material. I can't --

MR. CLARK: Well, for this material we're talking about.

DR. KHALED: I can't answer that.

MR. CLARK: Well, if we -- if this inner torque tube can withstand 75,000 pounds in tension or 25,000 pounds if we put a bending load on it, how much further down would that loading go if we were to try to induce a failure using the low-cycle fatigue?

DR. KHALED: It's only an empirical guess, you know. I am not sure. Probably half --

MR. CLARK: In your experience, half wouldn't be a reasonable --

DR. KHALED: Half would do a fatigue, most likely, maybe a large number of cycles. I don't have -- I can't --

MR. CLARK: I understand, but I was just looking for a --

DR. KHALED: It's lower. It's lower. It can be generated at lower -- at much lower --

MR. CLARK: It could be at half or 70 percent or something in that range?

DR. KHALED: Half, yeah. .4.

MR. CLARK: So, that 25,000 pounds, if we were to put a low-cycle fatigue, we may be able to introduce that in 12-15,000 pounds or something like that?

DR. KHALED: If the loading was identical.

MR. CLARK: Right. I understand. Okay. Thanks.

MR. EPPERSON: Dr. Khaled, you participated in -- with the Materials Group in the examinations and tear-downs of a significant number of other jackscrews that were removed from different airlines, other -- as a result of the AD following the Alaska accident.

DR. KHALED: Yes.

MR. EPPERSON: I guess I should say, did you not?

DR. KHALED: I did.

MR. EPPERSON: Okay. Could you kind of detail -- give us some brief description of the extent of those examinations, some of the findings of those examinations?

DR. KHALED: Yes. Basically, this was an examination of a group of eight jackscrews and five loose nuts, and these were performed both at Trig Aerospace in California and here at the NTSB.

Can we get this one? The jackscrews were removed for various reasons, and they are shown in this picture, which is Evidence 15-F -- excuse me -- Exhibit 15-F, Page 19, Figure 1, and mostly these were from MD-83s with the exception of a couple -- you know, MD-83s, excuse me, DC-9s, MD-90s, and in addition to those eight jackscrews, we examined five separate nuts or Acme nuts that were at Trig Aerospace for overhaul.

MR. EPPERSON: Of those eight jackscrews that were examined, how many of those were from Alaska Airlines or other airlines?

DR. KHALED: Two were Alaska Airlines, two were AirTran, one was Reliant, one was Northwest, one was Delta, and one was TWA.

MR. EPPERSON: Do we -- do you know that the causes of removal -- the reasons for removal in relationship to the AD for each of those?

DR. KHALED: Okay. The two Alaska were removed for end play, and the two AirTran were removed for particles in the grease. Excuse me. I have to look at my notes. The one Delta, which was an MD-90, was removed for free play.

MR. EPPERSON: For free play, not end play?

DR. KHALED: Free play.

MR. EPPERSON: Okay.

DR. KHALED: Yes, that's a separate thing. And the one TWA, which was formerly Alaska, was not reported, and the Reliant one was for a fractured Acme nut lug.

MR. EPPERSON: And the Northwest?

DR. KHALED: Northwest, for aluminum drill turnings in the grease.

MR. EPPERSON: Okay. Basically, what were the -- what were some of the tests and examinations that were performed on those jackscrews?

DR. KHALED: Exhibit 15-F, Page 22, Figure 5. We did on the jackscrews, we did end play tests, and we did that in the as-received condition and cleaned condition and regreased with AeroShell 33 condition, and each of those were done at the top, the middle and the bottom of the Acme screw.

We also did free play tests as received only, and we did the slewing test, which has to do with the gimbaling of the upper joint or the spherical ball bearing, and we did the rotational torque, which has to do with the rotation of the assembly.

MR. EPPERSON: Let me walk through each of those tests a little bit with you with some possible findings.

On the end play, this is -- we're referring to end play as opposed to free play. This is play in the nut, correct? The Acme nut and screw?

DR. KHALED: Yes. Between the -- the gap between the Acme nut and the screw, the Acme screw.

MR. EPPERSON: What were some of the results of those three different end play checks on these screws?

DR. KHALED: Of the eight, two decreased in value, and six increased from the initial value, and the average increase was about three mils -- excuse me -- 3,000ths of an inch, and the max was about six mils, 6,000ths of an inch.

MR. EPPERSON: Okay. So, between those three tests, two of them decreased because of the change from initial, two of them showed decreases in end play --

DR. KHALED: Yes.

MR. EPPERSON: -- with cleaning and then regreasing, and then the other six showed increases --

DR. KHALED: Upwards, yeah.

MR. EPPERSON: -- of values. Were these end play tests done -- these are obviously not done on an aircraft. How were they performed?

DR. KHALED: Basically, the upper support structure is held in the loading frame, that is not really very clear here, but up here, and there is a loading lever down here, and for the end play, which is gap between Acme screw and Acme nut, you index off the nut and pull down and zero the gauge and then push up and measure again.

MR. EPPERSON: Were the loads -- what loads were applied during these kind of tests? Were they aircraft loads into the thousands of pounds?

DR. KHALED: No. They were smaller, my understanding.

MR. EPPERSON: Okay. But they were all the same through all of the loads?

DR. KHALED: Yes.

MR. EPPERSON: Through all of the loadings?

DR. KHALED: Yes. And for the free play which measures the gap at the top, we indexed at the lower support plate, the aluminum support plate, lower support plate, and zero and, you know, measured off of the screw here, and we do the same thing, but this measures the gap up in the upper joint.

MR. EPPERSON: The swap in the bearing, you're referring to?

DR. KHALED: Yes.

MR. EPPERSON: Okay. What were some of the results of those free play tests? Were there variations?

DR. KHALED: Well, they varied from 1,000ths of an inch to about 16,000ths of an inch in the eight.

MR. EPPERSON: Let's go on to the slewing test. Let's talk a little -- just a touch about the slewing and the rotational tests.

Can you just generalize some of the findings in those two?

DR. KHALED: Yeah. In the slewing test, two of the eight were higher than all the others by a ratio of about 2:1.

MR. EPPERSON: So, the force required to slew them was twice as much --

DR. KHALED: Twice as much as the others.

MR. EPPERSON: And which two were those?

DR. KHALED: Alaska.

MR. EPPERSON: Okay. The rotational torque?

DR. KHALED: One was higher than all the others.

MR. EPPERSON: And by how much, and who?

DR. KHALED: By a factor of 5:1.

MR. EPPERSON: Five times harder to rotate --

DR. KHALED: Yes.

MR. EPPERSON: -- than the -- whose torque tube was that? Whose jackscrew assembly was that?

DR. KHALED: AirTran.

MR. EPPERSON: It was AirTran? Okay. In addition to these tests, were there -- was there anything else -- I presume these were done as received full up?

DR. KHALED: Yes.
MR. EPPERSON: Was there additional tests and examinations performed on these screws?
DR. KHALED: Yes. We did the tail-down on those jackscrew assemblies, and there was several things that were noted. As I mentioned earlier, the AirTran -- excuse me -- the Reliant jackscrew had a fractured lug.
MR. EPPERSON: The actual Acme nut was --
DR. KHALED: Acme nut.
MR. EPPERSON: -- fractured on that?
DR. KHALED: Yes.
MR. EPPERSON: Do you have an exhibit or something to show what you're talking about?
DR. KHALED: This is Exhibit 15-F, Page 27, Figure 13, and you can see the -- that's where the lug would ordinarily be, and it fractured, exposing this bolt here. You can see it there, and this is the complementary part to it. Does it show? And this is the same Exhibit 15-F, Page 27, Figure 14 now.
MR. EPPERSON: So, that's the actual lower lug portion of the --
DR. KHALED: Of the nut.
MR. EPPERSON: -- nut?

DR. KHALED: Yes. And --

MR. EPPERSON: Did you examine that to see why it fractured?

DR. KHALED: Yes. It fractured by an overload due to repeated contact -- excuse me -- to, you know, contact with the rotational contact.

MR. EPPERSON: Repeated rotational contact. Is that the word?

DR. KHALED: Yes.

MR. EPPERSON: Okay.

DR. KHALED: Overload.

MR. EPPERSON: Were there any other significant findings during those tear-downs?

DR. KHALED: Just for the record, this is the --

MR. EPPERSON: That is --

DR. KHALED: This is the lower --

MR. EPPERSON: -- Exhibit 15-F --

DR. KHALED: Yeah. 15-F, Page 25, Figure 11, and this is the lower mechanical stop that is -- was used with that fractured lug, and you can see the contact damage here when it hit.

MR. EPPERSON: Are there any additional -- I hate to see oddities, but differences, things that stood out in any of these --

DR. KHALED: Yeah. Basically, --

MR. EPPERSON: -- other nuts --

DR. KHALED: I'm sorry.

MR. EPPERSON: -- or other jackscrews?

DR. KHALED: Yeah. Basically, all the Acme nuts -- we did measurements on the nuts, and all of them show the wear to be on the lower flank as turns up in the aircraft, on the lower flank, and with the exception of one of them showed wear on both flanks, and I'm sure you're going to ask me that.

MR. EPPERSON: You're anticipating -- what was the airline?

DR. KHALED: Yeah. AirTran.

MR. EPPERSON: AirTran?

DR. KHALED: Yes.

MR. EPPERSON: Was there anything otherwise different about that AirTran part, too?

DR. KHALED: My recollection is that's it. It showed the wear on both.

MR. EPPERSON: Let's try to move along a little bit faster.

MR. HAMMERSCHMIDT: Mr. Epperson? It's about time for our next break. Would this be a good time to take it in terms of your questioning?

MR. EPPERSON: Yes, it would. I've got about probably 20 minutes, 20 to 30 minutes left. So, this would be a good time.

MR. HAMMERSCHMIDT: In that case, why don't we all take a 20-minute break?

(Whereupon, a recess was taken.)

MR. HAMMERSCHMIDT: Very good. Looks as if almost everyone's back in their respective places. We will continue with the questioning by Safety Board Metallurgist, Joseph Epperson.

MR. EPPERSON: Thank you, Mr. Chairman. All the important ones are here. Dick is not. So.

I just have a very quick few more questions for Dr. Khaled, and they basically deal with the exemplar accident nuts that were examined.

Can you give us just a very quick run-down on any tests on the exemplars?

DR. KHALED: We cut through one of nuts that were separate, not attached to jackscrews, attached to Acme screws, and I am looking now at Exhibit 15-F, Page 33, Figure 23. Can you hear me?

The most significant finding we found on that is this is the as-cut surface. This is at higher magnification, is that we confirmed that the wear happens on the lower flank. This is the lower flank. This is the orientation up with respect to the aircraft, and that the wear appears to occur by a displacement mechanism, like the screw would be displacing metal outward in this direction, such that you form this -- I don't know -- extrusion burr over there, and this was common to all of the nuts that we have looked at, and when you look at higher magnification at the root, we are now Exhibit 15-F, Page 34, Figure 24, this is the lower flank, and up here would be the small burr that we seen in the previous figure, and you can see that there is a shank here or a bevel, if you will, that matches the bevel on the Acme screw, suggesting that instead of being round as the design calls out, it conforms to the Acme screw bevel, suggesting that there was a wear process here in this area.

MR. EPPERSON: Okay. Thank you. Could you go back to the previous example there?

DR. KHALED: This one?

MR. EPPERSON: Yes. On that nut that was cut, that's the full thread form minus the wear. What was the reported -- do we know what the reported end play was?

DR. KHALED: At the time of the removal?

MR. EPPERSON: At the time of removal on that one?

DR. KHALED: Yes. It was 36,000th --

MR. EPPERSON: 36, --

DR. KHALED: -- of an inch.

MR. EPPERSON: -- 000ths. Could you please indicate about what 13 to 17,000ths is on that?

DR. KHALED: Can you clarify some more?

MR. EPPERSON: To replicate the thickness, the approximate thickness of the thread remnants that were found on 261. Just draw a line that's --

DR. KHALED: I would -- since there is no magnavision, I would guess it would be something like this.

MR. EPPERSON: That thickness between your line and to the left?

DR. KHALED: And to the left.

MR. EPPERSON: Okay. Comparison.

DR. KHALED: Give or take.

MR. EPPERSON: Approximately 10 times smaller than, one-tenth of the thickness of that?

DR. KHALED: The important thing to notice is that when this was very close to the limit of, you know, the end play that they allow, we still have a significant amount of thread left, like I said, an order of magnitude more than the thread remnants.

MR. EPPERSON: Thank you, Dr. Khaled. That concludes my questioning of this witness. I believe Mr. Guzzetti has some further questions for the panel.

MR. HAMMERSCHMIDT: Thank you. Please proceed, Mr. Guzzetti.

MR. GUZZETTI: Thank you, Mr. Chairman. If I could ask all of you witnesses to just do one more musical chair maneuver for me, this will be the last one for the evening.

Mr. Talay, if you could move next to the -- where Mr. Khaled is -- Dr. Khaled is at right now, and Dr. Khaled, if you could move where Mr. Kovacik is, all at the very end, and that leaves one more seat for you, Mr. Kovacik, and just for your information, Mr. Chairman, I will be, as far as we have planned here, I will be the final questioner. There may be some other ones, but in terms from -- for the rest of this panel, the questions will come from me, and we anticipate at least another hour to an hour and a half with this panel, the witness panel.

MR. HAMMERSCHMIDT: Very good. Thank you for that heads up.

MR. GUZZETTI: Mr. Kovacik, let me start with you. Just some clean-up issues from the last time we spoke in regards to the actual wreckage that we -- well, actually to the systems description, just to clarify something that you had testified to earlier in regards to the torque sum of the primary and alternate trim motors.

If you -- in Exhibit 9-A, Page 8, there's a little treatment about what happens if you operate both the primary trim motor and the alternate trim motor, what is the resultant jackscrew rotation and torque under flight load, and can you clarify that for us, about what could happen?

MR. KOVACIK: Would you like me to read from your text or --

MR. GUZZETTI: If that's helpful, yes. I'm looking at the middle of the page, second paragraph down, beginning "At this sum, however applies only up to the point".

MR. KOVACIK: I think your paragraph is comprehensive. So, I'd prefer to read that.

MR. GUZZETTI: Sure. Go ahead.

MR. KOVACIK: Okay. This is Page 8 of this document. "The differential gear box on to which both primary and alternate motors are attached is a speed sum device, not a torque sum. In normal operation, only one trim motor will be operated at a time. The opposite motor will remain fixed with its brake engaged, thus providing a ground for the functioning motor to drive the Acme screw.

In the case of running both motors together in the same direction, the two speed sums together resulting in a higher trim rate than the primary motor alone. This sum, however, applies only up to a point where the resisting air loads or a mechanical jam provide a reaction torque at the Acme screw equal to or greater than the capability of the alternate motor. That is, about 4,400 inch pounds, depending upon the motor condition.

At this point, the stronger primary motor will begin to back drive the alternate motor. The Acme screw held by the resisting air load will stop rotating and act as a grounding point. Upon subsequent release of the alternate motor command and reapplication of its brake or the reduction of the air load lower than the equivalent 4,400 inch pounds, the alternate motor comes around once again, and the Acme screw will begin to rotate as powered by the primary motor."

MR. GUZZETTI: Thank you. So, basically what that means is you could actually not have any rotation at all of the jackscrew, even though you've got both the alternate motor and the primary motor activated?

MR. KOVACIK: That is correct.

MR. GUZZETTI: It just depends on the flight loads or perhaps a mechanical jam in the system?

MR. KOVACIK: Yes.

MR. GUZZETTI: Thank you. Also, as far as overheating of these motors, specifically there's a footnote in that same exhibit, 9-A, on Page 17, regarding the design of that primary trim motor.

Based on your experience with Douglas and McDonnell-Douglas and Boeing, have you ever heard of -- before the accident, have you ever heard of primary motors overheating due to overuse? Is that something that's happened before?

MR. KOVACIK: Yes, that has happened before, and the thermal switches are there for protection of the motors, primarily in a stall condition. If current is continually applied to a stalled motor, it's going to heat up, and you could potentially do damage to the motor if you did not have these thermal switches in place. So, they're there to protect the motor.

In the circumstances that you're talking about, as you operate the motor, you know, command the motor to turn, it runs, it'll create heat. The motor will warm up. The same applies when the motor is shut down. There's an internal brake that is applied. Applying the brake causes heat.

So, if the trim motor is commanded sequentially for a number of times, the motor is going to heat up, and there is conditions where if you run the motor too many times in too frequent -- too frequently over a certain period of time, these thermal protections will trip, thus rendering the trim motor inoperative.

At a certain period of time, when the temperatures in the motor are reduced sufficiently, the thermal switches will again come back on line, and you will have availability of trim through that motor.

MR. GUZZETTI: Okay. So, when it comes back on line, it does so kind of automatically, is that correct, when the thermal switch cools down a bit?

MR. KOVACIK: That's correct. The function of the thermal switch is unbeknownst to the flight crew.

MR. GUZZETTI: Okay. Thank you. One final clean-up issue in that -- regarding an observation of the wreckage when it arrived in Oxnard, and when you and I and the rest of the Systems Group examined it. Page 19, again, of Exhibit 9-A.

At the very bottom of the page, it describes what the Systems Group members observed on the Acme screw and with field notes, and then it made it into this factual report. Could I get you just to read the last two or three sentences of Page 19?

MR. KOVACIK: Of course. Beginning with "The screw was bent"?

MR. GUZZETTI: Yes, that's fine.

MR. KOVACIK: Okay. "The screw was bent along its major axis toward the left side of the aircraft and was also bent aft. Upon closer inspection, a circumferential fracture was identified on the Acme screw above the upper stop location. The entire length of the screw was discolored with dirt deposits, white material deposits and red/orange/rust deposits. There was no visible evidence of grease on the Acme screw along its length where it normally travels."

MR. GUZZETTI: Okay. Thank you. Were we there to specifically take samples of grease off that Acme screw at the time?

MR. KOVACIK: No, we weren't. The Systems Group, myself included, were pretty much first on the scene to do an up-close visual inspection as well as a photo-documentation of the wreckage. We were there to review the mechanical system.

MR. GUZZETTI: Okay. And was our -- did we use any kind of magnification at all to determine if there was any grease on the screw or --

MR. KOVACIK: No. This was strictly a visual inspection, you know. We were allowed to get, you know, up close to the hardware. So, we were within several inches of the screw at that time, but, no, we did not have access to any magnifying glass or microscope or any of that type of apparatus.

MR. GUZZETTI: Now, were you or I or any -- were you or any of the other Systems Group members on the boat when this jackscrew was first, you know, broke the surface of the water when it was first recovered?

MR. KOVACIK: No, we were not. As far as I know, no one in the Systems Group was aboard the boat when the wreckage was recovered.

MR. GUZZETTI: Okay. And -- well, I'll just make the statement. There is an exhibit in the docket, Exhibit 7-U, that does have some written signed statements of folks that were on the boat and their observations of the appearance of grease or grease-like substance.

So, we have -- would you agree, we have both the surface -- when the jackscrew arrived, we have the Systems Group's observations on shore, as well as the personnel on the boat, their observations, also, into the docket?

MR. KOVACIK: Yes. I haven't seen that exhibit, but I will take your word that there is a document to that effect.

MR. GUZZETTI: Okay.

MR. KOVACIK: So, you are correct.

MR. GUZZETTI: Thank you.

MR. BERMAN: Mr. Guzzetti, just a second. Could I follow up on that a little bit?

Mr. Kovacik, how long after the jackscrew came ashore was your -- were you looking at that piece of equipment?

MR. KOVACIK: If I remember correctly, we were watching the piece of wreckage being lifted from the boat with a crane and placed on the dock. We were held back a certain safe distance so we wouldn't be in the way of the crane as it operated, but as far as I recall, as soon as it was down on the deck, we were available -- it was made available for us to inspect.

MR. BERMAN: Mr. Rodriguez mentioned that there was a second washing of it once it got ashore. Did you see that?

MR. KOVACIK: I personally don't recall that.

MR. BERMAN: What were your observations, your personal observations of the jackscrew when you saw it as far as grease?

MR. KOVACIK: My initial impression was from a mechanical design standpoint, what hardware was present, what was not, you know. Obviously this, you know, very stark, you know, piece of wreckage, and I would characterize it as my first thought was not looking for grease. I was looking for mechanical hardware, but as we had a chance to view it up close, I just -- I recall seeing the screw discolored.

Normally, I'm used to seeing, you know, a screw in a more pristine state from manufacture. So, the different colors, you know, orange, red, black, white, you know, I don't recall seeing any particular evidence of grease, something that would be noteworthy to me, you know.

At that time, we weren't looking for grease, let's say. So, -- but nothing registered in my mind saying, oh, that is grease.

MR. BERMAN: But did you think about the issue of grease at that time while you were looking at it closely?

MR. KOVACIK: That wasn't my primary concern.

MR. BERMAN: Did you -- I don't think that was -- I don't think you answered the question. Did you -- did the thought of whether or not there was grease on it occur to you while you were looking at it or any time shortly thereafter?

MR. KOVACIK: To follow on that comment, I had discovered the lower rotational stop. I was -- they presented a bag of components. In that bag, we found this lower stop. This clear plastic bag was discolored inside with a black substance. So, we pulled -- I pulled that lower stop out of the bag and, you know, realized it was the stop that was not on the Acme screw. We had noted that, you know, it was covered with this black substance that appeared to be grease.

So, from that point, we noted, you know, oh, there is a difference here between, you know, that component and what we had seen prior.

MR. BERMAN: And was the discussion about grease on the jackscrew with the other members of the group?

MR. KOVACIK: At that time, I don't recall any particular discussion about grease.

MR. BERMAN: So, when you said "we", "we talked about it" or "we noted the difference", who are you talking about?

MR. KOVACIK: I'm talking about the Systems Group in general, you know. As we reviewed the wreckage, you know, we have our notebooks where we took field notes, where our handwritten observations as we continued, and those field notes, you know, were -- well, our particular personal field notes were folded into the Systems Group field notes, which in turn were used to develop the factual report from the Systems Group.

So, the factual report has captured all of our thoughts at the time. So, I would refer back to the factual report being the sum total of what we saw when the wreckage was brought up.

MR. BERMAN: Were there group members -- was the entire group present when you looked at the jackscrew?

MR. KOVACIK: I believe, yes.

MR. BERMAN: So, there were representatives of all the parties --

MR. KOVACIK: I believe that to be true, yes.

MR. BERMAN: And do you recall any conversation among -- between Boeing and other party members of the System Group about it at that time?

MR. KOVACIK: At that time, no. I was -- my -- like I said, my particular interest and focus was on what we had discovered, you know, mechanically, particularly the metal ribbon that was found.

MR. BERMAN: When you were -- when your group was putting together its field notes and combining the field notes of the individual parties into one group report, did any party raise a concern or objection about the language that you've just read to us about the grease?

MR. KOVACIK: At that time when we assembled our field notes for that portion of the, you know, wreckage recovery, I don't specifically recall any discussions, you know, debating whether or not what, you know, we saw or what we recorded was true or accurate.

MR. BERMAN: Okay. Thank you.

MR. HAMMERSCHMIDT: Thank you, Mr. Berman. Mr. Guzzetti, I'd like to interrupt your train of thought as well or your line of questioning. Excuse me.

But in the previous questions, where Mr. Kovacik read from, I believe, Page 8 out of Exhibit 9-A, somewhere in there, I had been reviewing this exhibit last night at home, trying to understand the electrical systems of the horizontal stabilizer and the other systems, for that matter, and this might be the best time to ask a couple of questions in that area.

Regarding the use of the primary and alternate trim systems, what might cause the trim system's circuit breakers to pop open?

MR. KOVACIK: The circuit breakers in the system are there to protect the wiring from, you know, the power source to the motor itself. What might cause a circuit breaker to pop or to be put into an open condition, as it were, I think there are several reasons why that could be true.

The first of which, if there was a short in the electrical system. Take a power line to ground, you know, you potentially overcurrent, you know, the circuit, the circuit breaker would pop. Similar to what you might expect at home.

Another possible reason for the circuit breakers to be in that condition is due to impact damage. Just the forces associated with impact could cause a breaker to, you know, dislodge from its, you know, on-state to an off-state.

It is possible as well that the breakers were physically pulled or purposely pulled by the flight crew to be in that position. So, that's several ways that that can happen.

MR. HAMMERSCHMIDT: All right. What might be the result of resetting the circuit breakers in flight and reversing the trim direction back and forth?

MR. KOVACIK: Cycling of the circuit breakers, I would say generally, so long as the trim is not being commanded at that time, that's somewhat innocuous, that, you know, the system is not being operated. So, turning a switch essentially off and on is not going to, you know, have an issue or have an impact, you know.

The second issue of commanding trim back and forth in opposite directions?

MR. HAMMERSCHMIDT: Yes.

MR. KOVACIK: Is that in an inop condition or -- ordinarily, if the system's functioning properly, you can trim up, you can trim down, and the system will go up, go down, go up, go down, but if there's a failure scenario here, say an inop condition perhaps, you know, if the system is jammed in, say, one trim direction, I guess it would make sense to attempt trimming in the opposite direction to see if perhaps that jam can be, you know, alleviated or if the trim is inoperative, that it seemed to be -- make sense to try trim in the opposite direction.

If you don't get a response one way, perhaps the other. If the system is jammed or inoperative, then trimming in either direction, you know, may not accomplish anything in terms of regaining, you know, command of that system.

MR. HAMMERSCHMIDT: Is there a possibility that the electrical commands on the trim system could over-exert the physical properties of the jackscrew assembly?

MR. KOVACIK: In ordinary operation, you know, even though we have quite capable motors in terms of their torque capability, only the torque necessary to move the stabilizer against air loads is going to be utilized.

If there is some sort of jammed situation, and trim is applied, the full stall torque capability of either trim motor would be applied to that jammed condition.

Now, as to what effect that might have, that's well beyond my area of expertise.

MR. HAMMERSCHMIDT: Okay. Thank you. Thank you, Mr. Guzzetti. You may proceed.

MR. GUZZETTI: Thank you, Mr. Chairman. Mr. Kovacik, I'd like to go into another area of questioning with both you and Mr. Umeda for these next few questions.

Basically, for you, Mr. Kovacik, what -- could you please describe how Douglas chose the single Acme screw and nut design for the actuator for the horizontal stabilizer?

MR. KOVACIK: That's quite an involved question, but I'll see if I can begin here.

Basically, the Acme screw design was chosen for a couple reasons, one of which being the successful in-service performance of the DC-8 horizontal stabilizer actuation system, which utilized jackscrews. So, basically there was some precedence there to say there was a successful system there, let's pattern the twin jet system off of that system.

A general reason why you might choose an Acme screw is, first reason would be irreversibility, meaning once positioned, once the Acme nut is positioned or the screw is positioned in the Acme nut in this case, you cannot reverse load the device and have it move, meaning once you set the horizontal stabilizer in place, you can't load the stabilizer to try to move it again. It's resistant to that. It's called an irreversible design.

So, that's usually the primary reason an Acme screw is chosen, because of its irreversibility characteristic. That allows for a rather simple design to follow from that. It's -- you know, if there was irreversibility, if that -- if there was a reversibility issue, you would need additional components or systems to prevent that back driving of the screw and nut relationship.

MR. GUZZETTI: Okay. And are there -- are you aware of any other types of actuation systems on horizontal stabilizers? For example, all of the Boeing

North airplanes, the 72, 73, 74, 757, do they also utilize an Acme screw and nut?

MR. KOVACIK: The 7 Series Boeing Airplanes utilize what is called a ball screw actuator. Both ball screw actuators and jackscrew-type actuator systems are -- have both been proven reliable means of control surface actuation, just a slightly different philosophy, you know.

Douglas historically has been -- McDonnell Douglas/Boeing now had historically used an Acme screw or a jackscrew arrangement, whereas the Boeing North or the 7 Series airplanes are -- somewhat historically have used the ball screw actuators.

MR. GUZZETTI: And does the ball screw -- can you just give me a broad brush picture of the difference between an Acme screw and a ball screw? I know you're not an expert in ball screws, but what's the fundamental difference between the two?

MR. KOVACIK: There's several differences. As the name would apply, a ball screw utilizes ball bearings in essentially the element of their nut. The ball screw has a screw just like the Acme, but instead of having an Acme nut mating to it, the nut element is made up of a number of circuits of balls, ball bearings.

So, we have a difference between how we actually manage the interface between screw and nut. In the Acme screw, it's a sliding surface, you know, as we saw in the presentation.

In the ball screw design, we have a number of circuits or loops, as it were, filled with ball bearings that recirculate around. So, in that case, we have a rolling type of element mating between the nut and screw.

For the case of the ball screw, it is a reversible type of design, meaning if the nut element is placed on the screw at a certain position, you could forcibly move that nut and change positions on its screw.

So, the ball screw has some additional features, a secondary brake, as it were, a means to prevent that reversing action from happening.

MR. GUZZETTI: Okay. Are there any wearing components in a ball screw?

MR. KOVACIK: The ball screw is not really intended to wear because of the rolling element design, but as with all mechanical interfaces, there will be, you know, some wear experienced, but it's not intended to wear like the Acme nut in the jackscrew design is intended to wear.

MR. GUZZETTI: And does the ball screw design, as far as you know about it, does it compensate for the contingency of the ball bearings seizing or falling out or escaping?

MR. KOVACIK: Yes. There is a load path provided if there is a catastrophic failure of the ball circuits. I'll take one tangential step here. In a typical ball screw similar to an Acme screw, there's a number of, let's say, independent threads on the screw and in the nut.

In the case of the nut, each of the independent thread spirals of the screw is mated to two separate individual ball circuits. So, in a screw that has two thread spirals on it, they have a total of four recirculating ball circuits on there.

So, to get back to your point, there is a back-up load path in the event of a catastrophic loss of all of the ball circuits.

MR. GUZZETTI: And what is that back-up load path, essentially?

MR. KOVACIK: Essentially, it's made up of -- it could be made up of such items as the ball return tubes or ball deflectors. You know, to keep the balls circulating, there's mechanical components within that design that helps guide the balls back into the return tubes for its trip back through the loop.

There is also ice scrapers and fog scrapers on the nut element support assembly used to keep out, you know, foreign objects and ice and other dirt. So, either one of those components, you know, could be utilized as this additional load path.

MR. GUZZETTI: And if it is -- if a ball screw is riding on that additional load path, does the -- would the actuator always stop and alert the crew or would the crew even be aware that those -- that secondary stop was being -- secondary load path was being utilized?

MR. KOVACIK: Let me answer in this way. Generally, the -- since we have a rolling element design with a ball screw, the efficiency of the unit is a much -- it's much more efficient than the jackscrew design, meaning the power you put into the -- the ratio of the power you put into the power you get out.

So, because of that, ball screw actuators, say the electric motors, if you will, can be sized much smaller. So, in the failure case that you're describing, it is possible that the ball screw would discontinue functioning because you've now gone from a rolling friction interface between the nut and screw to something now which is sliding, which would be the ball return tubes or the ice scrapers.

So, it's conceivable that the actuator would stop working at that point because the capability of the motor would not be great enough to do that. I guess it's conceivable in the other way, too, that, you know, perhaps the motors are capable enough to continue working at that point.

MR. GUZZETTI: Okay. Getting back to the Acme screw, which is the screw in question for the MD-83, what was the justification to have a single Acme screw and nut assembly in the tail to drive the entire horizontal stabilizer?

MR. KOVACIK: As you can see by the pictures of the airplane in my presentation, the arrangement of the horizontal stabilizer is on top of the vertical stabilizer, known as a "T tail", you know. I think you might be familiar with an alternative design where the stabilizer is down more towards the empennage or the rear of the airplane.

Primarily because of that T tail, you know, envelope, a single jackscrew was chosen because that would fit within the envelope provided by that T tail design.

MR. GUZZETTI: Okay. Are there other Douglas or McDonnell-Douglas airplanes that have two jackscrews and not one?

MR. KOVACIK: Yes. The DC-8 design has a more conventional tail arrangement, and that has a dual jackscrew arrangement, as well as the DC-10 and MD-11 trijet airplanes. They have two jackscrews as well.

MR. GUZZETTI: Okay. So, to summarize, it was really a space issue with selecting one jackscrew in terms of the T tail design, having a smaller air cavity within the vertical stabilizer?

MR. KOVACIK: I would say that was one of the design considerations.

MR. GUZZETTI: One of them. Okay. Since there is only one Acme screw and nut in the DC-9 series, is that one of the reasons why there was a redundant torque tube placed in the Acme screw?

MR. KOVACIK: Absolutely. That addition of the inner torque tube was a new design for the DC-9 twin jet. The idea of this redundant load path was, you know, accomplished with the dual jackscrew. In this case, only having one jackscrew, means to achieve that had to be designed, and that's how the inner torque tube originated.

MR. GUZZETTI: So, the DC-8 and MD-11 jackscrews do not have a torque tube in them, is that correct?

MR. KOVACIK: That is correct.

MR. GUZZETTI: Okay. And just to clarify, the Boeing airplanes, the 7 series, that have a ball screw, is it just one single ball screw that drives their horizontal stabilizers?

MR. KOVACIK: Yes. To my knowledge, they all have single ball screws.

MR. GUZZETTI: And are those T tail -- are there any of those 7 series T tails?

MR. KOVACIK: 727, I believe, is a T tail airplane.

MR. GUZZETTI: Okay. I'd like to get into the issue of the original certification of the horizontal stabilizer trim system, if I can, and I guess the best way for me to do that is to talk about the regulations that were in force in the mid-'60s that Douglas was -- had to comply to or had to have available to them to certify the airplane.

So, if I could turn to Exhibit 9-W, and in fact, what Exhibit 9-W is, is an excerpt of the CAR Regulations, the Civil Air Regulations that govern aircraft certification, that were in existence in the '60s, and in fact, Dana, if you could put up the PowerPoint slide.

I've got some slides so the audience can read the excerpts that I'd like to discuss with you about them. The first one is CAR 4b.320, Paragraph A, and we're -- here we go, and I think that's -- I can barely see it.

First of all, let me ask you, was Douglas required to comply with this specific paragraph? It's CAR 4b.320(a), and the excerpt reads, "An adjustable stabilizer shall incorporate means to permit after the occurrence of any reasonably probable single failure of the actuation system, such adjustment that would be necessary for continued safety of the flight."

Was the Douglas Company required to comply with this specific regulation?

MR. KOVACIK: Yes, they were.

MR. GUZZETTI: Okay. The -- would you consider -- do you feel that the horizontal stabilizer trim actuation system does comply with this, in your opinion?

MR. KOVACIK: Yes.

MR. GUZZETTI: Okay. Would you say that the -- well, let me ask the question this way. How do you define reasonably probable single failure?

MR. KOVACIK: That's a very subjective, you know, question. My subjective answer at this time may not be the subjective answer that was determined, you know, at the time of certification between, you know, Douglas and the FAA at that time.

MR. GUZZETTI: Okay.

MR. KOVACIK: I don't know how to answer that question.

MR. GUZZETTI: Would you consider the stripping of the threads inside of the Acme nut after excessive wear to be a reasonably probable single failure of the actuation system?

MR. KOVACIK: Wear in itself is an aspect of the jackscrew design. It's part of the package. As such, it's not a failure or a fault. It's an aspect of the design.

MR. GUZZETTI: Okay.

MR. KOVACIK: So, --

MR. GUZZETTI: Does this -- did Douglas

interpret this regulation to apply to structural load paths or something else?

MR. KOVACIK: If I understand correctly, 320 is in regards to control systems.

MR. GUZZETTI: To control systems. Okay. Well, if we could put up -- let me -- let's go to the next excerpt of the regulation. It's CAR 4b.270, Paragraph B.

Did Douglas -- were they required by the FAA in 1960 -- in the '60s for the original DC-9 design, to comply with this regulation?

MR. KOVACIK: My understanding is that there was no compliance data submittal found relative to this particular CAR 4b.270.

MR. GUZZETTI: 270(b). I know it's difficult to read.

MR. KOVACIK: I think it says 320(b).

MR. GUZZETTI: Oh, I'm sorry.

MR. KOVACIK: 606(b).

MR. GUZZETTI: Let me get -- there's 320(b). I'm sorry.

MR. KOVACIK: We're talking about 270(b)?

MR. GUZZETTI: We need to get 270(b) up there. I apologize. Nope. That's not it. Oh, it might be a typo. Go ahead and click it one more time and one more time again and stop right there. Yeah. That's it. I apologize.

MR. KOVACIK: Okay. I was confused there.

MR. GUZZETTI: Yeah. The title of this PowerPoint slide is incorrect. It's not 4b.320. It's -- the text in the slide is from 4b.270.

MR. KOVACIK: Okay.

MR. GUZZETTI: So, --

MR. KOVACIK: I believe as I was stating, we did not find any compliance data submittal specifically for 4b.270.

MR. GUZZETTI: So, in your review of the certification data, you found no evidence to indicate that Douglas had performed any testing or had any -- were not -- had performed any testing to comply with this?

MR. KOVACIK: There's no evidence that there was a need to show compliance to this section of the CAR.

MR. GUZZETTI: Okay. Do you have any idea why that you couldn't find any compliance data?

MR. KOVACIK: You know, as we didn't find any compliance data, there wasn't any data found to have any explanation associated with that. Since this is a structural section of the CAR 4b, you know, perhaps Mr. Umeda might be able to help in that regard in explaining that.

MR. GUZZETTI: That would be fine. Mr. Umeda, can you answer that question? Do you know why the horizontal stabilizer actuation system was not -- that you have no data to indicate that you were required to comply with this specific regulation?

MR. UMEDA: As Mr. Kovacik has mentioned, there was no data found that was submitted to the FAA to comply with CAR 4b.270, and I believe that was at Amendment 16 for the original DC-9 certification.

However, the jackscrew assembly, due to the design nature of multiple load path, does comply with 270.

MR. GUZZETTI: Okay. So, the multiple load paths of the jackscrew assembly, you say, does comply with it, and do you -- have you found compliance data for CAR 4b.270(b) for other components of the -- what components specifically did Douglas show compliance for under this regulation that were related to the horizontal stabilizer actuation system?

MR. UMEDA: I have personally not done that research for the components for the original DC-9 certification on other components.

MR. GUZZETTI: Okay.

MR. UMEDA: I don't have that data at this time.

MR. GUZZETTI: Mr. Kovacik, can you shed any light on that?

MR. KOVACIK: As -- if any of the jackscrew assembly components or any of the components of the horizontal stabilizer system had compliance data submitted in relate -- relative to CAR 4b.270?

MR. GUZZETTI: Yes.

MR. KOVACIK: No. I haven't done that research, --

MR. GUZZETTI: Okay.

MR. KOVACIK: -- and to my knowledge, you know, I don't believe there was any data associated with stabilizer systems.

MR. GUZZETTI: Well, Mr. Umeda, when you testified regarding multiple load path philosophy, you were talking about the gimbal ring, is that correct, or you were talking about the jackscrew?

MR. UMEDA: I was addressing the entire jack-screw assembly.

MR. GUZZETTI: The entire jackscrew assembly?
MR. UMEDA: Yes, that's correct.
MR. GUZZETTI: And -- but yet there is no evidence to indicate that Douglas had any compliance data or performed any testing to comply with this specific regulation, is that correct?
MR. UMEDA: For the jackscrew assembly?
MR. GUZZETTI: For the jackscrew assembly.
MR. UMEDA: That is correct.
MR. GUZZETTI: Okay.
MR. UMEDA: We have not discovered any data that was submitted.
MR. GUZZETTI: Why do you think that is the case?
MR. UMEDA: I don't know.
MR. GUZZETTI: Okay. Would you consider the jackscrew assembly a primary structure?
MR. UMEDA: Yes, I do.
MR. GUZZETTI: Okay. For follow-on models like the MD-80 and the MD-95 or Boeing 717, were -- did you -- is there any evidence or are you aware of any compliance tests that were performed to show compliance with fail-safe strength for the jackscrews in those airplanes?

MR. UMEDA: For the certification basis for the MD-80?

MR. GUZZETTI: Yes.

MR. UMEDA: Referring to fail safety and -- do you have a specific paragraph?

MR. GUZZETTI: That's -- let me go on to another question. The -- let me move on to another regulation, and if we could go to CAR 4b.606, and actually 606 is not in 9-W, in that excerpt. It's contained in Exhibit 9-F.

Now, Mr. Kovacik, did --

MR. KOVACIK: Jeff?

MR. GUZZETTI: Yes?

MR. KOVACIK: I'm sorry. Mr. Guzzetti, perhaps Page 9 of that Exhibit 9-W.

MR. GUZZETTI: I'm not sure. Page 9?

MR. KOVACIK: I believe so.

MR. GUZZETTI: 606? Okay. Thank you for that clarification.

Mr. Kovacik, is there -- did -- was Douglas required to comply with this regulation?

MR. KOVACIK: To my knowledge, yes, we were.

MR. GUZZETTI: And what type of data, compliance data was found or why -- what proof of there is that?

MR. KOVACIK: I don't know the exact, you know, document or data submittal, but from what I understand, we were -- excuse me -- we were -- there was a requirement for us to comply with that section of the CAR 4b.

MR. GUZZETTI: Okay. In regard to this regulation, was a fault analysis performed on the jackscrew assembly?

MR. KOVACIK: A fault analysis was accomplished. I don't know if the fault analysis was accomplished as compliance data for this particular, you know, section of CAR 4b.

MR. GUZZETTI: Okay.

MR. CLARK: What's the nature of the fault analysis? What is it? Can you describe it? What's -- is it -- what kind of fault analysis?

MR. KOVACIK: The fault analysis was a document that looked at certain faults or failures within the DC-9 control systems in general, and that included horizontal stabilizer actuation.

This fault analysis was essentially a precursor to what you might be more familiar with, an FMEA. It was a rudimentary early attempt at that sort of quantitative analysis.

MR. BERMAN: Mr. Guzzetti? Mr. Kovacik, when you answered Mr. Guzzetti and said you're not aware of a fault analysis done on this part of the airplane, was Boeing asked whether or not there was a fault analysis done on this part of the airplane?

MR. KOVACIK: I believe my comment was that I was aware that a fault analysis was done. I was not -- I'm not aware whether or not that fault analysis was done with specific regards to 4b.606. I don't know if that was required to be submitted as a part of 606.

In a cursory read of the requirement, it doesn't indicate any requirement for any quantitative analysis or failure analysis or fault analysis.

MR. BERMAN: But you're saying a fault analysis was done on the jackscrew assembly?

MR. KOVACIK: A fault analysis was done on the entire control system, which included the jackscrew system, yes.

MR. GUZZETTI: Thank you. Would you say that after reading CAR 4b.606, Paragraph B, that in your opinion, does the jackscrew meet that regulation? Does it comply with that specific regulation?

MR. KOVACIK: Would it be appropriate to read that section or did you have that on a PowerPoint?

MR. GUZZETTI: I had it on a PowerPoint, yes.

MR. KOVACIK: Okay.

MR. GUZZETTI: Whatever you feel comfortable doing. I think they're putting it up for you right now.

MR. KOVACIK: Okay. In my understanding, you know, the jackscrew actuator as designed complies with this section of the CAR 4b.606.

MR. GUZZETTI: Okay. The fault -- getting back to the fault analysis, did Douglas consider Acme nut thread excessive wear or stripping in that fault analysis?

MR. KOVACIK: The condition of wear or wear-out was not included in the original DC-9 fault analysis. I would say, however, the concept of wear was addressed by Douglas Aircraft, and that's reflected in the design concept or the design philosophy of the jackscrew.

As Mr. Umeda has indicated in his presentation and in his testimony, because the Acme nut is intended to wear, if there's going to be wear happening in the actuator assembly, we want that wear to be in the Acme nut.

Since it is a wear element in the system, the component was designed with -- from a robust standpoint, meaning the nut element is significantly oversized to allow for the component to wear while maintaining, you know, its intended function, both as a mechanism and as a structural load path.

In addition to the robust or oversized design, because it is a wear element, there is maintenance intervention that is prescribed, that being lubrication (1) to manage the wear at that interface, and (2) a maintenance intervention inspection to monitor the overall wear of that element, the condition of the nut.

MR. GUZZETTI: I see. Well, we'll get into -- I'd like to get a brief description from Mr. Talay about those maintenance items, but before we do that, I want to close out some issues involving the fault analysis. So, let me stay on that for just a moment.

So, there was no formal consideration addressed -- is it correct that there was no formal consideration of Acme screw stripping, thread stripping, in the fault analysis, is that correct?

MR. KOVACIK: Are you referring to the Acme screw or the Acme nut?

MR. GUZZETTI: Excuse me. The Acme nut.

MR. KOVACIK: That condition, that wear-out condition, is not included in the fault analysis.

MR. GUZZETTI: Okay. But you -- but there was some consideration made that didn't make it into that document. There were -- were there -- is there evidence to suggest, whether it be through interviews or your discussions with retired engineers, to suggest that that -- that excessive Acme nut wear, thread wear, and stripping of the Acme nuts was discussed, was considered?

MR. KOVACIK: I think the design button -- the nature of the design itself states rather succinctly that this issue of wear was considered and was addressed in the design.

Now, in relation to how the fault analysis was developed or whether or not it needed to be included, I can't say. Obviously I wasn't there at the time, and I didn't receive any information or comments in all of our discussions with, you know, what would be termed the "gray beards" of our company.

MR. GUZZETTI: Okay. Did -- whenever there were follow-on models, the MD-80 series, the MD-90, the 717, were there brand-new fault analysis or FMEAs or any kind of hazard analysis performed for the horizontal stabilizer jackscrew assembly for those airplanes?

MR. KOVACIK: I say generally as -- if any changes to the systems were made, not necessarily stabilizer, but any changes to the system from the original DC-9, you know, as may have occurred during MD-80 design or MD-90 design or 717, as any of those changes were made to the system, whatever requirements at the time in place during that certification as negotiated with the FAA, you know, the -- you know, additional either changes to the fault analysis or additional quantitative analyses, say an FMEA, would have been accomplished only if the designs were changing.

MR. GUZZETTI: Well, let me be more specific. Did the -- was the original -- the revisions to the fault analysis throughout the evolution of the DC-9, MD-80, 717, did any of those revisions provide any kind of verbiage or formal consideration of Acme nut thread wear or stripping?

MR. KOVACIK: No.

MR. GUZZETTI: No, they did not. Okay.

MR. KOVACIK: They did not.

MR. GUZZETTI: The -- would you consider -- well, do you consider wear -- you may have already answered this, but I'll ask it more directly.

Do you consider wear a failure mode that should be addressed in FMEAs or fault analyses or things like that?

MR. KOVACIK: Wear is an aspect of the design. It's a design parameter, if you will. By definition, wear is not a failure or a fault.

MR. GUZZETTI: Is stripping of the Acme nut threads a failure?

MR. KOVACIK: That's a more difficult question to respond to. Is wear-out or stripping of the -- I would -- let's retract that. You know, you say stripping of the nut. Do you mean, you know, --

MR. GUZZETTI: The failure -- the complete failure of all of the threads inside of the Acme nut as a result of --

MR. KOVACIK: As a result of?

MR. GUZZETTI: -- the stripping?

MR. KOVACIK: As a result of?

MR. GUZZETTI: Whatever. I'm not going to give -- I don't have a parameter there.

MR. KOVACIK: Okay.

MR. GUZZETTI: Just whatever could cause it could cause it, but the end result, if you were to strip all of the threads inside of the Acme nut, would you consider that a failure?

MR. KOVACIK: The total wear-out of the Acme nut thread, I think, would be considered a multiple event failure.

MR. GUZZETTI: Okay. Well, we're not talking about wear-out. We're just talking about the end result of wear-out or anything that could get you there. A crack. I'm not going to speculate on what could cause stripping, but assuming whether you've got a full thread, a healthy thread or a very little thread, if those threads -- if all of the threads inside the Acme nut strip out, would you consider that a failure?

MR. KOVACIK: I would still state that whatever causation that led you to eliminate all of the threads, both thread spirals within the Acme nut, would be a multiple event failure.

MR. GUZZETTI: Okay.

MR. KOVACIK: I don't know how else to answer that.

MR. GUZZETTI: Okay. Fair enough. Would you consider the jackscrew primary structure or would you consider it a control system?

MR. KOVACIK: It is certainly a control system, but I believe it also has an additional function as a structural load path.

MR. GUZZETTI: Okay. So, the answer would be yes. The answer would be both. It is both a primary structure and both a control system.

MR. KOVACIK: Yes.

MR. GUZZETTI: Okay. That being said, was it -- I'll just ask this succinctly. Was it required to comply with -- as a -- as primary structure, was it required to comply with all of the regulations that address primary structure?

MR. KOVACIK: Again, this is a little beyond my particular area of expertise.

MR. GUZZETTI: Okay.

MR. KOVACIK: If Mr. Umeda can help in this regard.

MR. GUZZETTI: Sure. Mr. Umeda, if it is, as Mr. Kovacik indicated, it's both primary structure, and it's also a control system, should it have complied with or did it comply with the CAR regulations that all of them that deal with fail-safe strength and fatigue evaluation that are applied to aircraft structure?

MR. UMEDA: Because of the design features in the jackscrew assembly, it does comply with CAR 4b.270.

MR. GUZZETTI: Okay. Can you be more specific? Can you tell me -- well, no. I'll ask a more specific question.

Does the engagement of the Acme screw threads with the Acme nut threads, does that comply with CAR 4b.270, Paragraph B, for structure?

MR. UMEDA: Yes, it does.

MR. GUZZETTI: Yes, it does. And why do you say it complies with that? What is your justification?

MR. UMEDA: Do you have CAR -- I don't have CAR 4.b.

MR. GUZZETTI: Oh. We can even throw that PowerPoint slide back up there. The title is "Fatigue Evaluation", Dana.

MR. UMEDA: If you read the Introduction to CAR 4b.270 -- can I go ahead and read it?

MR. GUZZETTI: Let us get it up on the screen. It's one more PowerPoint slide, Dana, or maybe two. That's it right there. That's it right there. Sure. You're welcome to read it and then comment specifically on the -- your justification.

MR. UMEDA: Okay. This is CAR 4b.270, the introductory paragraph. "The strength to meet the design and fabrication of those portions of the airplane's flight structure in which fatigue may be critical shall be evaluated in accordance with the provisions of either Paragraph A or Paragraph B of this section."

Paragraph A is Fatigue Strength, and Paragraph B is Fail-Safe Strength.

The Acme nut threads and the thread in the Acme screw is not fatigue-critical. Therefore, it complies.

MR. GUZZETTI: I'm sorry. Could you repeat that very last sentence that you just --

MR. UMEDA: The Acme nut thread and the Acme nut screw threads, because of its robust design, robust nature, is not fatigue-critical. That is where it does comply.

MR. GUZZETTI: Okay. Is not fatigue-critical.

MR. UMEDA: That's correct.

MR. GUZZETTI: Okay. Would you say, Mr. Kovacik, that maintenance intervention is key to the safety of the Acme screw and Acme nut design?

MR. KOVACIK: It's fundamental to the design. It's fundamental to the robust design concept.

MR. GUZZETTI: Would you say that without maintenance intervention, the design could become unsafe?

MR. KOVACIK: Without maintenance intervention, the design, the type design could be violated.

MR. GUZZETTI: Okay. Is it possible that that violation could be catastrophic?

MR. KOVACIK: Potentially, yes.

MR. GUZZETTI: Okay. What about wear-critical components? Well, let's skip that for a moment.

Let's move on to -- I guess in order to delve into this maintenance intervention that you speak of, it would be appropriate at this point to educate me and the public about the exact type of maintenance intervention that you're talking about, and at that point, Mr. Talay, could you -- you're finally getting an opportunity to speak here. I'm sorry you had to wait so long.

But could you provide us with an overview of the type of -- the care and feeding of the jackscrew assembly which is essential to its safety?

MR. TALAY: Mr. Guzzetti, I also have a short presentation that might get us started on that, understanding this issue.

MR. GUZZETTI: Okay. Is it about -- about how long is it?

MR. TALAY: It's less than 10 minutes, I believe.

MR. GUZZETTI: Okay. Less than 10 minutes, and are you all set up on the -- on your presentation?

MR. TALAY: Yes, I am.

MR. GUZZETTI: Go ahead.

MR. TALAY: We've heard a basic description of how the system operates as well as what considerations went into its design.

At this time, I'll be discussing the maintenance procedures recommended for this assembly. As mentioned, the Acme nut is by design a wearing component within this assembly. The Acme screw is manufactured of a case-hardened steel while the nut is made of a softer aluminum/bronze material.

Maintenance actions are necessary to assure the continued airworthiness of the airplane. Accordingly, the recommended maintenance program for this assembly includes periodic lubrication to manage the rate of wear. The program also provides for an inspection used to monitor the amount of wear incurred in service.

The following maintenance procedures, although revised and enhanced over the years, have been in place since 1966 and currently affect 2,100 aircraft. They are addressed in the applicable aircraft maintenance manuals and maintenance planning documents which are published by Boeing and utilized by operators to support the aircraft while in service.

The actuator assembly, the actuator installation, is lubricated at several points. The main gear box has a cavity or reservoir filled with approximately one-half pint of jet engine oil. The upper bearing, the Acme nut, the screw gimbal and the stabilizer hinge bearings are lubricated with wide temperature grease applied to existing lube fittings.

Grease is applied to the fittings under pressure until it is observed exiting the cavity. This ensures adequate lubricant has been delivered. The procedure also calls for the brush application of a light coat of grease to the Acme screw threads. The mechanism is then operated through its full range of travel to distribute the lubricant over the length of the jackscrew.

Additionally, the lower portion of the Acme screw in the area of the rotational stop and the horizontal stabilizer hinge bolts are protected against corrosion by the brush application of a corrosion-inhibiting lubricant.

We'll now discuss the inspection procedure that will measure the amount a unit is worn while in service. The area of focus for this inspection is the interface between the threads of the Acme screw and the threads of the Acme nut. It is the clearance or gap between the two sets of threads that is being monitored.

For discussion purposes, that clearance will be referred to as end play. On the view that's up now, what we're measuring is this white gap on the lower side of the screw thread.

The following inspection procedure utilizes a restraining fixture and a dial indicator. The restraining fixture has a threaded mid-section with a threaded crevice screwed into each end. The dial indicator is an instrument used to measure small amounts of linear movement between two points. The movement is picked up by a plunger at the back of the indicator and read in thousandths of an inch.

During this inspection, the restraining fixture is installed alongside the actuator, mounted between the vertical stabilizer and the leading edge of the horizontal. Applying the specific torque to the restraining fixture mid-section has the effect of pulling down on the leading edge of the horizontal, changing the load on the screw from one of tension to one of compression.

The dial indicator, shown here mounted to the lower stop with the plunger on the dial indicator face resting against the lower surface, the dial indicator is mounted to the lower rotational stop with the plunger set against the lower surface of the Acme nut.

The relative movement between the Acme screw and the Acme nut is measured and is equal to the gap or clearance discussed earlier. The restraining fixture load is applied and reversed several times until consistent results are achieved. This load cycling ensures thread-to-thread contact.

A similar inspection, measuring the movement between the Acme screw and the upper support, is accomplished to monitor the condition of the spherical bearing within the upper support. We have a dial indicator mounted to the upper stop, with the plunger up against the upper support. We're going to monitor movement here and here with the same movement. That movement of the upper bearing is referred to as free play.

By design, a minimum clearance is maintained between the Acme nut and the Acme screw threads during initial manufacture and subsequent overhauls. The unit is manufactured with an end play of from 3 to 10,00ths of an inch. An end play measurement then is equal to the initial clearance at the time of manufacture, plus in-service wear. When the in-service end play measurement exceeds 40,000ths of an inch, the unit is replaced.

In order to understand the conservative nature of the established removal threshold, we can go back to a topic touched on earlier, that being the excess strength issue.

As mentioned, a new unit installed on an aircraft with zero wear of the Acme nut is 15 times stronger than the maximum design loads. That unit worn to an end play reading of 40,000ths of an inch remains 10 times stronger.

Taking the end play reading to 80,000ths of an inch or twice the removal threshold still leaves us with an installation five times stronger than the maximum design loads.

Current in-service end play limit of 40,000ths of an inch is conservative from both the strength and design standpoint. In summary, this assembly is recognized as a wear component which is addressed initially by its robust design and later by in-service maintenance action to control and monitor that wear.

And, Mr. Guzzetti, that finishes this presentation.

MR. GUZZETTI: Thank you very much. That's a good base to set up some of the following questions.

Before I get into the lubrication and the end play check, though, you indicated that at 80,000ths wear, that the threads are thick enough to handle five times the maximum design loads, is that correct?

MR. TALAY: And that's a conservative figure, yes.

MR. GUZZETTI: Okay. If they go beyond 80,000ths, is it -- it would be less than five times, is that correct?

MR. TALAY: It would -- when one increases, one decreases, right.

MR. GUZZETTI: Okay. And then quickly going back to the issue of stripped Acme nut threads, if the wear gets so excessive that you're just left with a small flat ribbon -- Mr. Umeda, I'll address this to you.

Is it possible that that small flat ribbon could strip out under the normal flight loads, in that we're talking about excessive wear well beyond 80,000ths?

MR. UMEDA: The analysis on the threads, on a small flat ribbon, becomes a little bit more complex than the trapezoidal shape of the Acme nut thread, such that, if you introduce different types of stresses, one of shear stress and then you add bending, that analysis is still on-going for that type of thread shape and thickness.

MR. GUZZETTI: Okay. But there would be some bending -- there could be bending involved in a very thin piece of the extremely excessively worn Acme nut thread?

MR. UMEDA: That is correct.

MR. GUZZETTI: That's correct. Okay. And

given the wear, if the wear is allowed to progress until there's -- well, to the whole limit where there's no thread left, would the jackscrew then be able to slide through the Acme nut?

MR. UMEDA: With any degree of excessive wear, you would reach a point where the threads would eventually fail.

MR. GUZZETTI: Okay. And when that failure occurs, is it possible that the Acme screw could slip completely through the Acme nut -- well, would begin to slip through the Acme nut under flight loads? Is that possible?

MR. UMEDA: Yes, that is possible.

MR. GUZZETTI: Okay. And what would be -- as it's slipping through -- assuming that scenario is correct, the jackscrew's slipping through the completely stripped Acme nut, would the bottom of the Acme nut strike the top of the lower stop?

MR. UMEDA: That is correct.

MR. GUZZETTI: Okay. And was that lower stop intended by Douglas back in the '60s to be designed as a final mechanical stop in that contingency?

MR. UMEDA: No, there was no design intent, that the lower stop or the upper -- mechanical upper stop is designed for rotational loads, not loads along the axis of the jackscrew.

MR. GUZZETTI: I see. So, it was never designed to be a contingency for a failure of a completely stripped Acme nut, is that correct?

MR. UMEDA: The lower stop was never designed to take an axial load along the jackscrew.

MR. GUZZETTI: Okay. That's a more accurate answer, I guess. By the way, this -- the lower stop -- what is beneath the lower stop? Directly beneath it?

MR. UMEDA: There's a small gap, and beneath the lower stop, there is the torque tube washer and the torque tube nut.

MR. GUZZETTI: Torque tube nut. Is there any part on the bottom part of the jackscrew that's known as an "end stop"? Is that -- have you ever heard that term before within the investigative ranks or within Boeing?

MR. UMEDA: I heard that term by non-structural engineers.

MR. GUZZETTI: Non-structural engineers. Okay. Getting back to the maintenance intervention that Mr. Talay just testified to, first of all, Mr. Talay, how many grease fittings are on the Acme nut?

MR. TALAY: One.
MR. GUZZETTI: And is it on the top part of the nut or the lower part of the nut?
MR. TALAY: It's on the top part.
MR. GUZZETTI: On the top part. And does that lube fitting provide a passage from the outside of the nut into the bore of the Acme nut?
MR. TALAY: Into the thread interface, yes.
MR. GUZZETTI: Into the thread interface. Why is there only one grease fitting on that Acme nut? In fact, maybe it would be better for Mr. Kovacik to answer that question. It might be out of your area.
Mr. Kovacik, do you know why there's only one Acme -- grease fitting on that Acme nut?
MR. KOVACIK: I don't know exactly why there is one, you know, grease fitting on that Acme nut.
MR. GUZZETTI: Okay. Are there -- is there more than one grease fitting on the Acme nuts from the MD-11, for example?
MR. KOVACIK: No. There is a single lubrication fitting on the MD-11 Acme nut.
MR. GUZZETTI: Okay. Are there any airplane horizontal stabilizer jackscrew Acme nuts that have more -- have less than one or more than one grease

fitting?

MR. KOVACIK: The DC-8 jackscrew design does not include a lubrication fitting on its Acme nut.

MR. GUZZETTI: Okay. Mr. Talay, what grease is specified for the jackscrew, and how is that -- you know, where do you find that specification in the Douglas --

MR. TALAY: All of these procedures, Mr. Guzzetti, are in the maintenance manuals, and we refer to the lubricant by a MIL Spec, and that would be MIL Spec 81322. In plant, we use Mobil 28.

MR. GUZZETTI: In plant?

MR. TALAY: Right.

MR. GUZZETTI: Okay. Does -- and I know --

MR. TALAY: The MIL Spec includes a number of lubricants.

MR. GUZZETTI: And is Mobil 28 --

MR. TALAY: Yes.

MR. GUZZETTI: -- one of those?

MR. TALAY: Yes.

MR. GUZZETTI: Okay. And that is specified in the Douglas Maintenance Manual?

MR. TALAY: Yes.

MR. GUZZETTI: Let me ask you about the

lubrication procedure, and if I could ask Dana to put up some photographs out of my factual report. It's Exhibit 9-B, Page 18. It's Photograph Number 30 and 31. Yeah. That's it right there. That's -- this is a photograph as if you were inside of the well of the vertical stabilizer --

MR. TALAY: Yes.

MR. GUZZETTI: -- looking out. Is that the -- and there's a gentleman's face there on the outside of the airplane. Is that the size of the access panel?

MR. TALAY: Yes. That's an access panel in the lower faring, and that's how you gain access to the upper portion of the nut. It's a hinged access panel.

MR. GUZZETTI: Okay. And, Dana, if you could slide that photograph up, and this is an external shot.

MR. TALAY: Right.

MR. GUZZETTI: You can see -- in fact, that's Dr. Brenner's hand down in the lower corner for scale. Is that the panel that is normally used on the line by a maintenance crew to lubricate the jackscrew?

MR. TALAY: Normally, that'd be two panels removed. It's that one which is 4X6 inches. There's a larger one on the lower side of the screw to gain access to the lower nut area, and that's 8X7 inches by dimension.

MR. GUZZETTI: In your years of service engineering, have you -- are you aware of a significant amount of complaints regarding the size of that Acme -- excuse me -- the size of that access panel or just challenges in general to lubricating the jackscrew?

MR. TALAY: No, I haven't. In my time with Service Engineering, I don't think we've fielded a question regarding trouble lubricating this thing for access.

MR. GUZZETTI: Okay. Let's see. The procedure for lubricating the jackscrew, and again this might be a bit repetitive, but does it involve buttering the threads of the jackscrew as well as hitting the grease fitting?

MR. TALAY: Yes. As mentioned in the presentation, you brush apply lubricant to the external surface of the screw through its entire length and operate the screw.

MR. GUZZETTI: Can it also be applied by hand instead of a brush?

MR. TALAY: Absolutely. It's a method of application, not a tool.

MR. GUZZETTI: Okay. Since we're still on this subject of lubrication, --

MR. TALAY: Yes.

MR. GUZZETTI: -- and then we'll move on to the end play, I'd like to move your attention to Exhibit 11-Q, and 11-Q is entitled "Telex Messages Between Alaska Airlines and Boeing Regarding Elevator Events and Grease Compatibility".

First of all, are you familiar with this type of telex?

MR. TALAY: Yes.

MR. GUZZETTI: Are these telexes -- do they -- are they sent routinely from your office?

MR. TALAY: These are the normal mechanism, called a BOECOM Message. It's our version of a telex, and that's the normal communication path from the operators into Boeing and back.

MR. GUZZETTI: Okay. The -- actually, this is one of a couple of telexes I wanted to talk about, but I wanted to talk about another one first.

Mr. Chairman, if you could just excuse me for just about 10 seconds while I dig up the proper exhibit here.

MR. HAMMERSCHMIDT: Well, please try to be efficient.

(Pause)

MR. GUZZETTI: I have another exhibit here, also, that's also another Boeing telex. I don't know whether you have it, Mr. Talay.

MR. TALAY: Okay.

MR. GUZZETTI: It's -- actually, it's Exhibit Number 11-K, entitled "Boeing Message Concerning AeroShell Grease 33 Lubrication".

MR. TALAY: I don't have that one.

MR. GUZZETTI: Okay.

MR. TALAY: It's on its way.

MR. GUZZETTI: Ms. Bellinger, I think, is going to provide you a copy right now.

But as she's doing that, this telex discusses something known as a "no technical objection", and just in general, is that a term that you're familiar with?

MR. KOVACIK: The no technical objection, NTO, is an industry-recognized mechanism whereby an operator may request of a manufacturer for an opinion or a position on a given technical issue.

In submitting the request for an NTO, the operator is not asking for any approval on a given action, and if it were submitted to the operator, it's not approved data.

The responsibility is the operator's to pursue approval of that action.

MR. GUZZETTI: Okay. I think you have the exhibit there.

MR. TALAY: Yes.

MR. GUZZETTI: It's 11-K. There's a quote, and I won't ask you to read it or -- and I won't read it, but basically it's a quote from a previous --

MR. TALAY: Yes.

MR. GUZZETTI: -- Douglas telex. It's referenced, I think, Reference B, that was dated 26 September '97.

MR. TALAY: Yes.

MR. GUZZETTI: And it addresses -- it says that -- it talks about Douglas having no technical objection to the use of BMS-3-33, and then in parenthesis, it says, "(AeroShell 33 Grease --

MR. TALAY: Yes.

MR. GUZZETTI: -- place of the MIL G-81322)". First of all, why was this telex sent? What was the purpose of the original one?

MR. TALAY: The original telex was sent to respond to an operator request for an NTO to substitute that grease.

MR. GUZZETTI: And who was that operator?

MR. TALAY: Alaska.

MR. GUZZETTI: Okay. And the NTO goes on to quote some results of some testing and things like that.

MR. TALAY: Yes.

MR. GUZZETTI: Were you involved with that specific testing?

MR. TALAY: No, I wasn't.

MR. GUZZETTI: Okay. Were you provided information about the results of those tests -- of that test?

MR. TALAY: This telex was sent from Service Engineering in Long Beach, but I'm not particularly cognizant on the actual testing that was accomplished. We do have a lubrication Boeing person that might be able to address your questions later on.

MR. GUZZETTI: Okay. Great. Thank you. We'll do that.

The -- let's talk about previous experiences involving Acme nut wear, cases back in history where operators have complained about premature wearing --

MR. TALAY: Yes.

MR. GUZZETTI: -- of the Acme nut, and I

guess I would like to address your attention to Exhibits 9-Q and 9-R in the -- what that is, one of them is a DC-9 All Operators Letter --

MR. TALAY: Yes.

MR. GUZZETTI: -- Regarding Premature Acme Nut Wear, and then the other exhibit is just some supporting data.

MR. TALAY: Yes.

MR. GUZZETTI: First of all, what is an AOL?

MR. TALAY: An AOL was -- is a method of communication from Boeing out to the fleet. It's usually -- it's an item that would not normally be handled by a service bulletin. It's an item that would provide advice or recommendation, and it's distributed to all the operators that are listed on the face of the AOL.

MR. GUZZETTI: Okay. Is it regulatory in nature?

MR. TALAY: No.

MR. GUZZETTI: Okay. It's not. Could you please summarize the intent of this 1994 --

MR. TALAY: This is an AOL that I wrote in '84. It dealt with two operators had reported three instances of premature wear of again three assemblies of jackscrews. We requested and received the units in to Boeing, in to Douglas at the time, and did a full analysis on the actual hardware itself.

We were able to actually capture these pieces of equipment and did an analysis and provided a recommendation at that time. The analysis that we did indicated that for a few different reasons, the assemblies had received inadequate lubrication.

So, we -- the recommendation here was just to comply with the OAMP Maintenance Task Lubrication Interval of 650 at that time. These units had -- they were not able to particularly report the lube interval that they had been using, and they sort of lost track of their lubrication interval, and we had blocked lube passages and things like that.

So, we determined, based on no hardware problems, the units were the correct finish and material and hardness and things. So, the determination at the time was lubrication.

MR. GUZZETTI: Was lubrication --

MR. TALAY: Yes.

MR. GUZZETTI: -- or lack thereof?

MR. TALAY: Right.

MR. GUZZETTI: And how much time did these two jackscrew units that Douglas examined -- how many -- how much total flight time did it have on it?

MR. TALAY: One had, I think, 6,000 hours, the other one, I believe, had close to 10.

MR. GUZZETTI: And were they at or near or slightly above the --

MR. TALAY: They were removed for wear. So, they were in the close to the 40 or just over 40.

MR. GUZZETTI: Okay. Would you say that a lack of lubrication can lead to excessive Acme nut wear?

MR. TALAY: That was the determination on this event, yes.

MR. GUZZETTI: Okay. Then in 1991, and this is explained in Exhibit 9-S, there was an additional All Operators Letter, is that correct?

MR. TALAY: Yes.

MR. GUZZETTI: And what was the upshot of that AOL?

MR. TALAY: The difference or the issue here was that an operator reported excessive wear of a unit but was not able to provide us the unit. It came to our attention at a team conference, which is a meeting we periodically have in Long Beach.

So, we wanted to address the operator's concerns, but in this case, we didn't have the piece of hardware to do an analysis on. So, the determination was made to go out with a polling-type survey and try to obtain some information from the fleet on the wear issue.

The problem with obtaining data like this is we don't require, and at that time the airlines did not track, wear as any kind of a measurable value. So, the information that we received back was usable but sparse as far as actually obtaining what their wear rate might have been in comparison to their lube interval.

MR. GUZZETTI: Okay.

MR. TALAY: We did make a determination at the time with the airlines that reported in, I believe we had -- the last page talks about receiving input from 10 DC-9 operators and 11 MD-80 operators, and again not all the questions that we wanted to have answered could be answered because they didn't particularly track the wear of the item.

So, we were basing it maybe on removal rates and things like that. We did also -- basically, the determination was that the existing maintenance interval that was referenced in the first AOL should be followed.

MR. GUZZETTI: Okay.

MR. TALAY: And again, these AOLs, from a Service Engineering standpoint, these are -- it's our function to obtain the optimum life of the part on the airplane. So, these were intervals that were recommended from a Service Engineering standpoint again to keep this part on the airplane for the longest period of time.

MR. GUZZETTI: Okay. And -- but the final -- one of the final conclusions in that AOL was an opinion by Boeing that it was lack of lubrication that could have led to the premature wear?

MR. TALAY: Could have led to the first one. We had again no hardware to look at, but --

MR. GUZZETTI: And, Mr. Kovacik, what was the average wear rate figure given for the MD-80 in that AOL?

MR. KOVACIK: Referring to --

MR. GUZZETTI: As a result of this survey that was --

MR. TALAY: I have that here.

MR. GUZZETTI: Okay.

MR. TALAY: The DC-9 -- you got it? The DC-9 had a wear rate of .0011, and the MD-80 fleet had .0013, which was the average of the data collected. If we compared that to the lube intervals of the airlines from the data collected, that's where we arrived at it.

We have a target wear rate of this assembly of about 1,000ths per thousand hours. So, these were slightly higher but not much.

MR. GUZZETTI: .001 --

MR. TALAY: Yes.

MR. GUZZETTI: -- per thousand --

MR. TALAY: Yes.

MR. GUZZETTI: .0013 or 4, depending on the model, per thousand hours?

MR. TALAY: Right.

MR. GUZZETTI: Okay. Mr. Kovacik, back in the mid-'60s, was there a problem with premature Acme wear, Acme nut wear of jackscrew assemblies early on in the DC-9 program?

MR. KOVACIK: Right. Upon entry into service, it was discovered that the jackscrew was wearing at a higher rate than the intended, you know, .001 per thousand hour wear rate, and at that time, the changes were accomplished to correct that situation.

MR. GUZZETTI: And how -- what were some of the corrective actions?

MR. KOVACIK: Apart from recommendations for improved lubrication practices, the actual hardware changes consisted of increasing the heat treat of the Acme screw to provide a more optimal interface between the screw and nut, and testing was done to support that change which again revalidated that a .001 per thousand hour wear rate could be achieved.

MR. GUZZETTI: So, there were some material issues with that jackscrew that could have led to the premature wear of the softer Acme nut in that case?

MR. KOVACIK: It led to a higher wear rate than what we had desired.

MR. GUZZETTI: Okay. Where did the 040 limit come from, Mr. Kovacik? Why is 040 the limit for an operator to remove the jackscrew when it reaches that wear?

MR. KOVACIK: The original entry into service had specified a wear limit, a removal limit of .0265, which was essentially a derived number from a MIL Spec. It was a conservative, you know, number placed on it, until we could develop or gather some in-service data to validate that.

When the original jackscrew design showed a higher than desired wear rate, you know, the end play limit of 026 was expanded to 040, to allow those jack-screws to remain on the airplane a little bit longer, until, you know, the design situation could be addressed and corrected.

Now, 040, where did that come from? Basically, you know, that number has a number of design considerations attached to it, one of which being a structural issue, and the other being an aerodynamic issue.

040 was established, you know, at this time, that, you know, allowed the jackscrews to stay on a little bit longer, but it also provided assurance that we still had adequate margins for, you know, strength and for the aerodynamic concerns. So, it was just a target number, a conservative number that was felt, based on the in-service data that was available, that it could be expanded from the 026 to this 040 number.

MR. GUZZETTI: So, structurally speaking, 040 is -- would you agree that's an extremely conservative wear thickness to hold for structural strength requirements?

MR. KOVACIK: Oh, absolutely. The presentations and the testimony, you know, prior to this question, you know, indicates that, you know, we have at least a factor of 10, I believe, at that point in time in terms of maintaining the structural load path.

MR. GUZZETTI: And what would you say would be an end play limit where it starts to become hazardous in terms of structural strength?

MR. KOVACIK: Well, we've already discussed the double that limit of 080.

MR. GUZZETTI: Okay.

MR. KOVACIK: It's still being five times that. I don't think we want to venture a guess beyond that point.

MR. GUZZETTI: And would -- is the maintenance intervention, the end play check, is that required for an operator to periodically check to ensure it doesn't get to 080, is that correct?

MR. KOVACIK: Well, that's -- the intention of the end play check is to monitor the amount of wear, you know, being experienced by the Acme nut. The intention is to discover, you know, the wear, you know, at a point of 040, you know. We wouldn't necessarily want it to go to 080, although it, you know, by structural considerations and aerodynamic considerations, you'd still be, you know, properly -- you know, have proper margins of safety, but the end play is designed to drive removal of that unit when the unit gets to around that 040 number.

MR. GUZZETTI: Okay. Mr. Talay, as per your maintenance procedures and in your opinion, if an operator got an end play check of exactly 040, what advice would you give that operator? Should he pull the jackscrew?

MR. TALAY: Per the maintenance manual recommendations and tolerances, that unit can go back into service at 040.

MR. GUZZETTI: What if that operator told you the end play reading was .039?

MR. TALAY: Again, it can stay. Both of them can stay on the aircraft.

MR. GUZZETTI: Okay.

MR. TALAY: The removal rate is in excedance of 040.

MR. GUZZETTI: Okay.

MR. TALAY: That's the removal threshold.

MR. GUZZETTI: After the accident, did Boeing take any action, issue any alert service bulletins, for -- immediately after the accident, in regard to the end play check or lubrication?

MR. TALAY: Surely. Within a few days of the accident, we issued an All Base Message, which is an all base BOECOM to all twin jet operators, to -- for airlines that had airplanes in an inspection situation, whether it be heavy maintenance or whatever, to give a look at the jackscrews visually. We gave them a list of criteria to look at and report back to us. We needed to try to get a handle on what we had here.

Shortly thereafter, we issued a series of alert bulletins affecting the entire twin jet fleet, and that was followed up a day or two after with the AD.

MR. GUZZETTI: With the AD, the FAA Airworthiness Directive?

MR. TALAY: Yes.

MR. GUZZETTI: And that mandated the service --

MR. TALAY: The compliance bulletins.

MR. GUZZETTI: -- bulletins you discussed, is that correct?

MR. TALAY: Correct.

MR. GUZZETTI: On Page 52 of my factual Exhibit 9-A, it summarizes data from the FAA --

MR. TALAY: Hm-hmm.

MR. GUZZETTI: -- about all of the jackscrews that were pulled off of airplanes in the domestic United States --

MR. TALAY: Yes.

MR. GUZZETTI: -- to due to positive end play findings.

MR. TALAY: Yes.

MR. GUZZETTI: There were 22 of them.

MR. TALAY: Yes.

MR. GUZZETTI: And actually that figure also includes South Central America and Europe North Africa Operators that reported in.

Were you expecting numbers that large or that small or what was your -- how did you react to that?

MR. TALAY: With the wear of these jackscrews, a worn jackscrew is sent in for overhaul, we have a specific vendor that -- an agent that we have overhauling these jackscrews.

So, they all basically come back to the same point, whether through Boeing or directly. So, that vendor is surely able to forecast and has been able to forecast the number of units in a given year that he would expect to see for wear. That number's been slowly increasing as the fleet ages.

For the year 2000, we were expecting somewhere between 80 and a hundred units to be removed from the fleet of 2000+ airplanes for wear. So, when we were releasing these alert bulletins, we knew we had the potential of removing that kind of number of parts from the fleet.

So, after three months, having removed this many, we were very happy with it.

MR. GUZZETTI: Okay.

MR. TALAY: Now, additionally, if we wanted to just take a look at these units, not only did we remove very few units from the fleet, trying -- which had a good impact on minimizing the impact on the fleet, the end play readings on these 22 units were where we would expect them to be. The majority of them were below 45,000ths. With the exception of one, I believe, they were all under 50, which is -- if we allow an airplane to go back into service with 40, we're acknowledging the fact that at the next check, it's going to be over 40.

So, not only were the number of units acceptable to us, the end play data from those units on the bench checks done at the vendor were within a range where we expected them to be.

MR. GUZZETTI: Okay. The exceptions that you speak of, though, that were beyond -- well beyond 040, --

MR. TALAY: Well, there were -- I believe they were all under 50, with the exception of one that was just over 50, I thought.

MR. GUZZETTI: There were two, I believe, and they were both --

MR. TALAY: Okay.

MR. GUZZETTI: If you'd turn to Page 54 of my factual, they were both -- Aircraft 981 and 982.

MR. TALAY: Okay.

MR. GUZZETTI: We have the on-wing end play, and there's actually an error in the bench end play.

MR. TALAY: Okay.

MR. GUZZETTI: But it --

MR. TALAY: Okay.

MR. GUZZETTI: They were both beyond 050.

MR. TALAY: Right.

MR. HAMMERSCHMIDT: Mr. Guzzetti, if I might, I know we're going long here, but I did have a question on this very page that you cited, and I may be jumping ahead. I'm not quite sure where your question's going to go, but on that information that was on Page 52, what caught my attention is that for Alaska Airlines, which was one of the reporting airlines, which has a fleet size of 34, and the number of positive end play findings were six, and that works out to -- and, of course, I know this is not necessarily a scientific data analysis, but it works out to about 18 percent, but then you look at Europe, and the airplanes in Europe and North Africa, fleet size 430, and there were only three with positive end play findings, less than one percent.

I'd be interested in knowing your -- any observations or insights you might have as to those disparities.

MR. TALAY: I surely have no particular knowledge of -- an example would be how much of the data from South America and Europe were included --

MR. HAMMERSCHMIDT: Right.

MR. TALAY: -- in this. I know the information comes back, even though it was AD-driven, is sporadic once you get out of the States.

MR. HAMMERSCHMIDT: Well, I thought I would ask that since we were on that very page.

MR. TALAY: Right.

MR. HAMMERSCHMIDT: So, that's all I had, Jeff.

MR. GUZZETTI: Thank you. The -- Mr. Talay, if an operator came to you and said that they performed an end play check, and they got, say, 15,000ths, and then when they performed the next one, you know, several thousand hours, and it went up to 040 or 045, in other words, the wear rate was extremely high -- actually, let's just say it went from 015 to 040 within one end play check.

MR. TALAY: It went from what? Excuse me?

MR. GUZZETTI: 015 --

MR. TALAY: Okay.

MR. GUZZETTI: -- to 040 --

MR. TALAY: Hm-hmm.

MR. GUZZETTI: -- within, you know, the period of one end play check.

MR. TALAY: Right.

MR. GUZZETTI: What advice would you give that operator?

MR. TALAY: That would be considered an abnormally high wear rate, and that unit should be considered suspect and not let back in service.

MR. GUZZETTI: Okay. The -- what were the intervals that were set by the Boeing Alert Service Bulletin for end --

MR. CLARK: Just a second, Mr. -- do the operators know that? Because they may not come to you with those wear rates.

MR. TALAY: The question was if it was brought to my attention, what my recommendation would be. The maintenance manual only gives the mechanic the end play check to accomplish. There is no --

MR. CLARK: So, --

MR. TALAY: There is no system in place to do that.

MR. CLARK: -- if they didn't pick up on it, then --

MR. TALAY: Right.

MR. CLARK: -- they aren't going to come to you and you wouldn't be able to advise them. So, that's --

MR. TALAY: Right.

MR. CLARK: -- basically not covered in the maintenance manual.

MR. TALAY: Not in the maintenance manual. Now, we have -- since the accident, we are, of course, as a result of the AD, accumulating a massive amount of data. The airlines have to do these end play checks per the alert bulletins and the ADs and report the data back to us. We are, of course, accumulating and tracking that data.

We have a few months back provided each airline an Excel spreadsheet to maintain the -- to help us to report the data in a more uniform manner, but also give them a mechanism to now maintain the data themselves.

We provided them at various meetings and through some correspondence a list of the benefits that they could attain in maintaining this data. It would be from everywhere from parts forecasting to better be prepared to remove a screw but also to identify a problem unit.

MR. GUZZETTI: Mr. Talay, do you have any experience with jackscrews that would come back because they were bent or out of concentricity? Have you ever seen that to be --

MR. TALAY: We have a straightness requirement on the screw. Normally, the screw is removed for wear, and then that screw is then broken down, and normally a new nut is bated on to it, but the screw itself has to pass a series of criteria in order to be able to be reprocessed and reused.

Straightness would be one issue that would reject a screw.

MR. GUZZETTI: How frequently does that occur? An out of round or --

MR. TALAY: I don't know.

MR. GUZZETTI: Okay. The -- some of these end play checks -- and if I could refer you to my factual report again. We summarized some of the end play checks taken as a result of the AD data that was coming in.

MR. TALAY: And what page are we on?

MR. GUZZETTI: Turn to Page 55, please. In the middle of the page, there's an Acme Screw Serial Number DCA110.

MR. TALAY: Hm-hmm.

MR. GUZZETTI: According to what we know so far, and we're continuing to investigate this, it had about 2,500 hours since its last overhaul where it left the manufacturer with 010 end play.

The operator, according to the records that we have, got an 043 end play check on the wing, --

MR. TALAY: Yes.

MR. GUZZETTI: -- and when it was sent to the manufacturer, the manufacturer got an 048 inch. Let me ask you. What would you consider a more accurate reading? One that's performed on the wing by the operator or one that's performed by the manufacturer after the manufacturer steam cleans the screw and the nut and performs a bench test end play on it?

MR. TALAY: The end play check, like any inspection, if you can do it in a controlled environment, a lab or a work bench, you do a get more accurate reading.

This test being done on the aircraft, we are by using this restraining fix from pulling down on the leading edge wear, we're offsetting an entire horizontal surface to measure a few thousandths wear on a few thousandths movement.

So, in answer to your question, the bench check would be the more valid number.

MR. GUZZETTI: And have you looked generally at some of the bench test end play checks figures and compared them with the on-wing operator end play checks?

MR. TALAY: It's -- that data has only recently been available to us. The airlines normally return a unit in for overhaul with just a mention that it exceeded the limit. They wouldn't necessarily include a value that it did exceed. So, we would have the bench check value, but we wouldn't know particularly what they removed it by.

Given the focus this year on this, we know what the units are being removed at. We've also asked the fleet to just write on the inbound paperwork to jot down the number that the end play check -- the actual value. We have a mechanism in place between ourselves and the vendor to capture that data, to again just arrive at some -- just a validation of the accuracy of the end play check.

Of the units that we've been able to capture in recent months, the values are within a range that would be considered acceptable for this test.

MR. GUZZETTI: What are -- what is that range that you consider acceptable? Range of error or difference between bench check versus the airlines' end play check?

MR. TALAY: A lot of the -- and when we talk about the accuracy of this test, it's a test that's intended to identify units worn to a certain point. I don't want to make it sound like a thousandth either way is not an issue, but in this case, we're working with such a conservative number, that we can absorb that.

We'll see what the data -- this database will get larger, of course, as time goes on, but right now, we're in the 10 percent accuracy range on the units that I've seen, and if we maintain that area or even 10 to 15 percent, I would be -- Boeing would be satisfied with the check.

MR. GUZZETTI: 10 to 15 percent?

MR. TALAY: Right. So, a unit measuring removed at 40, if it were to be measuring 10 percent, 15 percent higher on the bench, that's -- that to me is an adequate test.

MR. GUZZETTI: This -- going back to this particular Acme screw, if this -- as we -- you'll notice that it went from 043, and the actual more accurate thread, the measurement was 048. So, the -- it went more in the -- it -- the operator's --

MR. TALAY: Right.

MR. GUZZETTI: -- end play check kind of masked the level of wear --

MR. TALAY: We would expect a higher number normally on the bench just because you have again a controlled environment, and the unit is -- has been steam cleaned.

MR. GUZZETTI: Okay. But it would surprise you if it went beyond 10 to 15 percent?

MR. TALAY: We would expect and hope that it would be within that range, and data we've obtained so far shows it is.

MR. GUZZETTI: Okay. Let's talk a little bit about the -- some of the -- what could go wrong in an end play check. The -- first of all, I noticed that Boeing issued modifications to the maintenance procedure for the end play check after the accident.

MR. TALAY: Yes.

MR. GUZZETTI: They're contained in Exhibits 9-M and 9-Y, 9-Y being the most recent temporary revision that your office had issued.

Could you please summarize what those modifications were to the end play check procedure that you made after the accident, and why you made those procedure changes?

MR. TALAY: I don't seem to have one of the exhibits, but we can talk to it. If we need to go further, let us know.

The maintenance manual's procedure, whether it be end play check or any other, is constantly being revised. We look to improve it and enhance it and clarify any issue that might require it.

Surely with all the focus on issues here, there's been a lot of input from the operators on this end play check. I would say the majority of the changes made are not functional changes or procedural changes to the check itself.

An example would be we install a restraining fixture on the airplane very early in the procedure. We now -- based on problems encountered in doing the check, if I had to say which issue involved the most variance on the checks early on, it was the condition of the tooling being used.

So, now we just put in a note now to totally disassemble the restraining fixture, inspect it and put it back together with a light layer of lubricant. That to me is not a procedural change. It's just a step to improve the process.

MR. GUZZETTI: I understand that, but why -- why even emphasize that? What's wrong with using a rusty non-lubricated restraining fixture?

MR. TALAY: In applying -- in performing the check and in inducing torque into this restraining fixture, we're offsetting the weight of the horizontal to bring it into a neutral position, and plus adding additional torque to put in a load in a compression direction.

In doing that, we are putting in a specific load into the restraining fixture. We need to know we're getting a certain output back, an output out. If -- on any threaded surface, the condition of the thread has a bearing on the output of the tool.

MR. GUZZETTI: And --

MR. TALAY: We -- when we reference a tool in a procedure, we expect the tool to be -- basically to print and maintain correctly.

MR. GUZZETTI: Is it possible that the end play check reading could be erroneous if that tool was not the proper tool or not fabricated to print or not maintained with a lubricant?

MR. TALAY: It's no different than any procedure utilizing the tool. The tool has to be in a workable order.

MR. GUZZETTI: I understand. There was another issue in the temporary revision regarding jackscrew rotation.

MR. TALAY: Yes.

MR. GUZZETTI: Could you please briefly

describe what that is all about, and why you put that in there?

MR. TALAY: Yes. We had a -- in the procedure, we set the dial indicator to -- we preload the dial indicator against whichever surface we're measuring. We induce a load into the restraining fixture, and we cycle it back and forth each time again to try to ensure a thread-to-thread contact.

But on each cycling of this load, the dial indicator is required to come back to that original preset setting. If it doesn't, there's a problem. We had reports in the past of -- on a few occasions, the screw would be noted rotating slightly as this torque was applied in the downward direction, as the restraining fixture was shortened.

It had been relatively constant that the screw would turn, and it would give you a reading off of about 3,000ths, up to 3,000ths, but it was always in a conservative direction. It would give you a false high reading.

Earlier this year, we had an operator report that in doing the test, they had a screw again turn slightly in the same range, but in the opposite direction.

MR. GUZZETTI: But there was never more than 3,000ths?

MR. TALAY: Not to our -- not to my particular knowledge. I don't know if we've had any reports of it higher. It was -- it has not been a very common occurrence.

So, to basically address the issue, we now require as just a part of the procedural step a -- the screw to be restrained or held during the test. One of the lead airlines had actually put in that procedure into their manuals prior.

MR. GUZZETTI: Okay.

MR. TALAY: So, that's the issue with the rotation of the screw.

MR. GUZZETTI: I'm just about done with my questioning, and let me just ask you, Mr. Talay. Is it possible to get erroneous readings from an end play check with the improper set-up of the dial indicators? In other words, not putting them -- the plunger straight up and down but at an angle or perhaps using the wrong dial indicators? Is that possible, to get an erroneous end --

MR. TALAY: Again, the test is based on using equipment in a certain manner. If you alter the equipment or alter the procedure, I guess the results can't be guaranteed.

MR. GUZZETTI: Okay. So, it's possible that human error or errors in performing the end play check could give erroneous and false readings?

MR. TALAY: Again, we consider the procedure, when followed, and the tooling, when correct, will provide an adequate test.

MR. GUZZETTI: And this is --

MR. TALAY: You vary from that, then you vary from the test.

MR. GUZZETTI: Okay. And this end play check is key, essential to the design and to ensure that the -- you don't get excessively worn Acme nut threads, is that correct?

MR. TALAY: We -- the end play check is integral to removing these units at a certain point.

MR. GUZZETTI: Okay.

MR. CLARK: Mr. Guzzetti, just a second. When you do the measurements or you don't do it properly, are you more likely to get a high reading, an over-reading, or an under-reading? You described if the jackscrew moves, that typically or could give you an over-reading. It would read -- it would show too much --

MR. TALAY: Right. Which is in a conservative direction.

MR. CLARK: It's conservative, but what about other misrigging or misuse of the equipment? Typically, are they going to give you more over-readings or under-readings?

MR. TALAY: I guess you really don't have -- I don't have any data to show one way or the other.

MR. CLARK: Are there other ways to misrig it and get over-readings?

MR. TALAY: I guess it would be just a placement of tooling and stuff. I don't know how you could -- I don't know what aspects of, let's say, error in the procedure would be accounted for or considered.

DR. ELLINGSTAD: If I could follow up, has Boeing done any kind of an assessment of the reliability? Have you had operators perform these tests and then measure variation, other than just in an operational kind of a setting?

MR. TALAY: To validate the end play check?

DR. ELLINGSTAD: To validate the end play check.

MR. TALAY: The action that we're taking now again is to capture the data of the actual end play value on units that are removed for wear and compare that value to the values that are obtained at the vendor during overhaul and comparing those two numbers and coming up with --

DR. ELLINGSTAD: But you do this just in terms of a regular operational procedure --

MR. TALAY: Yes.

DR. ELLINGSTAD: -- in the field? You're not -- you haven't done any calibration of your procedure or any determination of what the reliability of this procedure is?

MR. TALAY: Well, we've gone out and looked at airplanes, done a measurement --

DR. ELLINGSTAD: They've repeated these measurements with looking at any -- between operator reliabilities in terms of making the measurements?

MR. TALAY: Comparing the efficiency of one operator doing the test versus another?

DR. ELLINGSTAD: Comparing the readings that you get, making the empirical determination of the reliability of your instrumentation.

MR. TALAY: No, we haven't.

DR. ELLINGSTAD: Is the equipment that you're using certified in any way?

MR. TALAY: No, it's not. It's not calibrated. The dial indicator is not calibrated. The -- excuse me. The dial indicator is. The restraining fixture is not.

DR. ELLINGSTAD: So that the apparatus as it's applied to the measurement is not calibrated or certified in any way?

MR. TALAY: The restraining fixture is not, no.

DR. ELLINGSTAD: Thank you.

MR. TALAY: You're welcome. Thank you.

MR. GUZZETTI: Mr. Talay, just going back quickly to the straightness -- well, let me get back to that in a moment.

In talking about the intervals that were set before the accident for the end play check and for the lubrication, did you set those intervals or were you involved in the setting of those intervals?

MR. TALAY: No. It's not a Service Engineering function. The AOLs merely referenced an existing maintenance planning document.

MR. GUZZETTI: Okay. And, Mr. Kovacik, let me ask you. As a Design Engineering person, are you involved in the setting of the intervals for this very important end play check interval and the lubrication?

MR. KOVACIK: No. No, Design Engineering is not involved in that.

MR. GUZZETTI: Who is at the Boeing Company?

MR. KOVACIK: That is in the area of our Maintenance Engineering organization.

MR. GUZZETTI: Okay. And you mentioned in your AOL, Mr. Talay, that back in both '84 and '91, you reiterated the lubrication interval of 650 hours.

MR. TALAY: Yes.

MR. GUZZETTI: Had that interval been escalated from 1991 to '95 or '98 or to the present day?

MR. KOVACIK: Perhaps I can address that question. When you say "escalated", do you mean from the Boeing standpoint or from an operator --

MR. GUZZETTI: Yes.

MR. KOVACIK: -- standpoint?

MR. GUZZETTI: From the Boeing standpoint.

MR. KOVACIK: The original intervals for lubrication and end play, in that time frame for lubrication, we would have, per the OAMP, the Boeing document, would have been a 600 to 900 hour interval for lubrication, and essentially a 2-C interval for end play check, the equivalent to 7,200 hours.

Subsequent to that, there was a convening of a maintenance steering group, an MSG. As a result of that MSG-3 meeting, those intervals -- a new set of intervals were established. The interval for lubrication out of MSG-3 was a 1-C or 3,600 hour lubrication interval, and --

MR. GUZZETTI: So, it went from 600 to 3,600?

MR. KOVACIK: Correct. And the end play interval remained at a 2-C interval.

MR. GUZZETTI: Okay. Were you involved in always being -- were you aware of the moment that they escalated the lubrication interval from 600 to 3,600?

MR. KOVACIK: No. I was not personally aware nor do I believe any of the design engineers were aware of that.

MR. GUZZETTI: Okay. I know we have some future witnesses to talk about the escalation from the FAA side of the house.

Just a couple more questions. Mr. Talay, did Alaska Airlines take any action that you're aware of immediately after the accident in an engineering order or a fleet campaign in regard to inspecting horizontal stabilizers for the MD-80?

MR. TALAY: I don't believe we had any coordination with them on anything other than what we had published. I'm sure that they've done some things in house, but I don't know what they were.

MR. GUZZETTI: Okay. Give me just 10 seconds. I'm going to pull up an exhibit here.

MR. TALAY: Please.

(Pause)

MR. GUZZETTI: Okay. Do you happen to have Exhibit 9-X in front of you?

MR. TALAY: Yes, I do.

MR. GUZZETTI: If you could turn to Page 4 of Exhibit 9-X, this is from an Alaska Airlines Engineering Order or more commonly known as a Fleet Campaign.

MR. TALAY: Okay.

MR. GUZZETTI: There's a note in the middle of the page that discusses -- it says, "The jackscrew may squeal during operation." Is that lifted out of a Douglas maintenance manual or is that verbiage that you're familiar with?

MR. TALAY: No, it's not. We don't have this note in our manual.

MR. GUZZETTI: What -- would you -- if an operator contacted you and indicated that their jackscrew was squealing, what advice would you give them?

MR. TALAY: That it would not be an acceptable condition.

MR. GUZZETTI: Okay. Why is that? Why would you give them that advice?

MR. TALAY: If the squealing was coming from the interface of the screw to the nut, it would be indicative of an unacceptable condition.

MR. GUZZETTI: Okay.

MR. TALAY: The squealing might be coming from motors. I don't know what this is in reference to. You know, I don't know what this infers.

MR. GUZZETTI: All right. It addresses the jackscrew.

Mr. Kovacik, are you aware of any premature Acme nut wear for horizontal stabilizers of the MD-11; specifically, that which is documented in Exhibit 9-U?

MR. KOVACIK: Yes, sir.

MR. GUZZETTI: And can you just briefly summarize what that was all about? Why Boeing issued this Alert Service Bulletin for the MD-11 back in 1999?

MR. KOVACIK: Basically, there was an issue with the MD-11 jackscrew itself. There was a lot of -- I don't mean a lot. I mean a certain segment of the jackscrews manufactured with a higher than specified surface finish.

When that discrepancy was discovered, a service bulletin was issued to go out and inspect the fleet essentially for this condition and to, you know, provide corrective action if that condition was found.

This particular alert service bulletin was in response to an operator that had discovered that one of their jackscrews had Acme nuts had worn completely through.

This particular airplane was -- I would say it was addressed by the original service bulletin when the discrepancy was found. For some reason, we don't know exactly if the service bulletin -- original service bulletin was not accomplished or was accomplished incorrectly. This particular airplane, you know, subsequent to that service bulletin, had experienced this wear-out condition, and that wear-out condition prompted the service bulletin to be upgraded to an alert service bulletin.

MR. GUZZETTI: Okay. And what was the --

what did Boeing determine as the cause of the premature wear of those Acme nuts?

MR. KOVACIK: It was due primarily to a higher than required or a rougher than specified surface finish on the MD-11 jackscrew itself, the Acme screw.

MR. GUZZETTI: Okay. The -- and that airplane has two jackscrews, is that correct?

MR. KOVACIK: That is correct.

MR. GUZZETTI: The -- if -- would you agree that a lack of lubrication could cause premature Acme nut wear?

MR. KOVACIK: Yes, I would agree. I think there's, you know, service history that supports that, yes.

MR. GUZZETTI: Would you agree that a rough surface finish or a manufacturing defect in the jackscrew itself could cause premature Acme wear?

MR. KOVACIK: I think we have evidence here that suggests a rough surface finish can cause excessive wear and excessive wear rates.

MR. GUZZETTI: Do you think that -- is it possible that there could be other modes, whether it be a bent screw or something, that there could be other possibilities that could lead to excessive Acme nut wear?

MR. KOVACIK: Yeah. It's speculative, but, you know, there may be other scenarios. I'm not aware of any, but that's possible.

MR. GUZZETTI: Okay. Just a last question or two. Does Boeing intend on altering the design -- are there any current plans in the works right now at Boeing to alter the design of the jackscrew assembly for the MD-80 aircraft?

MR. KOVACIK: Yeah. The jackscrew system is being reviewed, you know. As more information is gathered from the investigation, we'll take, you know, closer looks at certain areas of the design. Whether or not a design change is imminent or required or indicated, it's very early to suggest that.

MR. GUZZETTI: Would -- is -- would that answer also hold true for whether or not you intend on putting an additional jackscrew in the MD-80, to have two jackscrews?

MR. KOVACIK: Specific design changes, it would be speculation on my part, you know, what sort of change, if any change at all, would be, you know, considered.

MR. GUZZETTI: Okay. Mr. Talay, are you planning on modifying the lubrication procedure or the end play check procedure as a result of this accident above and beyond what you've already done?

MR. TALAY: Well, currently, we're under the alert bulletin and airworthiness directive mandate. That has a lubrication interval of 650 hours and an end play check of 2,000. That interval will remain in effect as long as the AD does. So, we're working to that interval right now.

MR. GUZZETTI: Okay. Mr. Chairman, that's --

MR. CLARK: Let me ask one question. Is there any movement under foot to extend those times now? Are you aware of any?

MR. TALAY: To extend the times in the --

MR. CLARK: To increase the time intervals.

MR. TALAY: No. The AD and the alert bulletins will stay that way until this investigation is complete, and we make some determinations after it.

MR. CLARK: Okay.

MR. HAMMERSCHMIDT: Other questions from the Technical Panel? Mr. Rodriguez?

MR. RODRIGUEZ: Yes, sir. Thank you. Mr. Talay, the question was asked of you about the straightness of jackscrews or the screw itself.

MR. TALAY: Yes.

MR. RODRIGUEZ: Am I to understand from your testimony that Boeing is not aware of any problems in service with respect to straightness of screws?

MR. TALAY: We have had screws come back in for overhaul that have been rejected due to straightness. Yes, there's a four -- I believe the overhaul manual has a 4,000th straightness requirement, and if it's beyond that, it's not usable.

MR. RODRIGUEZ: And you answered a question that you did not know what percentage that might be. Is that an accurate -- you don't know? You have no idea?

MR. TALAY: How many screws are scrapped due to straightness?

MR. RODRIGUEZ: Yes, sir.

MR. TALAY: I don't know.

MR. RODRIGUEZ: Okay. With respect to variances of the end play check on the wing and in the lab, --

MR. TALAY: Yes.

MR. RODRIGUEZ: -- could you comment on the -- what I'm interested in is the ratios, if you have any feel for the ratios between the number of occasions where that happens and there is agreement in the measurement.

MR. TALAY: Again, that kind of data, unfortunately, has not been available in any quantity up until this year. We do have some units that do measure either right on or within a thousandth. Some of them will be a few thousandth higher on the bench. I don't have any feel at all for ratio.

MR. RODRIGUEZ: All right, sir. I don't have the figures in hand, but it occurs to me that during the course of the investigation, we routinely experienced significant changes between on-wing and laboratory readings of end play checks on the various jackscrews we were collecting.

MR. TALAY: Hm-hmm.

MR. RODRIGUEZ: My recollection is that it was in excess of 10 percent, the figure that you gave. Either you or Mr. Kovacik, do you have recall of the specifics in that regard?

MR. TALAY: I don't. Were those units involved included in these --

MR. RODRIGUEZ: Yes. They were gathered. Generally, we became aware of them as a function of the accident investigation, and they were coming from all manner of operators. We've talked to about eight of them that we collected here.

MR. TALAY: Right.

MR. RODRIGUEZ: My recollection is that none of them matched the readings that were on wing. Sometimes it was lower, sometimes it was higher, but it was a significant difference.

MR. TALAY: I guess from the units that I've seen, Mr. Rodriguez, we are -- from a fleetwide issue, with the units coming back through the overhaul outfit with the data that I've been provided, the numbers are closer than that, and again we are involved in a documented effort to establish that value.

MR. KOVACIK: Can I amplify on that?

MR. RODRIGUEZ: Yes, please.

MR. KOVACIK: Yeah. Those particular instances that are referenced in the exhibits, you know, quite frankly, the Systems Group has not yet begun the evaluation of that data to determine what that means, you know. What is this data? Where did it come from? How is it derived? What is it telling us?

So, you know, an excellent question, but at this point, --

MR. RODRIGUEZ: Thank you.

MR. KOVACIK: -- you know, we're still looking at it.

MR. RODRIGUEZ: My last question is, Mr. Talay, prior to the accident, what knowledge did you have at Boeing with respect to operator's reporting removal rates or anything of that nature with regard to the jackscrew?

We've documented and discussed several instances of AOL letters or whatever discussing specific problems of excessive wear.

Other than those excessive wear issues, what kind of feel does Boeing have for the rate at which people were using up jackscrews prior to the accident?

MR. TALAY: Other than the fact that all units removed for wear would be funneling back to a single vendor, and we're able to sort of capture a -- if we looked at that as a removal rate, we're able to see how many units are removed from the fleet in a given year.

Other than that, again up until this year, we had not been uniquely looking at that data.

MR. RODRIGUEZ: In that case, it can't be my last question. Did you do such a thing? Did you monitor that kind of activity at Trig prior to the accident?

MR. TALAY: No.

MR. RODRIGUEZ: Since the accident, have you done a review of the numbers of jackscrews that are processed through Trig?

MR. TALAY: Since the accident, through the AD data that's coming back to us, we are monitoring the results of every check on the fleet. That would include flagging those items that are removed for wear. It's a criteria of the reporting. So, we are capturing that data now.

MR. RODRIGUEZ: But you're not in the position to comment on it at this time?

MR. TALAY: The data is massive, and I haven't -- we haven't even begun to look at it at depth yet.

MR. KOVACIK: May we take a moment? May we take a brief moment here?

MR. RODRIGUEZ: Yeah. Go ahead.

(Pause)

MR. TALAY: We have an MTBUR function within Boeing where we track components that the airlines would feed us in data. I think the data that's going to result from the AD will be infinitely more accurate than that.

MR. RODRIGUEZ: Yes, sir. Thank you. That's all the questions I have, sir.

MR. HAMMERSCHMIDT: Thank you, Mr. Rodriguez. Are there other questions from the Technical Panel at this point?

(No response)

MR. HAMMERSCHMIDT: Seeing that there are none, I would observe that we are two hours and 18 minutes since our last break. I was hoping we could finish this panel this evening. I'm not sure how many questions the Parties to the Investigation are going to have, but as I indicated earlier in the day, I was hoping that when we get towards the 7 to 8 time frame, that we can stay flexible and accomplish what we need to in clean breaks in terms of witnesses returning the next day.

Therefore, what I would like to do is take a -- I'm sure the panel may need a break, at least we'll go on that assumption. The witness panel as well as the Technical Panel.

Let's take a five-minute break, keep it tight, and we will reconvene in almost precisely five minutes.

(Whereupon, a recess was taken.)

MR. HAMMERSCHMIDT: If we could, let's please return to our places.

(Pause)

MR. HAMMERSCHMIDT: I see the witness panel has reassembled, and we are now ready to go to the Parties to the Investigation for questions.

Beginning with Alaska Airlines, do you have any questions?

CAPTAIN FINAN: Thank you, Mr. Chairman. The question I have is for Mr. Kovacik, and, Mr. Kovacik, you first observed or you mentioned that you first observed the jackscrew and the lubrication condition of it as a member of the Systems Working Group on the dock after the recovery of the jackscrew?

MR. KOVACIK: Yes, that's correct.

CAPTAIN FINAN: I think you also mentioned that you were unfamiliar with Exhibit 7, Uniform, which is Investigator Michael Stockhill's observations which he made on the boat as to the lubricant or emulsified material at various points on the jackscrew, and you're not familiar with that?

MR. KOVACIK: No. I don't have it up here, and I don't recall reviewing that document prior to this.

CAPTAIN FINAN: Have you seen the letters that were submitted by Andy Leiper, Mr. Andy Leiper, who was a member of the Systems Working Group, and Mr. Gerardo Hueto, who's a member of the Structures Working Group, in which they observed an oily substance, dirt, grease and oil, on the jackscrew throughout its entire length.

MR. KOVACIK: No, I have not seen those letters.

CAPTAIN FINAN: Mr. Chairman?

MR. HAMMERSCHMIDT: Yes?

CAPTAIN FINAN: The referenced letters were submitted, and we were under the understanding that they were rejected because they were observations made on the dock as opposed to on the boat, and I was -- I'd like to respectfully request that we have those letters admitted as part of the record.

MR. HAMMERSCHMIDT: Mr. Rodriguez, can you shed some light on that issue?

MR. RODRIGUEZ: Yes, sir. At the --

MR. BERMAN: Captain Finan, what's the exhibit number again?

CAPTAIN FINAN: They are not exhibits yet.

MR. RODRIGUEZ: It's Exhibit 7-U he's talking about, and it does not contain the two letters.

(Long Pause)

MR. HAMMERSCHMIDT: Captain Finan, we're going to take under advisement your request. We're not going to admit that information this evening, but we will let you know tomorrow what the disposition is.

CAPTAIN FINAN: Thank you, Mr. Chairman. The reason for the request is that Mr. Hueto makes a fairly detailed observation of the treatment of the jackscrew on the dock after recovery, the washing of it, and was specifically looking for grease on the jackscrew, and we feel it relevant that his observations be included as well as Mr. Leiper's.

MR. HAMMERSCHMIDT: Okay. And again, remind me, what is the date on his observation?

CAPTAIN FINAN: The letter -- Mr. Hueto's letter was December 8th. He observed the jackscrew when it was recovered on the dock at Port Hueneme.

MR. HAMMERSCHMIDT: I understand, but the date of the letter or his statement that would be entered for the record is December 8th?

CAPTAIN FINAN: Yes, sir. Mr. Hueto's was

December 8th, and Mr. Leiper's was December 7th.

MR. HAMMERSCHMIDT: Exactly.

CAPTAIN FINAN: Mr. Chairman? Mr. Chairman, those letters were in response to a request from the Board.

MR. HAMMERSCHMIDT: Yes. We're considering your request, and we will have a decision for you in the morning.

CAPTAIN FINAN: Thank you, sir. And I just had one further question for Mr. Kovacik, and I may have missed this in your testimony.

You mentioned the DC-8 as being a jackscrew Acme nut assembly without a lubrication fitting in the nut or a zerc fitting. Can you describe for me how the Acme nut on the DC-8 is lubricated?

MR. KOVACIK: The lubrication of the -- is this on? Okay. Great. The lubrication of the DC-8 jackscrew assembly is through the direct application of grease to the screw itself, either by brush or by hand application. So, that is how the entire, you know, interface between Acme nut and jackscrew is lubricated.

CAPTAIN FINAN: And the assumption is that that allows for adequate lubrication of the DC-8 Acme nut?

MR. KOVACIK: Well, the in-service experience suggests that that is adequate.

CAPTAIN FINAN: Thank you, Mr. Kovacik. Mr. Chairman, I have no further questions.

MR. HAMMERSCHMIDT: Very good. Thank you, Captain Finan.

Does the Air Line Pilots Association have any questions?

CAPTAIN WOLF: Yes, sir, Mr. Chairman. Thank you. We have several.

First, I'd like to refer to Exhibit 9-X and direct it to Mr. Kovacik, and just for further clarification, on Page 4, where the note is, "the jack-screw may squeal during operation", you said that Boeing would not necessarily agree with this, that that should take place during that time period.

On Page 6 of the same exhibit, --

MR. CLARK: Just a second. Let him get the exhibits.

MR. TALAY: And my name's Jim Talay. I'll handle that question.

CAPTAIN WOLF: Okay.

MR. TALAY: That number was 9-X?

CAPTAIN WOLF: Exhibit 9-X.

MR. TALAY: I have it. What page would you like to go to?

CAPTAIN WOLF: Okay. I was referencing Page 4 of the note there about the jackscrew.

MR. TALAY: Yes.

CAPTAIN WOLF: Okay. So, I just wanted to refer over to Page 6, under Number 11 and Number 12 there, where it said concerning the upper mechanical stop and the lower mechanical stop.

MR. TALAY: Hm-hmm.

CAPTAIN WOLF: And it said -- there's a quote there saying that "some deformation evidence of contact is acceptable", and I was just wondering what your feelings were on that from Boeing's perspective. Would that be normal?

MR. TALAY: It would be -- and again, depending on the severity of the damage, any -- a single contact, let's say, between the two stops would score or mark the stop, we wouldn't consider that necessarily a driver to replace the unit.

If a part of the stop was actually broken off, then we would consider that criteria for removal. This is an item that -- it's not intended to make contact, but we do check for the general condition of that stop.

Does that answer your question?

CAPTAIN WOLF: Yes, it does. Thank you.

MR. TALAY: Thank you.

CAPTAIN WOLF: This is for Mr. Khaled, and the question is, you mentioned earlier that the case depth of the accident gimbal nut was not per the spec at the time of manufacture.

What effect, if any, would an out-of-compliance case depth have on either the wear characteristics or operation of the gimbal nut?

DR. KHALED: I don't believe it would be any much difference.

CAPTAIN WOLF: Okay. Thank you. This is just a short question on design and certification criteria for Mr. Kovacik. To what criteria was the MD-83 certified, and CAR 4b or FAR Part 25?

MR. KOVACIK: You know, I don't know that off the top of my head. So, I don't want to misspeak. I can get that information for you.

CAPTAIN WOLF: Okay. And kind of on a similar follow-up on that, is there much of a difference, if any, between the CAR 4b certification and the current Part 25 requirements for certification of the trim systems?

MR. KOVACIK: Oh, boy. That's a very broad statement, you know. It encompasses, you know, quite a number of FAR paragraphs. Without having the present day FAR in front of me and compare it to the CAR, we might have some difficulty in answering that properly and accurately.

Again, I don't think I can answer that at this point.

CAPTAIN WOLF: Okay. There's several questions that kind of combine that with the CAR 4b and the Part 25 and has to do with the fail-safe design concept, and what we're curious is whether any such single failures should not prevent continued safe flight, and based upon that, is it based upon the fail-safe design concept?

In other words, does the current design comply with Part 25 criteria?

MR. KOVACIK: Perhaps Mr. Umeda can address that.

MR. UMEDA: You're referring to the fail-safe requirement, CAR 4b.270?

CAPTAIN WOLF: I think it's 270.

MR. UMEDA: 270? Yes, it does comply.

CAPTAIN WOLF: Okay. Thank you.

MR. CLARK: Excuse me. Does it comply with today's requirements, Part 25 requirements?

MR. UMEDA: Well, the requirements -- the difference of requirements between CAR 4b and FAR 25, up to Amendment 96, do have differences, and they have differences for many paragraphs.

Are you addressing one specifically?

CAPTAIN WOLF: Specifically for the trim system.

MR. UMEDA: I could address the durability and damage tolerance requirements, if you wish.

CAPTAIN WOLF: Okay.

MR. UMEDA: Yes, it does comply with the latest requirements.

MR. CLARK: Let me -- if you don't mind, if you were going to put this system on a new design airplane today to today's standards, could you certify this system the way it is now?

MR. UMEDA: Specifically, it does comply to the durability and damage tolerance requirements of FAR 25.571.

MR. CLARK: Okay. What other requirements are out there that you would have to meet?

MR. UMEDA: It's a very large document. I don't think I could answer that.

MR. CLARK: So, you don't know whether -- today, whether you would have to make major changes or whether it would even be acceptable by today's standards?

MR. UMEDA: We do not have the data in front of us to make the comparisons to determine design --

MR. CLARK: And also, what I heard earlier, you don't even have the data that you originally used to certify the design back in -- when? In the 1960s?

MR. KOVACIK: That's only for specific sections of the CARs that we didn't find data for. Whether or not we were required to submit data for that is under question as well.

MR. CLARK: But by today's standards, you would have to submit data?

MR. KOVACIK: Yes, we would.

MR. CLARK: And you'd have to generate that data to find out if your system did comply?

MR. KOVACIK: Right. And based on my understanding of the applicable FAR equivalent, you know, present-day FAR, I believe we would be able to certify the current design of the system.

MR. CLARK: But you wouldn't know if they went through the process?

MR. KOVACIK: I think that would be a correct statement. That would be a process. It's not just my determination. It is a process of manufacture and regulatory agency.

MR. CLARK: Okay. Thank you. I'm sorry to interrupt.

MR. UMEDA: May I expand on that, please?

MR. CLARK: What's that?

MR. UMEDA: May I expand on that?

MR. CLARK: Please.

MR. UMEDA: You're specifically talking about the fatigue and fail-safe requirements. We do not find records of data submittal to the FAA to comply with CAR 4b.270. However, we do have internal documents analysis that shows compliance with CAR 4b.270.

MR. CLARK: Okay.

MR. HAMMERSCHMIDT: Captain Wolf, please proceed.

CAPTAIN WOLF: Okay. Thank you, sir. This would either be again for Mr. Kovacik or Mr. Umeda, and it pertains into Exhibit 9-A, Page 9, which is the Systems Group Factual Report, and again the question has to do with CAR 4b, Section 4b.325, entitled "Control System Stops".

It states that "The control system stops will be located such that wear, slackness or take-up adjustments will not adversely affect the control characteristics of the airplane."

In this particular regulation, where it's accounted for as the possible cause of adverse control characteristics, why would it not be accounted for as a failure mode in certification, and wouldn't a total wear be considered a failure of that particular system?

MR. KOVACIK: I think what this section is referring to, you know, in terms of normal wear of the system, the system stops that are in place, the amount of change and the range of surface travel is not affected.

When we look at the electrical shut-off system, which is the primary stop in the system, you know, that accounts for -- you know, if there's any wear at the interface, the range is not going to change appreciably.

At 040 end play reading, the resultant stabilizer angle is on the order of .05 degrees. So, even at the wear "limit" of .040 end play, you know, the range of travel of the horizontal is still well within, you know, controllability, you know, parameters.

So, I believe that's what this section is referring to.

CAPTAIN WOLF: Okay. Thank you. Just as far as getting a couple things corrected in our mind here, again for yourself. The torque tube is constructed of titanium, correct?

MR. KOVACIK: That is correct.

CAPTAIN WOLF: Okay. And did we determine at all what its design load was, what its design limit is in pure tension?

MR. KOVACIK: I think Ken has addressed that.

MR. UMEDA: Yes. The maximum design load for the torque tube is for the ultimate design case, and that produces a limit load of approximately 30,000 pounds, ultimate load of 57,000 pounds with a factor of safety of one and a half, and we have documents that we do show compliance to meet these loading conditions.

CAPTAIN WOLF: Okay. Is the lower support of the gear box made of magnesium?

MR. KOVACIK: The lower support of --

CAPTAIN WOLF: The gear box lower support.

MR. KOVACIK: The gear box itself is a magnesium housing, both body and upper mounting plate.

CAPTAIN WOLF: Okay.

MR. KOVACIK: The support assembly beneath it is not magnesium.

CAPTAIN WOLF: All right. How would the Acme screw itself be held into the gear box assembly in the event of a torque tube failure?

MR. KOVACIK: The Acme screw would be held into the support assembly structure in the event of, you said, a torque tube failure. The design of the Acme screw at the top of the screw is what i would term like a bell-mouth design, and it is -- a bell mouth is held within the lower plate of the support assembly.

So, if there's a failure of the torque tube, the resultant load from the stabilizer will be reacted through the support assembly to the Acme screw and into the Acme nut.

CAPTAIN WOLF: Is the gear box support designed to or intended to withstand the flight loads being experienced by the assembly?

MR. KOVACIK: Absolutely. That's the normal load path in the jackscrew assembly.

CAPTAIN WOLF: Okay. This would be to Mr.

Talay, and it has to go with our grease subject and our grease change, and the grease change took place back in November of '97, and in September '97, Douglas responded to Alaska Airlines with an NTO on the grease change.

Douglas indicated that it would be the responsibility of Alaska to monitor for adverse reactions on the grease.

Were there any recommendations made to Alaska by Douglas as to how to accomplish this, how to track this and see what kind of response there was?

MR. TALAY: No, we didn't put any procedures on to that requirement.

CAPTAIN WOLF: Did you feel that there should have been or in hindsight or in the future, would that be something that would be -- that might possibly be recommended by Boeing?

MR. TALAY: Not knowing where even the lubricant was intended to be used, whether it was aircraft or why we provided some restrictions of its potential use in the NTO, the requirement or the recommendation was just to monitor the use of the lubricant, and the request was made to forward any findings, positive or negative, back to us.

But we didn't feel it was a requirement to put in any kind of method of monitoring this usage.

CAPTAIN WOLF: Okay. Kind of along that same line here in jackscrew end play measurements, --

MR. TALAY: Yes.

CAPTAIN WOLF: -- and processes that are in place for you, the manufacturer, and other aircraft manufacturers that need to make modifications, that would be complied with by the operator.

In other words, if the manufacturer feels that a particular action should be strictly followed by an operator, what processes are in place to make that a mandatory action?

I know there's FAA involvement. There's bulletins. There's ADs and that type of thing. But as far as you, as the manufacturer?

MR. TALAY: There's very few mechanisms that we, the manufacturer, can mandate anything on to an operator. There's a document called the "CMR Document" that basically ties -- I'm not overly familiar with it, but it ties a function to the certification of the airplane.

CAPTAIN WOLF: Okay. Mr. Chairman, just a few more questions, and we'll be done here.

Just on lubrication intervals, --

MR. TALAY: Yes.

CAPTAIN WOLF: -- and just for a little bit of clarification on our part, could you give a history of the lube intervals for the stabilizer jackscrew as recommended by Boeing and just shortly describe how this information has been disseminated to operators over the years?

MR. TALAY: The lubrication intervals, like any other task on the aircraft, is included in different maintenance planning documents. The airlines are provided these documents as a Douglas recommendation. It goes into part of their FAA-approved maintenance program.

The MRB process involves the airlines as well as the manufacturer and the FAA. So, the airlines are involved in the process, and the information is disseminated back.

CAPTAIN WOLF: Okay. And again, on the lubrication interval, just so we have a hard time for clarification, that we're all playing on the same field here, what lube interval for the stabilizer jackscrew is recommended by Boeing at the time of the accident?

MR. TALAY: You want to deal with that one?

MR. KOVACIK: Based on the MSG-3 process, the recommended lube interval would have been 3,600 hours.

CAPTAIN WOLF: All right. Thank you.

MR. KOVACIK: And that 3,600 hours was arrived at based on, you know, reliability and maintenance information from the operators who participated in that MSG-3 meeting.

CAPTAIN WOLF: All right. Again for Mr. Talay, do you have any ideas at this time why only four of Alaska Airlines' airplanes experienced excess wear rates out of our fleet?

MR. TALAY: No, I surely don't. This investigation is no where near the point of determining that, and I don't know.

CAPTAIN WOLF: Okay. And for Mr. Umeda, you mentioned earlier that at 15 degrees and nose-down, the Acme screw would exit the gimbal nut. Would it exit the nut smoothly or would there be some binding due to over-travel on the Acme screw angular range of motion?

MR. UMEDA: We had performed a lay-out to consider the pivot limit of the Acme screw, about its upper bearing. The pivot limit is about 7.9 degrees, and at that point, at 15 degrees, the jackscrew or Acme screw will exit the Acme nut.

CAPTAIN WOLF: Okay. Let's say that you had to -- the torque tube fails. The Acme screw fails or the gimbal nut fails, and how is that load redistributed then in the jackscrew assembly, and what type of redundancy you would have on that basis, and if there's anything that the flight crew -- that a flight crew or maintenance people -- that would alert to the maintenance personnel or a flight crew, if that's at all possible?

MR. UMEDA: Could you repeat the question? The torque tube failure, and did you consider another failure?

CAPTAIN WOLF: Right. In other words, if you had a torque tube failure, Acme screw fails or the gimbal nut fails.

MR. UMEDA: One at a time? All together?

CAPTAIN WOLF: No, no, no, no, no. In each different case scenario. In other words, not all three at the same time.

MR. UMEDA: If the torque tube fails, then the load will be carried in tension by the upper portion of the Acme screw into the support bearing from the Acme nut.

If the Acme screw fails, then the load will be carried by the torque tube to the Acme nut, in which case, the Acme nut will be in compression. So, even though you have a crack, you could still transmit a load across a crack in compression.

CAPTAIN WOLF: Would the crew -- in that type of a scenario, would there be any indications, any feel or whatever, to the flight crew, any noises, any vibrations indications?

MR. UMEDA: I believe Mr. Kovacik would be able to answer that question.

MR. KOVACIK: From a functional standpoint, if the inner torque tube were to fail, say, to separate apart from the loading description that Mr. Umeda said, you know, you've lost part of your drive train of the jackscrew system.

So, the response would be that you wouldn't be able to command trim or you could command it, but you wouldn't get any trim response.

Similarly, with a failure of the Acme screw below the nut, the same thing would apply. You would maintain the structural load path, but the indication would be, you know, no trim available.

CAPTAIN WOLF: All right. Earlier, Mr. Guzzetti had talked about the MD-11, and the system it has with the two Acme screws, and there's no torque tubes, but you've got the chain connecting both of them.

If you had the total failure of one of the gimbal nuts, would the other jackscrew assembly be able to maintain the integrity of the overall system?

MR. KOVACIK: When you say "maintain the integrity of the system", --

CAPTAIN WOLF: Yeah.

MR. KOVACIK: -- you mean from a functionality standpoint?

CAPTAIN WOLF: Right. In other words, would just the one jackscrew be able to maintain the control of the system?

MR. KOVACIK: From a strength standpoint, yes. From a functionality standpoint, yes, based on the design of the system, and in all likelihood, the system would turn itself off because of the differential load between the two jackscrews.

CAPTAIN WOLF: Okay. Would there be any indications or feel to the flight deck?

MR. KOVACIK: Well, if the system inops itself, again you would end up with a loss of trim function.

CAPTAIN WOLF: So, would the loss of one jackscrew, but the other one operating normally, the crew would get some sort of an indication or a feel?

MR. KOVACIK: I believe that to be true, yes.

CAPTAIN WOLF: And just one or two questions, quick ones here. On the earlier model MD-80s, what type of attachment points are in place for the end play restraining fixture, and are these brackets available through Boeing or is this something that the airlines themselves manufacture or adapt?

MR. TALAY: The brackets that attach the tool to the airplane -- well, let me put it this way. The tool is -- the lower bracket that mounts the tool is permanently installed on all aircraft. On the early MD-80s and DC-9, the upper bracket also was permanently installed on the airplane.

Later in the '80s, the upper bracket became a removable part, and it's included with the tool, and you buy it. It's included with the drawings and the tool, if you would fab it locally.

CAPTAIN WOLF: I'd like to just refer to Exhibit 11-F real quick.

(Pause)

MR. TALAY: I have a copy of it.

CAPTAIN WOLF: Okay. Again for Mr. Talay.

MR. TALAY: Yes.

CAPTAIN WOLF: Would it be possible to review the letter to all operators that was originated on April 13th, 2000, regard the specifications for stabilizer end play checks?

MR. TALAY: Yes.

CAPTAIN WOLF: And was a copy of this letter sent to all the airlines and/or specifically sent to Alaska Airlines?

MR. TALAY: Yes. Yes. This is an All Operator Letter, and it goes to -- this went to all twin jet operators. On the third or fourth line, up in the text, it went to all DC-9, MD-80, MD-90, 717 operators.

CAPTAIN WOLF: Hm-hmm. What effect would the improper restraining tools that would be used for end play checks at Alaska Airlines have on the end play measurements performed with this tool? Would there be much of a variation?

MR. TALAY: We have not -- I have not seen the Alaska Airlines tool. So, I really don't know what the variance would be. Those tools are in the possession of the NTSB.

Again, we do -- we are applying a specific torque into this tool, and we do expect a certain output. As the letter states, any variation in the tool and thread quality pitch or amount of thread engagement can affect the wear check results.

So, other than that, I can't comment much about the specific Alaska tools.

CAPTAIN WOLF: Okay. All right. That's all the questions I have. Thank you, sir.

MR. HAMMERSCHMIDT: Thank you, Captain Wolf. Moving next to the Aircraft Mechanics Fraternal Association.

MR. PATRICK: Thank you, Mr. Chairman. We have just a few questions we'd like to address to Mr. Talay.

MR. HAMMERSCHMIDT: Okay.

MR. PATRICK: In reference to jackscrew assembly wear, you stated earlier that maintenance interview is required to maintain the airworthiness.

MR. TALAY: Yes.

MR. PATRICK: With that statement in mind, therefore, why did Boeing have recommended maintenance intervals rather than required maintenance intervals?

MR. KOVACIK: Let me see if I can address that question. Based on the nature of the maintenance tasks, they are viewed as reasonable in nature, and the paradigm is that because they are of a reasonable nature, it is realistically anticipated that those maintenance functions will be accomplished to maintain the type design of the airplane.

MR. PATRICK: Okay. Thank you. This is also to Mr. Talay. Is it possible that there may be more reliable testing methods available for performing the end play check in the future and/or do you feel that the current procedures and tooling are adequate?

MR. TALAY: The data that we have had so far with this check has shown it to be an adequate test for the measurement that we're looking for, and the function of it and the intent of it in identifying units when they hit a certain range.

We don't -- I don't know of any more elaborate testing that could provide a more accurate result. Surely if our data collection shows a problem, we'll address it, but the test has been there for quite awhile, and it's done its function.

MR. PATRICK: Thank you. Also for Mr. Talay. Does Boeing consider a C clamp to be a stable platform for taking precision measurements?

MR. TALAY: The C clamp is used to secure the dial indicator to either the lower or the upper stop. It's proved adequate thus far.

MR. PATRICK: Thank you. Okay. In reference to Exhibit 15-F, that would be Pages 21 and 22, --

MR. TALAY: You have to give us one moment, please.

MR. PATRICK: Sure.

MR. TALAY: We don't have a lot of the exhibits that are being referred to now.

MR. PATRICK: Well, I can make this easy. It's in reference to the DTI bracket, the dial indicator bracket, that's shown --

MR. TALAY: I have the exhibit. Can you refer to a page, please?

MR. PATRICK: 21 and 22.

MR. TALAY: Got it.

MR. PATRICK: Okay.

MR. HINDERBERGER: Excuse me, Mr. Chairman. This exhibit was not on the list for this witness to be prepared to testify for. So, if it's necessary for him to testify as it pertains to this exhibit, I'd like him to have an adequate amount of time to prepare himself.

MR. HAMMERSCHMIDT: Oh, absolutely. Please take your time.

MR. PATRICK: Mr. Chairman, I was going to point out, it is listed for Mr. -- Dr. Khaled. I don't know what the question thrust is, but he perhaps could answer the question.

MR. TALAY: I've looked at this. I can address this question, I think.

MR. PATRICK: It's just your own personal observation. Do you feel that this dial indicator bracket that is shown would be adequate for on-wing testing, and could this be a future change?

MR. TALAY: I guess I'm -- just by going by the view, I wasn't at -- obviously involved in this test. I don't know how it's actually secured to the screw. All you're looking for is a solid connection of the dial indicator.

You know, right now, we feel we're getting an adequate clamp-up using the C clamp down by the nut. This is not the way obviously that a check is done on the aircraft. This was done for an NTSB test.

MR. PATRICK: Okay. Thank you. That's all the questions I have for the panel. Thank you very much.

MR. HAMMERSCHMIDT: Very good. Thank you, Mr. Patrick.

Moving next to the Federal Aviation Administration for questions.

MR. DONNER: Thank you, Mr. Chairman. Just two or three, and the first one is a point of clarification for me for -- here I am -- for Mr. Kovacik.

Earlier today, you were talking about the Douglas fault analysis of the flight control system.

MR. KOVACIK: Yes, that's correct.

MR. DONNER: And I believe you referred to it as a "quantitative analysis".

MR. KOVACIK: Yes. I believe I mentioned it as a quantitative analysis.

MR. DONNER: Yeah. Did you -- did that system and did that fault analysis include any probability calculations?

MR. KOVACIK: No, it did not.

MR. DONNER: Would you like to discuss then the differences between a qualitative and a quantitative calculation or analysis?

MR. KOVACIK: Thank you for picking that up. In essence, because it didn't go through a probability analysis, a number analysis, it wouldn't have been a quantitative analysis. It would have been a qualitative analysis. So, I misspoke.

MR. DONNER: Thank you very much.

MR. KOVACIK: Thank you.

MR. DONNER: And just one or two for my colleague Terry Khaled. I promised not to call him Doctor today.

DR. KHALED: Please don't.

MR. DONNER: Terry, much earlier today, you discussed the quill shaft failure, the reflective band, and the indication that that band was fatigue.

In a low cycle fatigue situation, such as this, are the available data reliable enough to accurately predict a crack propagation failure?

DR. KHALED: No.

MR. DONNER: On the particular accident quill shaft, do you believe that you could accurately estimate the loads in the cycles or times that were involved?

DR. KHALED: No.

MR. DONNER: Okay. Thank you. Thank you, Mr. Chairman.

MR. HAMMERSCHMIDT: Thank you, Mr. Donner.

Going next, finally, to the Boeing Commercial

Airplane Group for questions.

MR. HINDERBERGER: Thank you, Mr. Chairman. We have only a few questions here.

I'd like to, first of all, clarify an issue that came up a few minutes ago regarding the Boeing-recommended lube interval. There was a question about that recommended interval, and I believe the answer was that the recommended interval associated with the MSG-3 document was 3,600 hours or one C check.

This question is for Mr. Kovacik. Is it -- is there also an additional on aircraft maintenance planning document that would be associated with an MSG-2 operator that also contains for the MD-80 a recommended lube interval?

MR. KOVACIK: Yeah. That is correct.

MR. HINDERBERGER: And what would that interval be?

MR. KOVACIK: To my understanding, the lubrication interval for the MSG-2 OAMP is 600 to 900 hours.

MR. HINDERBERGER: Also, relative to the 3,600 hour lubrication interval, does Boeing have any data to indicate that airplanes lubricated at the 3,600 hour interval produce an acceptable wear rate?

MR. KOVACIK: There is data from the AD repetitive inspections that -- where we can isolate certain airplanes that were delivered to an operator, who was using the MSG-3 3,600 hour or above lubrication interval. That data suggests strongly that even with a 3,600 hour lubrication interval, the target or desired wear rate of .001 inches per thousand hour can be achieved or bettered.

So, there's several examples from the present day data being reviewed that suggest that, you know, that lubrication interval is appropriate.

MR. HINDERBERGER: Thank you. Captain Wolf was asking a question earlier relative to the DC-10 and its dual jackscrew installation, and the question was relative to if a single -- if one of those jackscrews in the DC-10 were to fail, would there be an indication to the flight crew.

Likewise, on the MD-80 correctly illustrated to us in your presentation, the dual load path through the torque tube and the Acme screw.

So, my question is, on the MD-80, if the torque tube were to fail, does the flight crew get an indication that the torque tube failed in some way through the trim system?

MR. KOVACIK: I think I answered that question when I answered --

MR. HINDERBERGER: Okay.

MR. KOVACIK: -- Mr. Wolf, to say if the torque tube did break, separate, that we lost the drive capability of the system, and therefore the indication to the flight crew would be, you know, loss of trim capability.

MR. HINDERBERGER: Okay. And likewise, with the Acme screw, the same answer?

MR. KOVACIK: Yes, that is correct.

MR. HINDERBERGER: Okay. And my last question is relative to certification. Since there's been a lot of discussion about that today, I was hoping that I could ask a question here to help clear it up.

So, Mr. Kovacik, my last question is, does Boeing believe that the system that we're discussing today, the MD-80 system, meets the requirements of FAR Paragraphs 25.671 and 25.1309?

MR. KOVACIK: I believe the answer is yes. I believe I testified to that question.

MR. HINDERBERGER: Okay. Thank you. It was just that we had gone around and around through several iterations. So, I wanted to get back to the FAR paragraph for that. Thank you.

That's the last question I have, Mr. Chairman.

MR. HAMMERSCHMIDT: Thank you, Mr. Hinderberger, and thank the parties for keeping their questions efficient here towards the end of this day.

Seeing that we have no signals, further signals from the Tech Panel, let's move to the Board of Inquiry for questions. Mr. Berman?

MR. BERMAN: Thank you, Mr. Chairman. Mr. Kovacik, you've discussed several times today that you didn't have any concerns about activating the primary and alternate trim in either the same direction or opposite directions.

Can you just draw it together for me? Do you have any problems with the crew troubleshooting the system in that way?

MR. KOVACIK: From a -- I'm not an operations expert nor am I a pilot, certainly not a commercial pilot at that. I know there is abnormal procedures, you know, in the event of, you know, loss of stabilizer function or "run-away" stabilizer.

As to the appropriateness of a flight crew troubleshooting, I don't know how I can comment on that. I don't have the background or the expertise to comment.

MR. BERMAN: Okay. But you still stand by no negative outcomes that are in your mind right now?

MR. KOVACIK: In a normal system operation, you know, I don't see a problem, you know, commanding a primary trim and an alternate trim at the same time. I don't believe again in any of our documents, we recommend doing that, but I don't see that being a problem.

As for any abnormal situation, application of, you know, primary and alternate trim, either, you know, together or in opposition, that would be speculation as to whether or not that has any impact at all.

MR. BERMAN: Okay.

MR. KOVACIK: So, I can't answer that.

MR. BERMAN: All right, sir. Well, I'm just myself a country pilot from Washington, D.C. You said earlier, I think, that because the Acme nuts are a wear item, Douglas and Boeing later didn't have to plan for its failure or didn't have to make it fail-safe. I mean, that's your reason that it didn't have fail-safe built into it. It's a wear -- an item that's planned to wear out, and I think that's what you were saying, is that right?

MR. KOVACIK: I think the intent of the design, the three elements of that wear design, the over-sizing or the robust design of the Acme nut element, plus the two maintenance interventions, my understanding is that that applies an equivalent degree of, you know, safety for the system.

MR. BERMAN: Well, that's what I'm wondering about, because, I mean, to me, it's confusing. I would think that if you have an item that's a key structural part of an airplane, and it's one of the ones that you know wears, that it would be more important to make that one fail-safe than an item that doesn't wear, because when you don't plan for failure of a wear item, you're putting an awful lot of load on the maintenance system to do everything right every time through, isn't that right?

MR. KOVACIK: I think the paradigm or the belief is that the maintenance would be, you know, accomplished, and the in-service history suggests that the maintenance tasks of lubrication and end play checks had been accomplished and were being accomplished. That would support that initial, you know, belief or paradigm.

MR. BERMAN: I really wonder if that's true, because you've got a couple of -- at least several cases cited where jackscrews wore out prematurely in the 1980s, 1960s, and Boeing's thought was that lubrication wasn't being performed correctly.

So, there's actually evidence the other way, that it isn't always done right.

MR. KOVACIK: Well, let's be careful there. Those particular references you made, those were instances of high wear rate. The actual total wear on those components were, as Jim -- Mr. Talay had indicated, were at or near the recommended removal limits, which would suggest to us that that element of the maintenance intervention, that being the end play inspection, was actually doing its job in identifying problematic, you know, jackscrews and driving that replacement.

Moreover, you know, those instances are about in number three or four over the course of 30 years. That, you know, in a fleet size of, you know, over 2,000 airplanes, that doesn't suggest that there's some sort of systemic problem with accomplishing lubrication. It just says on some instances, it would appear that, you know, lubrication, you know, wasn't done properly.

MR. BERMAN: Well, I don't know how much you planned this whole system around averages or, you know, the 99.999 percent of the time it's done right as opposed to if it was done poorly, if that was true three or four times, that could have been three or four accidents, if it went long enough, and that would, of course, be unacceptable.

Let me just turn to Mr. Talay, and this is another one of my philosophical questions. Originally, it was established by data that it was really important to lube this thing every 600 hours.

The reliability was then used to stretch the lubrication interval. How did that new data overwhelm the old data that said it was really important to lubricate it every 600 hours?

MR. TALAY: The analysis and the recommendations provided by Service Engineering was with a slightly different goal maybe. We were looking to provide a recommendation to keep this part, to maximize the use of the part.

As I -- the logic of our MSG-3 process is to take other processes into account, and they would come in with the airlines provided reliability data, suggesting that that -- the effect of extending lubrication interval did not negatively affect the wear rate of this component.

So, Service Engineering, we would -- our intent was just to reiterate and stress an existing movement of oil at that time as being the prudent thing to do to keep that plane on the -- to keep that part on the airplane.

The MSG-3 process takes into account of the different line of thinking that I'm not particularly familiar with.

MR. BERMAN: But you had those several airplanes that, yes, were caught, they were caught by the then existing --

MR. TALAY: Yes.

MR. BERMAN: -- lubrication and inspection intervals. Then those intervals were all stretched. It doesn't come together for me.

MR. KOVACIK: May I comment on that, Mr. Berman?

MR. BERMAN: Yes, sir.

MR. KOVACIK: It would be -- the references in the AOLs were made to a certain lube interval based on the existing Boeing recommendation documents at that time.

Now, subsequent to when those OEMP documents were issued, through, you know, the appropriate, you know, procedures with the operators and their local regulatory agencies, those lube intervals have been escalated, you know, accordingly from that point, you know.

When it came time for MSG-3, the truth of the matter is that the fleet operators were, you know, represented a full spectrum of lubrication intervals, and that would provide a certain bulk of data, a certain body of data, that would suggest, you know, these lubrication intervals were appropriate, you know, for the task.

MR. BERMAN: Okay. For most airplanes, maybe not for all airplanes.

Let me turn to Mr. Talay. You mentioned that you had some data about the average wear rates, and that the maintenance schedule was built on those averages.

Did Boeing ever look at the variance of the wear rates or just the average?

MR. TALAY: The wear rate that you might be referring to, Mr. Berman, is the -- was a targeted wear rate of this 1,000 per thousand hours that was established in the -- early on in the program. I believe the 8 also had the same targeted wear rate.

The only data, I guess, that I referred to was in the '92 AOL, where we had obtained actual airline data from 19 or so airlines, and that was the only actual wear rate information that we've actually published as far as an actual industry wear rate.

I don't have the exhibit in front of me, but I think it was .011 on one model and .013 on another.

MR. KOVACIK: Okay. Can I add something to that, Mr. Berman?

MR. BERMAN: Yes, sir. Please.

MR. KOVACIK: The existing interval for the end play check is, you know, from an hour standpoint, is, you know, 7,200 hours. Based on that interval, you know, you rightly said, you know, we have a target wear rate, an average wear rate, and it has been confirmed on several occasions, back in the '90s and even in present day AD data, that 001 per thousand hour wear rate is achievable.

Now, in regards to variances, obviously the end play check is there to evaluate or monitor the amount of wear. With a 7,000 hour or approximately a 7,000 hour, you know, interval, that tells me you can accommodate quite a variance in wear rate before the total amount of wear could be -- become a concern.

For instance, if, say, from a jackscrew delivered on a new airplane, you know, the next end play check is scheduled 7,000 hours out, you know. With the current limit of 040 wear for removal, you could anticipate a wear rate six times the 001 per thousand and still result in, you know, an end play check catching the unit, you know, at its limit.

So, I would think that based on the interval that's prescribed, it can handle a significant variance in actual wear rate.

Moreover, that sort of wear rate, on the order of five or six or, you know, in that order, we've only seen that sort of wear rate in the in-service history because of a lubrication starvation issue.

So, provided that, you know, some degree of lubrication is being applied, you know, we should be able to, you know, have variances of wear rate much less than that limit, and even that large limit should be accommodated for in the end play check.

MR. BERMAN: Well, we have the uncomfortable situation of this accident, and we don't know or we haven't established why the failure occurred here, but clearly the inspection interval was not adequate for the wear rate. That goes without saying, isn't that right?

MR. KOVACIK: Obviously we don't know exactly the nature of the event or condition or series of events or conditions that led to the defeat of our system. We don't know that. That's why we're here, and that's why we're so interested, you know, in following through with the investigation, to find out what actually happened.

MR. BERMAN: But do you agree that the interval was not adequate in this case at least?

MR. KOVACIK: It would appear that way.

MR. BERMAN: Okay. All righty. Was there any kind of certification activity involving the horizontal stabilizer trim during the certification process of the MD-80, the MD-90 and Boeing 717?

MR. KOVACIK: Was there any --

MR. BERMAN: Papers, anything, any papers written for the FAA, any fault or FMEA analyses on that system?

MR. KOVACIK: In terms of specific documents, I don't know that for certain, but I do know generally as a rule, if there were significant changes to any system, that those changes would be re-evaluated based on, you know, later amendments to the regulations.

MR. BERMAN: Okay. Well, I know the requirement that you just stated, but I'm asking were there any papers or documents?

MR. KOVACIK: I don't know that for certain. So, I can't say.

MR. BERMAN: Okay. Could you please find out and submit that for us?

MR. KOVACIK: I -- the Boeing can take an action on that.

MR. BERMAN: Thanks. Just a couple more questions. If there's an airplane that was inspected by an operator at .040, would you recommend that the -- I guess this is for Mr. Talay mostly.

Would you recommend that the operator do anything special in terms of accelerating the next inspection or anything like that or should they just keep going out to the next schedule --

MR. TALAY: Currently, the procedure allows that unit to go -- that airplane to go back in service with 40,000ths until the next check currently established at 2-C.

MR. BERMAN: Well, what would you recommend, based on your knowledge of the system?

MR. TALAY: I -- given my knowledge of the system and history with it, we're comfortable with that maintenance action.

MR. BERMAN: Is Boeing working on any kind of a redesign of the jackscrew system?

MR. KOVACIK: Maybe I can --

MR. BERMAN: Yes, sir.

MR. KOVACIK: -- best address that question. Are we working on any design changes?

MR. BERMAN: Yes, sir.

MR. KOVACIK: The system as a whole is being reviewed, you know, looked at, you know. As it applies to any particular change that we have in mind, you know, that hasn't been established yet. This is still, you know, preliminary review of the design, and as more information is gleaned from the investigation, you know, appropriate, you know, consideration will be made, you know, of the adequacy of the design, and there's no question about that.

But at this point, you know, there's nothing specific.

MR. BERMAN: Okay. So, I understand you're reviewing the design, but no specific changes are on the drawing boards. Is that second part true?

MR. KOVACIK: That's correct.

MR. BERMAN: Let me ask one more question. I believe it's for Mr. Talay.

Did you take note over the last three years or so of any questions from Alaska Air about problems with AeroShell 33 grease? Any concerns they had about that grease?

MR. TALAY: The only issue that has come up --

MR. BERMAN: Apart from the accident.

MR. TALAY: -- apart from the accident, we had a series of troubleshooting phone calls on rotation problems being experienced out of Fairbanks, Alaska, in cold weather environments, and during that series of troubleshooting phone calls, the AeroShell issue came up, yes.

MR. BERMAN: What were the problems that were discussed in those phone calls?

MR. TALAY: Regarding the lubricant?

MR. BERMAN: Yeah.

MR. TALAY: It was just another question of the compatibility of mixing the lubricant on the airplane.

MR. BERMAN: What was -- sorry.

MR. TALAY: There was a possibility that the grease was applied to the fittings and basically had just been cut in rather than any special procedure to purge out the old grease. So, we had a -- we just wanted to revisit the mixing possibility of the two greases. So, that was accomplished at that time.

MR. BERMAN: What was the specific symptom that Alaska Air was reporting to Boeing on those Fairbanks airplanes?

MR. TALAY: There was a rotation, difficult to rotate or heavy to rotate, on --

MR. BERMAN: Oh, a heavy to rotate?

MR. TALAY: A heavy to rotate airplane on take-off after being on the ground there in 50-degree, minus 50-degree Fahrenheit weather. Lubrication was just one of many issues looked at with -- during the course of that investigation.

MR. BERMAN: And did Alaska Air or Boeing establish that there was a cut-in issue of the lubricant mixtures? Was there a problem with introduction of the new lubricant?

MR. TALAY: The lubricant, as it was reported to us, there was a cut-in date where the lubricant might have been just started to been used on the airplanes. There was no definite action to purge out the old grease which would have been a preferred way to do it.

So, we had looked at the -- we took that into account and said, all right, if that action did not happen, what would be the ramifications of having the lubricant mixed.

MR. BERMAN: Just so I'll be sure, are you saying that Alaska Air specifically reported that they had not taken special precautions on the introduction?

MR. TALAY: Yes. Yes.

MR. BERMAN: Okay. Do we have a copy of that, Mr. Guzzetti? That correspondence on Boeing's side?

MR. GUZZETTI: Yes, we do.

MR. BERMAN: Okay. And I know that Boeing's response to that is in our records. So, I won't belabor that.

Thank you very much. No further questions.

MR. TALAY: Thank you.

MR. HAMMERSCHMIDT: Thank you, Mr. Berman.

Mr. Clark, do you have some questions?

MR. CLARK: Dr. Khaled, I think you mentioned when you're answering questions for Mr. Donner, the -- you were talking about the fatigue area on the bottom of the nut, and that you could not estimate the amount of time that it existed or the amount of cycles it went through to create that.

DR. KHALED: That is correct.

MR. CLARK: Okay. Is it possible that that could have been a pre-existing crack?

DR. KHALED: Pre-existing in what sense, if you might?

MR. CLARK: Before the accident. It was existing before the nut failed. Several flights earlier.

DR. KHALED: I guess it's conceivable.

MR. CLARK: It's possible?

DR. KHALED: Yeah.

MR. CLARK: Okay. Mr. Kovacik, we've been talking about redundancy, reliability. Is this system considered a critical flight system?

MR. KOVACIK: I guess yes, based on -- I'm sorry. Yes. Based on our, you know, test-loading in our presentation, yes, it is a critical system.

MR. CLARK: Basically, if it fails, we lose the airplane?

MR. KOVACIK: Right. It's required for, you know, proper balance of the airplane.

MR. CLARK: Okay. And you've described the dual load paths throughout the structure, and the one thing that wasn't considered in the design was the failure of the brass threads, that had they failed, that that wasn't a part of the design consideration.

MR. KOVACIK: Well, in actuality, the dual threads within the Acme nut does address, you know, certain specific failures that were, you know, considered.

MR. CLARK: Okay. Part of the sense of putting in dual threads is that if one set of threads failed, the second set is there to carry the load.

MR. KOVACIK: That's correct.

MR. CLARK: Okay. But if we -- what is your definition of redundant in this environment? What makes it redundant?

MR. KOVACIK: What makes the --

MR. CLARK: What makes the system redundant? What makes the dual thread area redundant?

MR. KOVACIK: That loss of one of the thread elements has a back-up element that can, you know, maintain the integrity of the load path.

MR. CLARK: But the threads are -- that -- you're talking about two independent failures or two independent systems? Is that --

MR. KOVACIK: I guess I'm not following you. I apologize.

MR. CLARK: Well, we've talked about redundant systems, dual load paths, that part of the redundancy is that a single failure will not cause both load paths to fail at the same time.

MR. KOVACIK: Okay. Yes.

MR. CLARK: And in this consideration, it appears that both load paths failed at the same time.

MR. KOVACIK: That appears to be true, yes.

MR. CLARK: Okay. And part of your discussion is that you would believe that right now, the theory on the table is that those dual threads failed because of lack of lubrication?

MR. KOVACIK: Boy, that's --

MR. CLARK: Okay.

MR. KOVACIK: Obviously we're -- the investigation is not complete, and I don't know if we can make that sort of determination at this point. It would be evident that both threads exhibited wear, excessive wear.

As to the nature and root cause of that, that's still to be determined.

MR. CLARK: But since they both wore out at about the same time, and both sets of threads were essentially gone at the same time, it would appear that we had a single thread going on that caused both to fail at the same time?

MR. KOVACIK: There was some common process going on. I don't know if it's necessarily singular, but some common process or common events or common conditions or --

MR. CLARK: But common is the -- something common is going on that caused both of these to fail, and that in a sense defeated the redundancy of the system.

MR. KOVACIK: I would say that's a fair estimation.

MR. CLARK: Okay.

MR. KOVACIK: Not knowing any more about the nature of the investigation, where we're going, --

MR. CLARK: Okay.

MR. KOVACIK: -- what we might discover.

MR. CLARK: All right. Also from your testimony, it appears that you put a great amount of necessity on the mechanics reliably performing their job.

MR. KOVACIK: That's true. There are maintenance dependencies associated with this design, yes.

MR. CLARK: Okay. But out of this dual system, and I think somebody talked about 93 million hours in the system, how many failures could we have in the mechanics environment to fail to lube that jackscrew and not get into this type of situation?

MR. KOVACIK: Yeah. Boy, that's difficult to assess, you know. Obviously the lubrication is a repetitively-done task. Let's say if, for some reason, that particular task was omitted or missed, you know, by the next interval, if that task was accomplished correctly, whatever potential increase in wear experienced during that interval would be arrested, and you'd be back at a more nominal target wear rate.

So, for, you know, some sort of very adverse condition to arise, there would potentially have to be multiple, you know, problems with those maintenance tasks, you know, to --

MR. CLARK: That would be one -- that could be a possibility, but right now, we don't know how many multiples we need to have before we could introduce a failure into that redundant system.

MR. KOVACIK: You know, there is the end play check that is prescribed as well to monitor the overall wear. So, you know, to answer -- I guess I can't answer the question. That's --

MR. CLARK: Okay. If we were to -- right before the accident, I believe we were up to around 10,000 hours between end play checks for Alaska Airlines, 9,500-9,200 hours. I would assume a lot can go on during that period of time, if we missed a couple lubrications?

MR. KOVACIK: Potentially, yes.

MR. CLARK: Okay. Also, if we had part of the dual load paths consideration, if we had pre-existing damage, such as a fatigue crack, would that be considered a latent failure and really defeats the capability of the system to provide dual load paths?

MR. KOVACIK: When you say "fatigue failure", --

MR. CLARK: Low cycle fatigue with the nut, like we believe Dr. Khaled testified to.

MR. KOVACIK: And how does that relate to the scenario that you're --

MR. CLARK: Well, if you have a fatigue failure going on somewhere in that system, in the jackscrew or in the torque tube or at the nut threads, doesn't that also defeat the possibility that dual -- that's defeating the level of redundancy that you have?

MR. KOVACIK: You know, I'm not an expert in fatigue, but if there is a failure in that torque tube, you know, we've already testified to that effect, you know, that we would lose the trim capability. We would not lose the load path.

So, I guess I don't understand --

MR. CLARK: I'm saying if there were a pre-existing crack in that torque tube, and we then had a failure somewhere else in the structural system, the pre-existing failure's a latent failure, it's a hidden failure, and nobody knows about it.

MR. KOVACIK: You know, I don't know how to respond to that.

MR. CLARK: Okay. All right. If we -- in the system, if we were defeating the electrical stops, the electrical stops didn't work, what happens to the jackscrew if we run it till it stops?

MR. KOVACIK: You know, like the presentation I gave, we do have back-up mechanical rotational stops. The intent there is to stop the screw from turning. So, if we have an instance where the electrical shut-off system, let's say, is not working properly due to a misrigged condition or a cable breaking, then you'd have a condition where the screw could potentially rotate such that the mechanical rotational stop would contact the Acme nut stop.

MR. CLARK: And that could cause structural failure in the brass nut or in that whole gimbal nut mechanism?

MR. KOVACIK: I think there is -- you know, from the metallurgy report, there was one instance of the Acme nut lug suffering damage from the --

MR. CLARK: That came in because of the on-going inspection after the accident.

MR. KOVACIK: Right. I guess a follow-on to that in regards to that particular Acme nut, you know, I personally haven't seen t hat or understood the nature of what that indicates, you know, part numbers, etc.

MR. CLARK: Also, in the area of MIL Specs, I think Mr. Talay talked about -- I'm sorry. Mr. Talay.

MR. TALAY: Talay.

MR. CLARK: Talay. Sorry. You talked about the issue of -- that MIL Specs -- you use MIL Spec numbers to define the types of grease that can go on the airplanes.

MR. TALAY: Yes.

MR. CLARK: Okay. So, if any grease met a certain MIL Spec, it can also go on an airplane?

MR. TALAY: True.

MR. CLARK: And there are -- for any MIL Spec number, the AeroShell 33 comes under one MIL Spec, and there's a number of those, and --

MR. TALAY: The MIL Spec that we use have several greases listed under it.

MR. CLARK: Right. Okay. Is it possible that those types of greases that may -- there may be several greases that all comply with one MIL Spec, but those greases in and of themselves may be incompatible?

MR. TALAY: When we get into the actual aspects of the grease and its compatibility issue, I would prefer to defer that to the lube person we have coming on tomorrow.

MR. CLARK: Okay. Where we're at right now then is we have this redundant system, and there are --

and I think one of you testified that there may be other unknown failure modes out there, that the way this system is right now, that whatever can take out two sets of threads on a jackscrew, basically we've lost our redundancy in that system.

We have a single failure that can lead to a catastrophic accident.

MR. KOVACIK: I guess I agree with you.

MR. CLARK: Okay. In this area, if we're relying this much on mechanics to do their job properly before we could perhaps introduce a failure into this jackscrew, you mentioned that there were -- did not appear to be systemic problems in mechanics performing their job.

MR. TALAY: That's true.

MR. CLARK: Okay. But we also -- Mr. Berman raised the issues that there's a number of prior failures, plugs zerc, high wear rates because of lack of lubrication. So, that says that there are some problems out there.

MR. TALAY: The units that drove the AOLs, again we've talked about them as being failures, they just -- they wore prematurely, and they were removed on schedule. So, they were far from failing by the nomenclature that we have been using "failing" today.

We do have -- we have had those events that drove those AOLs or at least the first one where we observed plugged lube passages. The second AOL was based on data that was acquired from the airlines. We really didn't have the chance to view that accelerated wear part. So, we don't know what transpired there, but it's a true statement.

MR. CLARK: Okay. But in light of the 10,000 hours or 9,500 hours between checks, we find jackscrews that are making metal. There's slivers. There's mix in the brass threads. All right.

MR. TALAY: Could you just repeat the question? I didn't catch it.

MR. CLARK: I guess the question is that, how do we know what the wear rate is going to be in the next 9,000 hours if we just passed an 040 check, when we see jackscrews out there, I've heard the term, "making metal"? It's putting out slivers. It's putting out fragments.

MR. TALAY: When we first put out the alert bulletins, we had the issue on some of the early findings of metal on or around the screw. Now, we have an aluminum bronze nut that is wearing. We would have every expectation of finding trace amounts of aluminum bronze in the grease.

We have an area that is -- when sealed up in service, it's in a protected area, but during the maintenance environment, there is all sorts of work being done on and around the screw.

We have not seen as a result of the ADs screws shedding metal. The bulletins were written very conservatively initially, but they've been revised twice to allow a lot of minor amounts of metal in the screws.

So, the term "making metal" was not accurate. It was a term that was thrown around very early in this process, but we have not, and it's shown, I think, by the number of removals, that we have not seen a big issue with metal, and truly most of the ones that were removed for "metal" would not be removed in today's language in those alert bulletins.

MR. CLARK: Just because you found metal down there?

MR. TALAY: Just because you found metal wouldn't drive you to replace the unit. The vast majority of them had nothing to do with the jackscrew. It was debris from surrounding work.

MR. CLARK: But that's -- all of that is the history as we know it after the accident, and is that directly transferrable to what we've -- what was going on before the accident?

MR. TALAY: I think in the first few months of this year and every 60 days after, we've been sort of purging the -- we've been looking at this fleet repeatedly, and once the areas were -- the part of the procedure was to clean the area, to start from a clean work environment or clean working environment.

We have not seen any removals, I'll say any, but we haven't had a problem with removing units for metal since that first purge of the systems, a separate go-around of the other bulletins.

MR. CLARK: Okay.

MR. TALAY: If that's -- I hope I'm addressing your question with regard to this metal. It was an issue that has been dealt with.

MR. CLARK: Okay. Thank you.

MR. HAMMERSCHMIDT: Mr. Berman, would this be an appropriate time for you to ask that question that you had?

MR. BERMAN: Sure. Thank you, sir. I'd like to go back to the 1960s when everyone, except Mr.

Rodriguez, was too young to be doing this. Why --

MR. RODRIGUEZ: No, sir. I joined the Civil Aeronautics Board in 1962.

MR. BERMAN: I think that's great.

MR. RODRIGUEZ: As a matter of fact, I worked the first DC-9 fatal accident in New York.

MR. BERMAN: Great. To the panel, please. Why was it decided to make the Acme nut the soft part? It seems like if the Acme screw had been the soft part, if the working area of that one wore out, it would slide up to a part where the threads were intact. If the nut wears out, the whole thing goes. Why was that done?

MR. KOVACIK: I think it's an issue of strength. You know, the -- I don't think you could make the screw out of aluminum bronze and accomplish the load path that you're looking for, and in an Acme nut design, you need to have one stronger element and one softer element. So, if you have two strong elements, the system won't work.

So, if the -- I guess the decision is that you want -- if there's going to be wear occurring, you want to have the wear driven into one component. So, you could monitor that one component instead of having to, you know, monitor several components, for example.

I think it's a loads issue. I may be incorrect, but that's my initial read.

MR. BERMAN: Okay. Thanks. That makes sense actually. The bronze would not have been strong enough to take the loads of the Acme screw, but it did transfer the wear into the nut which was more susceptible.

Okay. Thank you for explaining that.

MR. HAMMERSCHMIDT: Okay. Thank you. Mr. Clark?

MR. HINDERBERGER: Mr. Chairman?

MR. HAMMERSCHMIDT: Mr. Hinderberger, yes?

MR. HINDERBERGER: Yes, sir. Since we're approaching the 10 hour point, and it seems that about an hour or so ago, we've had our air conditioning turned off, and this panel's been up there all day, I'd like to respectfully request that we adjourn for the day, and since we still have two more Board of Inquiry members yet to go.

MR. HAMMERSCHMIDT: All right. Well, that's certainly a reasonable request. The current time is 8:50 in the evening, and as I indicated, my hope is that we could complete this panel so that we cannot inconvenience them tomorrow, so that they would be -- have this behind them.

Let me check and see here how much more we have to go. I have no more questions. Mr. Clark, how much more do you have?

MR. CLARK: I'm going to guess 10 minutes.

MR. HAMMERSCHMIDT: 10 --

MR. CLARK: If I have more, I'll quit.

MR. HAMMERSCHMIDT: Okay. We have 10 minutes here. Dr. Ellingstad?

DR. ELLINGSTAD: I'll just pass on it.

MR. HAMMERSCHMIDT: Okay.

DR. ELLINGSTAD: I'll let John finish up.

MR. HAMMERSCHMIDT: I believe we're on the home stretch here. So, let's continue, and let -- I'm glad you brought that up, and we are running long, but I'll have just a very few closing comments, and then we will be adjourned.

MR. CLARK: Okay. We'll get going. I said I'd use 10 minutes. I'll use Mr. Rodriguez's watch. I'll buy a little more time than that.

Mr. Umeda, the -- earlier, you described several -- you went through a process of describing witness marks and the drawings that showed the movement of the stabilizer.

When the threads finally let go on the brass nut, and the unit started to move, at what point is that stabilizer going to stop?

MR. UMEDA: The first contact point would be contact with the lower rotational stop collar.

MR. CLARK: And would that hold the unit at that point?

MR. UMEDA: That was -- it really depends on the loads. It will sustain the unit for a certain degree of loads. Those loads haven't been determined yet.

MR. CLARK: Okay. And when you found the unit finally could not sustain the loads, wow far did the actuator -- the stabilizer move at that point?

MR. UMEDA: At that point, the rotation -- the lower rotational stop would displace and make contact with the torque tube washer and nut.

MR. CLARK: That's a mechanical stop collar unit?

MR. UMEDA: The mechanical stop collar would displace, and it would come into contact with the torque tube washer and nut at the bottom of the jackscrew.

MR. CLARK: Is that the 3.1 degree position?

MR. UMEDA: Yes, that is, nominally.

MR. CLARK: Nominally. Okay. Then, if the torque tube broke, what's the next thing that's going -- what will be the next thing that will stop the stabilizer?

MR. UMEDA: The next contact point will be the horizontal stabilizer, front spar, upper cap, upper surface, contacting the kit faring.

MR. CLARK: Okay. Is that strong enough to hold it?

MR. UMEDA: I can't answer that question. The loads analysis is under development. I don't know what the loads are.

MR. CLARK: Okay. So, it's -- right now, it's possible that it could hold? Is it in your estimation likely? Is that structure that strong? If you don't know, that's fine.

MR. UMEDA: You're asking me to answer a question that I don't have --

MR. CLARK: Okay. That's fine.

MR. UMEDA: -- numbers for.

MR. CLARK: No, I don't want to do that. After that, what's the next major structure that has some ability to hold it or is there any?

MR. UMEDA: Well, then the elevator control sector pulley would contact the horizontal web in the faring structure, in the aft section of the horizontal stabilizer.

MR. CLARK: Okay. What has been the difficulty in getting the aerodynamic loads that you can use in your structural analysis? Do you know? To get estimates or to get reasonable engineering numbers?

MR. UMEDA: The horizontal stabilizer traveled beyond its normal operating trim position.

MR. CLARK: Okay. Okay. Thank you. That's all I have right now.

MR. HAMMERSCHMIDT: Right now? This will be the last chance. Thank you, Mr. Clark, and thank everyone for many good questions.

Of course, -- Captain Finan, you don't have a question, do you?

CAPTAIN FINAN: Yes, sir. Well, just a small statement, if I may. If we had a break, I was going to address it otherwise, but 20 seconds?

MR. HAMMERSCHMIDT: Okay.

CAPTAIN FINAN: Mr. Berman raised an issue about the Fairbanks elevator investigation the NTSB was involved in to Mr. Talay, and since he won't be here tomorrow, I just wanted to clarify that -- to refer to the Board Exhibit 11-Q, which -- in which Boeing states they reviewed the use of AeroShell 33 grease used by Alaska for lubrication of the elevator hinges and mechanisms, and that they advised that no compatibility problems could be identified mixing AeroShell 33 grease, and I thought that was important to close the issue before the panel that's present departed.

MR. HAMMERSCHMIDT: Very good. We appreciate that.

CAPTAIN FINAN: Thank you, sir.

MR. HAMMERSCHMIDT: And I also want to mention that one of the reasons I had hoped that we would stay with this panel until completion is that all this information and these ideas and our interchanges would be fresh in our minds, and we might lose something if we went to another day with them.

We have been very long here today. I want to sincerely thank this panel for their participation in this public hearing.

Mr. Rodriguez, will we need them any more in this hearing?

MR. RODRIGUEZ: No, sir, but they're not

excused yet.

MR. HAMMERSCHMIDT: Okay. So be it. You've been very articulate and good witnesses, very informational, very expansive with your answers, and that's one of the reasons we've been a little bit long, but that's good.

And the whole purpose of this public hearing is as a work session, essentially, and our investigators have questions that they need answers to. They have ones that we want in the final report, and we need those questions asked while we have everyone in the room to provide information to one another.

I might mention to the witnesses, you may stand down, and thank you again.

Again, we ran, I guess you'd say, at least an hour longer than we had hoped to. The internal schedule that we had hoped to complete for today was to go through the next witness, Mr. Mike O'Neil. So, we're one witness behind at this juncture in terms of our schedule.

I was told earlier that Mr. O'Neil will not be a very lengthy witness, but we don't need any performance on that necessarily.

I would just close in saying that in terms of the utilization of this nice new NTSB Board Room and Conference Center, this is the first time it has been used for what we call a public hearing, and, so, you might say that this was the inauguration of this facility for use as a facility to hold a public hearing, and I would say that we have, in that respect, we have provided a very industrious beginning.

We will recess until 11 a.m. tomorrow. Thanks to everyone.

(Whereupon, at 8:59 p.m., the public hearing was adjourned, to reconvene tomorrow morning, Thursday, December 14th, 2000, at 11:00 a.m.)